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THÈSE DE DOCTORAT

présentée par

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Designing and Modeling Collective Co-located Interactions for Art Installations

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to my son, Tsolag

Abstract

With works such as *Kinoautomat* by Radúz Činčera, *SAM - Sound Activated Mobile* by Edward Ihnatowicz, and *Glowflow* by Myron Krueger, artists have deployed, as early as the 1960s, art installations engaging novel situations of collective co-located interaction, i.e involving multiple or even many spectators interacting in the same place via and with a digital apparatus. The number of those works has continued to increase since the beginning of the 21st century, taking advantage of the new opportunities offered by advances in real-time computer vision technologies and the advent of ubiquitous computing marked by the multiplication and interoperability of mobile computing devices. While experiences in this area are more and more frequent, they have not yet been the subject of structured analysis and, even less, of proposals for dedicated tools and design methods. How can we, nowadays, conceive such interactive art installations whose intrinsic complexity involves questions of the technical, social, cognitive and aesthetic order?

This dissertation draws on previous work in the fields of human-computer interaction (HCI), computer-supported cooperative work (CSCW), and interactive arts research with the aim of increasing our knowledge of the challenges faced both by art practitioners and participants in such collective interactive installations, and, beyond, the designers of apparatus in a promising future. A set of tools and guidelines are proposed when designing collective co-located interactions for digital art installations. First a classification system is developed centered on the most decisive aspects that allow the emergence of a collective experience. Two distinct approaches are then explored to find the bases of a graphical modeling language for the design and analysis of such apparatus. Build on top of Petri nets, the second approach supports modeling the spatial and material resources of an installation, as well as the human-machine, human-human and human-machine-human interactions.

The investigations conducted for this research have required laying particular emphasis on the conditions — whether spatial, material, or human — which affect the ability for participants to co-construct a common aesthetic experience in the absence of orchestration or a preannounced goal to be achieved. While this singular approach primarily concerns interactive arts, it may be relevant to a wide range of research communities, including, and foremost, that of HCI, as well as CSCW,

New Interfaces for Musical Expression (NIME), interaction design, and even culture, museography in particular.

Keywords: co-located collective interaction, interactive art, collaboration, audience engagement, Petri nets

Résumé

À l’instar d’œuvres telles que *Kinoautomat* de Radúz Činčera, *SAM - Sound Activated Mobile* d’Edward Ihnatowicz et *Glowflow* de Myron Krueger, des artistes ont développé, dès les années 1960, des installations artistiques engageant des situations d’interaction collective co-localisée inédites, c’est-à-dire impliquant plusieurs voire de nombreux spectateurs interagissant dans le même lieu via et avec un dispositif informatique. Le nombre de ces travaux ne cesse d’augmenter depuis le début du 21^{ème} siècle, profitant des nouvelles opportunités offertes par les avancées dans les technologies de vision par ordinateur en temps réel et par l’avènement de l’informatique ubiquitaire marquée par la multiplication et l’interopérabilité des appareils informatiques mobiles. Si les expériences en la matière sont de plus en plus fréquentes, elles n’ont jusqu’à ce jour fait l’objet d’aucune analyse structurée et, encore moins, de propositions d’outils et de méthodes de conception dédiés. Comment, aujourd’hui, concevoir de tels dispositifs artistiques interactifs dont la complexité intrinsèque implique des questions aussi bien de l’ordre technique, social, cognitif qu’esthétique ?

Cette thèse met à contribution des travaux antérieurs dans les domaines de l’interaction homme-machine (IHM), du travail coopératif assisté par ordinateur (TCAO) et des arts interactifs dans le but d’accroître notre connaissance quant aux défis auxquels sont confrontés à la fois les artistes et les participants de telles installations et, au-delà, les concepteurs de ces dispositifs en devenir. Un ensemble d’outils et de lignes directrices sont proposés pour la conception de systèmes d’interaction collective co-localisée pour les installations d’art numérique. Est d’abord développé un système de classification centré sur les aspects les plus décisifs permettant l’émergence d’une expérience collective. Deux approches différentes sont ensuite explorées pour trouver les bases d’un langage de modélisation graphique pour l’analyse et la conception de tels dispositifs. S’appuyant sur les réseaux de Petri, la deuxième approche permet de modéliser aussi bien les ressources spatiales et matérielles d’une installation, que les interactions homme-machine, humain(s)-humain(s) et humain(s)-machine(s)-humain(s).

Les investigations menées pour cette recherche ont nécessité de mettre un accent particulier sur les conditions — qu’elles soient spatiales, matérielles ou humaines — qui affectent la capacité pour les participants de telles installations de co-construire

une expérience esthétique commune en l'absence d'orchestration ou d'un objectif pré-annoncé à atteindre. Si cette approche singulière concerne en premier lieu les arts interactifs, elle peut revêtir également un caractère pertinent pour d'autres communautés de recherche, y compris et en premier lieu, celle de l'IHM, ainsi que celles du TCAO, des Nouvelles interfaces pour l'expression musicale (NIME), du design d'interaction ou encore de la culture, en particulier de la muséographie.

Mots clés : interaction collective co-localisée, art interactif, collaboration, participation du public, réseaux de Petri

Résumé étendu

Introduction

Les installations d'art interactives permettant la participation du public co-localisé en temps réel ont émergé dès les années 1960 avec des œuvres telles que *Kinoautomat*¹ (1967), *SAM - Sound Activated Mobile*² (1968) et *Glowflow*³ (1969). Avec l'avènement des ordinateurs personnels et des technologies avancées de surveillance et de suivi telles que les techniques de vision par ordinateur, les projets d'art interactif co-localisé sont devenus plus courants dans les années 90. Cependant, les mécanismes d'interaction utilisés étaient difficiles à mettre en place et ne s'adaptaient pas aisément au nombre de participants.

Au début des années 2000, des projets tels que *Dialtones (A Telesymphony)*⁴ et *Blinkenlight*⁵ ont mis à profit les appareils personnels largement accessibles — en premier lieu, les téléphones portables — rendant ces projets plus faciles à déployer auprès d'un large public.

Suite au lancement des premiers smartphones pour le grand public à la fin des années 2000, de puissants appareils informatiques mobiles sont devenus de plus en plus omniprésents. Les nouvelles opportunités offertes par cette multiplication et l'interopérabilité des terminaux informatiques ont favorisé l'émergence de nouveaux

¹<http://www.kinoautomat.cz/index.htm?lang=gbr>

²<http://www.senster.com/ihnadowicz/SAM/sam.htm>

³<http://dada.compart-bremen.de/item/artwork/1347>

⁴<http://www.flong.com/projects/telesymphony/>

⁵<http://blinkenlights.net/>

dispositifs artistiques, tels que *Bloc Jam*¹ et *Overexposure*², partageant un objectif commun : celui de déployer des situations d'interactions collectives co-localisées originales et sans précédent, capables d'un profond renouvellement des formes de l'expérience esthétique.

Tandis que la grande diversité des modalités d'entrée et de sortie intégrés aux terminaux mobiles a ouvert la voix à un large champ des possibles, elle a aussi apporté de nouveaux défis lorsqu'il s'agit de concevoir des interfaces permettant la participation collective du public. L'un de ces défis implique la capacité des participants à identifier et suivre leurs propres actions à l'échelle collective et d'en comprendre distinctement les effets. Un autre défi concerne la bonne gestion de la charge attentionnelle des interfaces individuelles et partagées afin de favoriser le déplacement du centre d'attention des utilisateurs depuis les interfaces individuelles vers les interfaces partagées et ainsi mieux promouvoir une expérience collective commune.

En effet, lors d'expériences antérieures menées dans le cadre du projet *Discontrol Party*³ de Samuel Bianchini en 2009 et en 2011, j'ai constaté que les individus interagissant au sein du groupe avaient une grande difficulté à localiser leurs propres actions sur les représentations graphiques partagées en temps réel.

Avec un intérêt particulier pour les installations d'art interactif — qui n'appelle que rarement l'exécution d'une tâche précise, et ne dicte pas un objectif commun à atteindre qui pourrait servir de guide ou de support à l'activité — cette thèse vise à mieux comprendre les différents défis rencontrés par les artistes lors de la conception de telles œuvres, ainsi que les difficultés éprouvées par les participants, et ainsi proposer un ensemble d'outils et de lignes directrices pour la conception de systèmes pour le grand public favorisant l'interaction co-localisée au sein d'un groupe.

¹<http://www.dailytouslesjours.com/project/bloc-jam/>

²<http://www.surexposition.net/>

³<http://dispotheque.org/en/discontrol-party>

Problématique

Cette recherche vise à mieux comprendre les différents attributs et caractéristiques des installations artistiques interactives co-localisées qui entravent ou favorisent l'émergence d'expériences collectives, avec la problématique centrale suivante :

Comment concevoir des interactions collectives co-localisées afin de favoriser l'émergence d'expériences esthétiques communes dans des installations d'art numérique ?

En sus, la thèse aborde les questions significatives suivantes :

- Quels sont les aspects des œuvres interactives qui affectent la nature des interactions individuelles, pluri-individuelles et collectives ?
- Qu'est-ce qui doit être considéré lors de la conception et le développement d'installations artistiques combinant à la fois des interfaces utilisateurs individuelles et partagées pour mieux soutenir l'émergence d'une expérience esthétique commune ?
- Comment pouvons nous modéliser les interactions homme-machine, homme-homme et/ou homme-machine-homme dans de tels systèmes, et serait-ce utile pour les artistes ?

Conduite et méthode de la recherche

Le projet de thèse a été mené conjointement au sein de l'équipe "Médias Interactifs et Mobilité" du groupe "Interactivité pour Lire et Jouer" du laboratoire Cédric (Centre d'Études et de Recherche en Informatique et Communication) du CNAM (Conservatoire national des arts et métiers) et le groupe "Reflective interaction" à EnsadLab (laboratoire de recherche de l'École nationale supérieure des Arts décoratifs - Université PSL, Paris), et a pris part au projet *CoSiMa*¹ (Collaborative Situated Media - ANR-13-CORD-0010) à travers la participation au développement de briques logicielles de la plateforme – notamment celles utilisées pour le rendu graphique – ainsi qu'à travers le design et développement d'interfaces utilisateurs de différents prototypes ayant donné lieu à des expérimentations avec des publics lors desquelles

¹<http://ensadlab.fr/cosima/>

des études et observations ont pu être menées.

En plus de ces expériences, cette recherche, mêlant théorie et pratique, s'appuie sur un examen approfondi de travaux et publications antérieurs, ainsi que des activités de conception et de développement avec des étudiants, des artistes et des chercheurs dans des ateliers pratiques.

État de l'art

Ce chapitre est consacré à la définition de quelques notions-clés ainsi qu'à une analyse basée sur l'état de l'art scientifique.

Définitions

Dans cette section, je m'efforce de mettre en évidence les concepts-clés et de leur trouver la meilleure définition dans le contexte de ma recherche.

Interaction co-localisée

L'interaction co-localisée est un sujet émergent dans les communautés de l'Interaction Homme-Machine (IHM) et du Travail coopératif assisté par ordinateur (TCAO). Bien que ce terme ait été utilisé dans de nombreuses publications, il ne semble pas avoir encore été formellement défini. Je propose donc d'apporter la définition suivante dans le cadre de cette thèse :

Un groupe d'individus se trouve dans une situation d'interaction co-localisée lorsque tous ses membres partagent le même espace physique, et que chaque membre a la possibilité de percevoir tous les autres membres du groupe directement (c'est-à-dire sans l'utilisation d'un dispositif de communication autre que les dispositifs utilisés pour compenser un défaut ou une invalidité tels que des lunettes). Chaque membre du groupe doit également être en mesure d'agir sur une plateforme numérique commune.

Art interactif

Dans sa définition la plus simple, une œuvre d'art peut donc être considérée comme interactive lorsque sa mise en œuvre nécessite la participation du spectateur. Le spectateur, alors participant actif, devient ainsi partie intégrante de l'œuvre. L'art interactif diffère de l'art de la performance et des happenings car il n'exige pas la présence de l'artiste lors de la participation du public (Kwastek 2013).

Expérience esthétique

Selon Dufrenne (Souriau 2010), le terme expérience, vu du point de vue du récepteur ou spectateur d'une œuvre d'art — par opposition à celui du praticien ou du créateur — “désigne le fait même de vivre une présence”, et “un certain mode de percevoir qui rend justice au perçu pour l'accomplir”. Il note également qu'une expérience esthétique, ou sensible, nécessite d'abord une certaine appréhension, et que cette expérience repose non seulement sur les expériences passées de l'individu, mais aussi sur les antécédents culturels de son groupe social.

Dans le contexte de cette thèse, je me référerai au terme *expérience esthétique* pour désigner une expérience utilisateur qui cherche à maintenir le bon équilibre entre performance, efficacité de l'action, et fidèle perception et réflexion de la situation interactive, à la fois à l'échelle individuelle et collective.

Interface, appareil et dispositif

Les termes *interface*, *dispositif* et *appareil* sont souvent utilisés dans le contexte de l'IHM et de l'art interactif. Les deux derniers termes sont même parfois utilisés de manière interchangeable. Afin d'éviter toute interprétation erronée, je tenterai de les distinguer et de clarifier leur signification dans le cadre de la présente thèse.

Interface De nos jours, le terme interface désigne généralement une frontière commune entre deux systèmes par lesquels ils peuvent communiquer par un échange d'informations, que ce dernier soit unidirectionnel ou bidirectionnel. Le terme est

utilisé, par exemple, pour désigner la description formelle des points d'entrée et de sortie d'un logiciel lui permettant d'échanger des informations avec d'autres logiciels. Sauf indication contraire, le terme interface sera utilisé ci-après pour désigner les interfaces utilisateur, permettant à un humain d'interagir avec une machine, de la contrôler ou d'en recevoir un retour d'information.

Appareil Alors qu'une interface utilisateur est un point de médiation entre un humain et une machine, un appareil est un outil ou un équipement généralement complexe qui reçoit l'information ou l'action, la traite et la renvoie sous forme de retour d'information ou d'action. Un appareil peut en effet comprendre plusieurs interfaces utilisateur fournissant des modalités d'interaction multiples. Un smartphone, par exemple, fournit un écran tactile, des haut-parleurs intégrés, un microphone, une caméra et d'autres interfaces d'entrée, de sortie, ou d'entrée et de sortie. Le terme appareil sera utilisé dans cette thèse en tant que tel ; pour désigner un équipement utilisé par les participants leur permettant d'interagir avec l'œuvre.

Dispositif Le terme dispositif est quelquefois utilisé de manière interchangeable avec celui d'appareil. Cependant, ce premier sera employé ici pour désigner l'ensemble du cadre spatial, technique et matériel d'une installation interactive, qui peut, et c'est souvent le cas, inclure plusieurs appareils.

État de l'art de la recherche

Ayant clarifié certains des termes les plus importants dans la section précédente, je passe en revue dans cette section l'état de l'art de la recherche sur les questions liées à l'interaction co-localisée dans l'art.

Art interactif

Cornock and Edmonds (1973), Bell (1991), Graham (1997), Nardelli (2010) et Winkler (2000) ont analysé et classé des œuvres d'art interactives selon différentes caractéristiques, dont certaines seront discutés dans le chapitre suivant. D'autres, tels

que Edmonds et al. (2006), ont cherché à détecter, comprendre et évaluer l'engagement créatif du public avec une œuvre interactive.

Interaction co-localisée

En sus du domaine de la sociologie, qui c'est sans aucun doute intéressé de près aux rencontres sociales humaines et les interactions en face-à-face — notamment à travers les travaux de Goffman (1966), Boudon (1979) et Zhao (2003) — les communautés de l'IHM et du TCAO ont également montré un intérêt accru au cours de la dernière décennie pour les systèmes conçus pour les interactions co-localisées (Myers et al. 1998; Greenberg et al. 1999; Luyten and Coninx 2005; Isenberg 2009). Néanmoins, les recherches dans ces domaines se sont principalement concentrées sur les systèmes prévus à un usage par des utilisateurs avertis. Rares sont ceux qui se sont intéressés à un usage par le grand public, tels que Kaviani et al. (2009a,b), Reeves (2008), Ludvigsen (2006), et Bedwell (2010), qui ont, entre autres, étudié les difficultés liées à la conception d'interfaces pour grand écran dans l'espace public.

Engagement mutuel

D'autres encore ont exploré de nouvelles approches interactives pour inciter les utilisateurs à communiquer et à collaborer les uns avec les autres (Krogh et al. 2004; Maynes-Aminzade et al. 2002; Isenberg et al. 2010; d'Alessandro et al. 2012; Dahl et al. 2011), mais se sont également concentrés sur les systèmes prévus à un usage dans le cadre du travail pour un public averti, ou nécessitant une modération ou orchestration pour canaliser les actions des utilisateurs et orienter la réaction du système.

Vers une taxonomie d'interaction collective co-localisée

Sur la base d'un examen et d'une analyse approfondie d'un large éventail d'œuvres existantes, je propose dans ce chapitre de classer les installations artistiques conçues

pour une interaction collective co-localisée sur les aspects qui me semblent avoir un impact significatif sur l'émergence d'une expérience collective.

Liste des installations d'art existantes

Tableau 3.1 liste les projets qui ont été sélectionnés selon les critères suivants :

- **Art interactif numérique**

J'ai choisi dans cette étude de considérer exclusivement les projets conçus comme des œuvres d'art interactives créées avec les technologies informatiques.

- **Avec peu ou pas d'orchestration**

La recherche s'intéressant spécifiquement aux problèmes qui surviennent lorsqu'aucune médiation ou orchestration humaine n'est mise en place, les œuvres qui nécessitent une telle médiation, notamment celles qui relèvent de l'art performance et des happenings, ne seront pas examinées ici.

- **Se rapportant aux arts visuels**

Cette recherche s'intéresse particulièrement aux œuvres présentant des éléments esthétiques visuels prédominants.

- **Conçus pour une interaction co-localisée**

Pour m'en tenir à mon sujet, seuls les projets spécifiquement conçus pour permettre la participation active simultanée de plusieurs individus dans un espace commun ont été considérés.

Dimensions de la classification

Principalement intéressé par les attributs qui influencent la nature et l'émergence d'une expérience partagée, j'ai choisi de porter une attention particulière aux sept facteurs suivants :

- **Échelle**

L'échelle d'une œuvre indique le nombre de participants actifs simultanés pouvant être pris en charge par le dispositif. Largement déterminé par les

ressources matérielles et spatiales disponibles, ce facteur a un impact évident sur la nature de l'expérience collective.

- **Modalité d'interaction**

La modalité d'interaction (directe, facilitée, ou ambiante) fait référence à la méthode par laquelle le public interagit avec l'œuvre, ce qui influence l'expérience individuelle et collective car elle a des effets, entre autres, sur la mobilité des participants. Elle détermine également le type d'attention requis pour interagir avec l'œuvre, ce qui, à son tour, a un impact sur l'attention qui peut être accordée aux autres participants et aux interactions sociales.

- **Distribution des entrées et des sorties**

Ces deux dimensions concernent le degré de distribution (centralisé, partiellement distribué, ou entièrement distribué) des interfaces d'entrées et de sorties.

- **Attribuabilité du retour d'information**

La capacité des participants à détecter qu'un changement dans le système est causé par leurs actions permet aux participants de se sentir, d'une certaine manière, en contrôle du système, affectant ainsi l'expérience collective et partagée. D'une certaine manière, l'attribuabilité est ainsi étroitement liée au concept psychologique du 'sentiment de pouvoir' comme décrit par [Gallagher \(2000\)](#). J'ai choisi d'évaluer l'attribuabilité sur une échelle relative de trois valeurs : **forte**, **moyenne**, et **faible**. Une forte attribuabilité implique une grande facilité à percevoir et à comprendre la corrélation entre ses actions et les retours d'information.

- **Type d'activité**

Qu'elle soit solitaire, collaborative ou compétitive, l'activité qu'une œuvre sollicite est un autre facteur qui peut façonner l'expérience individuelle et collective. L'activité est considérée comme collaborative si un certain résultat ne peut être atteint que lorsque les participants synchronisent leurs actions ou travaillent ensemble. Une activité compétitive est, quand à elle, impliquée lorsque plusieurs participants ou groupes de participants doivent s'affronter et déterminer un gagnant.

- **Symétrie de participation**

La symétrie de participation a été discutée dans la thèse de Bell (1991, p. 22).

Les œuvres dans lesquelles les participants peuvent participer de manière égale aux différentes activités sont considérées comme symétriques, tandis que celles dans lesquelles les participants jouent des rôles différents sont asymétriques. Ce facteur peut avoir un impact sur l'organisation collective, car il peut stimuler la discussion et la négociation entre les participants de différents rôles afin d'atteindre un certain résultat.

Motifs de conception

Les graphiques dans Fig. 3.8 et Fig. 3.9 classent chacune des œuvres échantillonnées dans les sept dimensions. Chaque dimension est associée à une couleur différente et les valeurs de la dimension sont représentées par des saturations décroissantes dans le même ordre qu'elles apparaissent plus haut, comme indiqué dans la légende du graphique.

Pour surmonter la difficulté de lire un tel graphique complexe, une version interactive est disponible en ligne à l'URL suivante : <http://thesis.semiaddict.com/radial-heatmap>, et une vue alternative sur les données, sous la forme d'un diagramme de Sankey, est représentée dans Fig. 3.10.

À l'aide de ces graphiques, on peut remarquer qu'étonnamment, ni l'échelle ni l'attribuabilité ne semblent être directement corrélées avec les autres dimensions. En fait, la seule corrélation discernable semble être celle qui existe entre la distribution des entrées et des sorties. En effet, Fig. 3.9c indique que lorsque les entrées sont centralisées, les sorties le sont aussi, mais le contraire ne tient pas. La figure indique également que les entrées sont entièrement distribuées lorsque les sorties le sont aussi. Nous pouvons également remarquer que près de la moitié des œuvres combinent une modalité d'interaction ambiante avec des entrées et des sorties centralisées, et qu'environ 23% des œuvres traitées partagent la même classification à l'exception de l'échelle : modalité d'interaction ambiante, entrées et sorties centralisées, attribuabilité élevée, activité solitaire et participation symétrique.

Études de cas

Le travail décrit dans cette thèse a été réalisé dans le cadre du projet de recherche *CoSiMa*¹ (Collaborative Situated Media) avec un financement de l'ANR (Agence Nationale de la Recherche). Réalisé par un consortium de six acteurs (IRCAM², EnsadLab³, Orbe⁴, ID Scènes⁵, Nodesign⁶, et Esba TALM⁷) entre 2015 et 2017, le projet visait la mise en place d'une plateforme portant le même nom destinée à faciliter la conception, le développement et le déploiement de médias interactifs multisensoriels collectifs et collaboratifs. Grâce à des ateliers, des prototypes et des études d'utilisateurs, le projet a également exploré de nouvelles expériences esthétiques impliquant la participation active du grand public.

Dans ce chapitre, la plateforme *CoSiMa* est brièvement décrite, et quelques-unes des principales leçons tirées à travers différentes expériences autour du projet *CoSiMa* sont discutées.

Contexte

Pour atteindre son objectif, le projet *CoSiMa* a exploité deux percées technologiques : (1) l'ubiquité des appareils mobiles actuels avec leur puissance de traitement et leur large éventail de modalités d'interaction, et (2) les avancées des standards du web et leur vaste implantation dans la plupart des principaux navigateurs. Ces deux percées technologiques combinées permettent le développement et le déploiement rapide d'installations multimédias participatives.

¹<http://cosima.ircam.fr/>

²<https://www.ircam.fr/>

³<http://www.ensadlab.fr/>

⁴<http://orbe.mobi/>

⁵<http://www.idscenes.com/>

⁶<http://www.nodesign.net/en/>

⁷<http://www.esba-talm.fr/>

La plateforme CoSiMa

Formée de plusieurs composants logiciels et matériels indépendants et interdépendants, la plateforme prend en charge une grande variété d'applications comprenant des installations d'art interactif multi-utilisateur, des expériences de réalité augmentée sonore, ainsi que des performances participatives audiovisuelles.

Mobilizing.js

Constituée de Dominique Cunin, Jonathan Tanant et moi-même, sous la direction de Samuel Bianchini, l'équipe EnsadLab était en charge de la conception et de l'implémentation du moteur graphique et des modules utilisés pour la gestion des interfaces graphiques. Déjà en cours de développement à EnsadLab, l'environnement logiciel auteur *Mobilizing.js*¹ a été utilisé dans la plateforme *CoSiMa* à cette fin.

En plus de cette mission, l'équipe EnsadLab était en charge de la conception et du développement des interfaces graphiques de projets prototypes, en particulier celui du tout premier prototype intitulé *Collective Loops*, qui servait non seulement de projet pilote de la plateforme, mais aussi d'opportunité pour réaliser des études qualitatives et quantitatives.

Cas central : Collective Loops

*Collective Loops*² est une installation expérimentale qui met en œuvre une version collaborative d'un séquenceur à boucle en huit temps, permettant aux membres du grand public de s'y connecter avec leurs smartphones via une page web locale et de créer de simples mélodies en temps-réel à travers un environnement partagé.

Les participants ont accès à deux interfaces utilisateurs : (1) une interface individuelle sur leur smartphone permettant de modifier le son émis, et (2) une visualisation circulaire partagée au sol d'environ 3 mètres de diamètre, montrant tous leurs choix de notes ainsi que la position actuelle de la tête de lecture du séquenceur. Le schéma dans Fig. 4.2 donne un aperçu de la configuration générale.

¹<http://www.mobilizing-js.net>

²<http://cosima.ircam.fr/2015/11/25/collective-loops-forum-workshops/>

Une première version du prototype a été déployée et testée auprès du grand public lors des journées portes ouvertes de l'IRCAM en juin 2015. Cette première confrontation avec le public nous a permis d'effectuer un test grandeur nature de la plateforme *CoSiMa* et de détecter des problèmes techniques difficiles à évaluer autrement. Cela nous a aussi permis d'obtenir des commentaires sur l'interface utilisateur et les aspects de conception d'interaction de *Collective Loops* à travers une étude exploratoire avec des interviews, des questionnaires (voir [annexe C](#)) et des captations vidéo.

Suite à plusieurs semaines de développement, une deuxième version améliorée du prototype a vu le jour, et un nouveau déploiement public a été organisé lors des *Ateliers du Forum* à l'IRCAM en novembre 2016.

J'ai saisi cette occasion pour mener une étude qui visait à vérifier l'hypothèse que révéler les choix de tous les utilisateurs sur l'interface commune et partagée favoriserait une expérience plus collaborative. Ainsi deux versions différentes de l'interface partagée, projetée au sol (illustrées dans [Fig. 4.6](#)) ont été testées dans cette étude comparative : (a) les choix des participants étaient affichés sur l'interface ainsi que la position actuelle de la tête de lecture, (b) seule la position actuelle de la tête de lecture était affichée.

Basée sur les impressions des participants concernant leur engagement dans le processus collectif et leur capacité à créer un résultat commun satisfaisant, l'étude n'a pas permis de déterminer clairement si la projection partagée des choix de tous les participants avait un impact sur l'émergence et la qualité d'une expérience collective commune. Cependant, cette expérience ainsi que d'autres ont été très fructueuses pour le projet *CoSiMa* et mes recherches. Les leçons tirées seront discutées dans la section suivante.

Leçons tirées

Attractors, sustainers, relaters ... et facilitators

Edmonds et al. (2006) ont décrit certains aspects des installations interactives qui peuvent influencer les changements de degré d'engagement des participants. Ils

désignent ces aspects comme les attributs de l'engagement créatif : les *attractors*, les *sustainers*, et les *relaters*.

Les effets de certains de ces aspects ont bien été observé dans *Collective Loops* et *Surexposition*. Il semble cependant que nous puissions ajouter un quatrième attribut : les *facilitators*, désignant les aspects d'une installation qui simplifient ou facilitent la rencontre dans ses premières étapes, et qui sont de fait étroitement liés à l'intuitivité de l'interface et à l'affordance. Pour faire place aux *sustainers*, il pourrait être nécessaire de diminuer progressivement les *facilitators*, en augmentant lentement la complexité de l'interaction ou les possibilités interactives du système, sans quoi l'expérience pourrait devenir un peu banale.

Conflits dans le rythme d'interaction

Dans les installations d'art interactif, les participants sont généralement libres de rejoindre et de quitter l'expérience à tout moment, ce qui a un impact direct sur la nature et la probabilité d'émergence d'une expérience collective. Ceci est particulièrement problématique dans les installations spécifiquement conçues pour la collaboration comme c'est le cas avec *Collective Loops*. En effet, un effort de collaboration peut être grandement perturbé par l'arrivée d'un nouveau participant ou le départ d'un participant actif, obligeant les autres participants à se réadapter et se réorganiser.

De plus amples recherches sont nécessaires pour évaluer les impacts de l'arrivée et du départ des participants dans l'engagement collectif et collaboratif, et comment réduire ou réguler ces impacts.

Poids attentionnel des interfaces

Dans les environnements multi-écrans et multi-sensoriels, un autre défi de conception est impliqué : celui de la gestion de l'attention des participants. En effet, les participants de *Collective Loops* ont été confrontés à pas moins de quatre sources d'attention tout au long de leur participation : (1) l'interaction individuelle sur leurs smartphones, (2) la visualisation de toutes les interactions sur la projection partagée, (3) les sons émis par les appareils individuels, et (4) leur collaboration avec d'autres

membres du public. Alors que nous souhaitons promouvoir le quatrième au moyen des interfaces individuelles et partagées, les quatre semblaient être en concurrence les unes avec les autres. Elles sollicitent toutes, de différentes manières, l'attention de l'utilisateur. Il semble donc difficile aux participants de prêter attention aux autres si leur esprit est déjà occupé par une, deux ou même trois autres sources d'attention.

En s'appuyant sur des recherches antérieures comme celle de Witka (2016), dans laquelle a été évaluée l'importance de différentes propriétés de perception telles que la couleur, la luminosité, le champ de vision et l'attention sur différents types d'environnements multi-écrans, plus de recherches doivent être entreprises pour trouver un équilibre entre des sources d'attention concurrentes. Nous pourrions, par exemple, considérer le poids attentionnel des interfaces individuelles et partagées pour les équilibrer, ou gérer dynamiquement leur capacité à retenir ou libérer l'attention des utilisateurs, et ainsi mieux contrôler quel type d'interaction nous aimerions privilégier afin de soutenir l'émergence d'une situation collaborative.

Angle de l'affichage partagé : horizontal vs vertical

L'interface partagée de *Collective Loops* étant projetée au sol, elle est dans un champ visuel contigu avec celui de l'interface affichée sur les dispositifs mobiles individuels, simplifiant ainsi les aller-retours d'attention visuelle entre les deux interfaces comme représenté dans Fig. 4.13a et Fig. 4.13b.

L'angle vertical de l'affichage partagé dans *Surexposition* et *Mobilisation*¹ demande aux participants de lever la tête lorsqu'ils passent du dispositif individuel au dispositif partagé (comme dans 5.1.2 et 5.1.3). En conséquence, les participants utilisant l'application sur leur smartphone semblent être momentanément en marge de l'expérience collective.

Concevoir en prenant en compte les files d'attente

Qu'elles régulent l'accès aux ressources spatiales ou matérielles, les files d'attente font partie intégrante de nombreuses installations. La manière dont elles sont gérées

¹<http://dispotheque.org/fr/mobilisation>

peut profondément affecter l'expérience participative. Bien qu'elle soit généralement perçue comme étant un effet indésirable des limitations de ressources, il est parfois possible de concevoir autour de l'expérience de la file d'attente afin d'améliorer l'expérience utilisateur globale.

Lors d'une interview avec l'architecte et artiste Usman Haque (voir [annexe A](#)), celui-ci a révélé comment l'expérience de la file d'attente du projet *Assemblance*¹ a été utilisée comme *facilitators*.

Cette stratégie peut être efficace pour les installations qui présentent des files d'attente physiques avec des participants passifs qui attendent leur tour pour interagir. Cependant, d'autres stratégies doivent être envisagées dans les installations similaires à *Surexposition*, dans laquelle les ressources limitées résident principalement dans les capacités de sortie de l'interface partagée — la vitesse d'obturation des projecteurs de lumière du monolithe — et non du côté de la participation à proprement parler.

Dans le chapitre suivant, un autre défi est abordé : celui de la modélisation des interactions collectives co-localisées.

Modélisation des interactions co-localisées

Comme indiqué précédemment, le type et la qualité de l'expérience esthétique dans les installations artistiques qui permettent des interactions co-localisées sont déterminés et influencés par de nombreux facteurs différents, rendant la conception de tels systèmes complexe et ardue.

Afin de guider les artistes et les concepteurs dans cette tâche, je me suis efforcé de créer un langage de modélisation graphique spécifique au domaine. En tant qu'abstraction d'un système, un modèle permet, en fait, d'extraire des aspects et des caractéristiques essentiels du reste du système. Le système peut ensuite être analysé, comparé ou évalué de manière rapide et efficace.

Dans ce chapitre, je présenterai deux approches différentes d'un langage de modélisation graphique. La première se concentre principalement sur la visualisation

¹<http://umbrellium.co.uk/initiatives/assemblance/>

des relations et des arrangements des interfaces utilisateurs à travers des abstractions de très haut niveau. La seconde est centrée sur l'humain et met l'accent sur l'expérience de l'utilisateur, avec un niveau de détail ajustable.

Schéma relationnel des interfaces

Ma première approche a été initialement créée comme aide visuelle dans une étude de la topologie des interactions collectives co-localisées (Mubarak et al. 2016, 2017). L'étude a examiné et analysé les configurations possibles de l'espace interactif en fonction des actions et des relations entre ses agents — humains et machines — dans quatre installations d'art interactif conçues dans le cadre de la recherche sur le «Large Group Interaction» à EnsadLab : *Discontrol Party*, *Surexposition*, *Mobilisation* et *Collective Loops*.

Comme illustré dans Fig. 5.1, le langage est composé de deux symboles principaux : (1) un carré représentant les interfaces individuelles avec un indicateur spécifiant s'il s'agit d'interfaces d'entrée, de sortie, ou les deux, et (2) un symbole hexagonal pour les interfaces partagées avec les indicateurs identiques pour l'entrée et la sortie. De plus, le nombre de chaque interface supportée par le système est représenté par une petite icône superposée dans le coin en haut à droite de chaque symbole, l'arrangement ou l'organisation des interfaces individuelles peut être indiquée en utilisant l'une des icônes de Fig. 5.1d, et la direction du flux de données d'interaction entre les interfaces individuelles et partagées est illustrée par les différentes flèches de Fig. 5.1e.

Conçu pour être facile à utiliser, le langage de modélisation proposé est constitué d'un petit ensemble de symboles d'un très haut niveau d'abstraction. Ce langage s'est déjà avéré utile pour esquisser le graphe relationnel des interfaces de différentes installations. Révélant une partie de la topologie de chaque installation, les modèles peuvent aider à les examiner, les classer et les comparer.

Une telle approche pourrait également être utilisée comme langage de programmation visuel facilitant la mise en place de composants logiciels d'une installation. La configuration réseau d'un serveur, par exemple, pourrait être gérée automatiquement grâce à l'interprétation des besoins de communication d'un modèle.

Le pouvoir expressif de la langue en tant qu'outil de modélisation est cependant très limité. Dans son état actuel, il ne peut pas, par exemple, être utilisé pour modéliser des cas particuliers comme l'œuvre *SMSlingshot*, dans laquelle une interface individuelle, la fronde numérique portative, est passée d'un participant à un autre (Fischer et al. 2013). Le langage ne permet pas non plus d'indiquer des emplacements fixes ou prédéfinis pour des interfaces individuelles comme c'est le cas dans *Kinoautomat*, *Dialtones (A Telesymphony)* et *PixelPhones*. La modélisation de tels cas nécessiterait donc d'enrichir la langue avec de nouveaux symboles.

CoPN : vers une approche centrée sur l'humain et basée sur les réseaux de Petri

Les lacunes et les faiblesses détectées dans ma première approche m'ont incité à en explorer une nouvelle dans laquelle les propriétés souhaitées suivantes ont été identifiées :

- capable de modéliser les interactions homme-machine, homme-homme et homme-machine-homme
- capable de modéliser les ressources spatiales et matérielles
- supporte différents niveaux d'abstraction et le raffinement progressif d'un modèle
- pratique pour la description, la comparaison et la classification des systèmes d'interaction co-localisés
- assez précise pour être éventuellement utilisée dans les processus de vérification, de spécification et d'implémentation du système modélisé
- accessible aux non-informaticiens
- facilite le dialogue entre les artistes, les designers et les ingénieurs logiciels dans le processus de conception

J'ai choisi de baser cette nouvelle approche sur un langage de modélisation existant avec une base solide. Suite à une évaluation de plusieurs langages couramment utilisées, tels que UML, SysML, et le réseau de Petri, ce dernier semble être la solution la plus adaptée pour répondre aux objectifs déterminés.

À la fois un langage de modélisation mathématique et graphique, le concept des

réseaux de Petri a été initialement décrit dans la thèse du mathématicien Carl Adam Petri (Petri 1962). Un réseau de Petri est composé de deux types de nœuds et d’arcs reliant les nœuds entre eux, et des jetons sont utilisés pour indiquer l’état actuel, appelé marquage, du réseau. Pour une description plus complète et une définition formelle, se référer à Reisig (1985, 2013); Kordic (2008); Murata (1989).

Les modèles mathématiques sous-jacents des réseaux de Petri et les différentes techniques analytiques qui leur sont applicables permettent d’analyser, vérifier et simuler des systèmes avec des processus “simultanés, asynchrones, distribués, parallèles, non déterministes et/ou stochastiques” (Murata 1989). Les réseaux de Petri peuvent ainsi être utilisés pour modéliser une grande diversité de systèmes complexes et leurs composants avec un ensemble minimal d’éléments graphiques.

En outre, en plus d’être bien adaptés à la modélisation de composants matériels et logiciels, les réseaux de Petri peuvent être utilisés pour modéliser les interactions homme-machine (Ortega et al. 2013) et homme-homme (Khaddaj and Makoond 2010).

Modélisation des interactions homme-homme

Puisque les interactions homme-homme sont beaucoup moins souvent modélisées avec les réseaux de Petri que les systèmes informatiques ou les interactions homme-machine, j’ai commencé par vérifier que la modélisation des conversations humaines en face-à-face était possible afin de valider mon choix du langage sur lequel me baser. Mon but ici est de vérifier qu’il est possible de simuler le temps qu’une personne passe dans une conversation avec ses pairs ; temps qui n’est par conséquent pas passé en interaction directe avec le dispositif interactif.

Suite à plusieurs itérations qui ont abouti au modèle illustré dans Fig. 5.8, il a été possible de valider, du moins pour nos objectifs, la faisabilité d’utiliser des réseaux de Petri pour modéliser des conversations humaines à deux et à trois personnes. Nous pouvons également supposer qu’il serait possible de modéliser des conversations avec un plus grand nombre de participants, mais que cela créerait des modèles exponentiellement plus grands, entravant grandement leur lisibilité.

Des réseaux bas niveau à ceux de haut niveau

Avant d’aborder ces problèmes de lisibilité, j’ai entrepris la modélisation de certaines de nos installations (en particulier *Collective Loops*) en utilisant les réseaux de Petri élémentaires. Pour cette tâche, j’ai profité de l’un des atouts des réseaux de Petri : la possibilité d’affiner progressivement un modèle. Ainsi, partant d’un modèle avec un très haut niveau d’abstraction comme celui dans Fig. 5.9, j’ai progressivement ajouté des détails jusqu’à atteindre le niveau d’abstraction souhaité, aboutissant au modèle dans Fig. 5.11.

Suite à ces travaux, il a été constaté que, bien que la modélisation de telles installations soit possible avec des réseaux de Petri élémentaires, les modèles deviennent rapidement trop grands et complexes. Cependant, il existe plusieurs extensions de réseaux de Petri qui peuvent aider à remédier à ces problèmes et rendre la modélisation des systèmes complexes plus pratique. La plupart des extensions sont regroupées sous le terme *réseaux de Petri de haut niveau*. Certaines de ces extensions, telles que les *réseaux colorés* (Jensen 1998), sont rétro-compatibles — préservant les propriétés des réseaux de Petri élémentaires — tandis que d’autres étendent véritablement le pouvoir expressif des réseaux de Petri, comme les arcs de vidange, les arcs inhibiteurs (Lakos and Christensen 1994; Verbeek et al. 2010) et les réseaux de Petri temporisés (Boyer and Roux 2008).

En employant de telles extensions — en particulier celle des réseaux colorés — il a été possible de grandement améliorer mes modèles. Ainsi, le modèle de *Collective Loops* illustré dans Fig. 5.16 et son sous-modèle Fig. 5.15 permettent de prendre en charge un nombre variable de participants tout en conservant la lisibilité.

Vers un langage dédié

Ces recherches préliminaires m’ont permis de m’assurer que les réseaux de Petri de haut niveau peuvent bien être utilisés pour modéliser les interactions co-localisées homme-homme, homme-machines, ainsi que homme-machines-homme autour des installations artistiques, tout en intégrant des notions de ressources spatiales et matérielles et leur gestion. Cependant, les modèles peuvent être difficiles à interpréter et à manipuler, en particulier pour les artistes ou les designers qui n’ont souvent pas

d'expérience préalable avec les outils de modélisation ou le langage de programmation sous-jacent. De plus, contrairement aux réseaux de Petri élémentaires, les jetons d'un modèle sont souvent représentés textuellement, rendant le suivi visuel des jetons difficile.

Pour tenter de remédier à ces inconvénients, j'ai entamé la création d'un langage de modélisation graphique dédié aux interactions collectives co-localisées — que j'ai nommé *CoPN* — tout en me basant sur les réseaux de Petri de haut niveau. Fig. 5.19c illustre quelques-uns des symboles graphiques spécifiquement conçus pour *CoPN*, permettant, par exemple, de créer le modèle de *Surexposition* figurant dans Fig. 5.20.

Suite à des entretiens avec les artistes Usman Haque et Mouna Andraos (voir respectivement annexe A et annexe B), il a été conclu que, pour que *CoPN* devienne un outil adapté à leur communauté, des niveaux plus élevés d'abstraction pourraient être requis. Ainsi, de la même manière que *Mobilizing.js*, qui vise à permettre aux utilisateurs de travailler sur différents niveaux d'abstraction en fonction de leurs compétences de développement, *CoPN* pourrait tirer avantage des concepts hiérarchiques des réseaux de Petri colorés pour permettre aux utilisateurs de commencer avec un modèle à un niveau d'abstraction presque aussi élevé que ma première approche de modélisation.

Une fois abouti, un tel langage pourrait non seulement être utilisé pour la modélisation et la simulation, mais pourrait également servir de support à la spécification technique et à la programmation logicielle. Il pourrait également servir de base à un outil de visualisation en temps réel, permettant aux artistes de suivre leur installation et de modifier ses paramètres en temps réel afin de promouvoir une organisation collective particulière.

De plus, même si je me suis concentré sur la modélisation des interactions co-localisées pour les installations artistiques, la plupart des concepts s'applique à d'autres contextes tels que les environnements de travail avec des interfaces distribuées localement et les interactions avec les grands écrans publics. Ainsi, avec des ajustements mineurs, le langage de modélisation pourrait également servir la communauté TCAO parmi d'autres.

Conclusion et perspectives

Dans cette thèse j'ai d'abord clarifié quelques termes importants et donné un aperçu de l'état de l'art dans divers domaines. Puis, sur la base d'un examen d'un large éventail d'installations artistiques répondant à un ensemble de critères, j'ai proposé une taxonomie qui se concentre sur les aspects qui affectent l'émergence et la nature d'une expérience collective et partagée dans un même lieu à travers une médiation technique. J'ai ensuite présenté plusieurs cas de conception, en portant une attention particulière à une étude réalisée sur le projet prototype *Collective Loops*, et discuté quelques-unes des principales leçons tirées, avant de mettre l'accent sur deux approches graphiques pour modéliser les interactions co-localisées. Si cette approche singulière concerne en premier lieu les arts interactifs, elle peut revêtir également un caractère pertinent pour d'autres communautés de recherche, y compris et en premier lieu, celle de l'IHM, ainsi que celles du TCAO, des Nouvelles interfaces pour l'expression musicale (NIME), du design d'interaction ou encore de la culture, en particulier de la muséographie.

La recherche limitée dans le domaine de l'interaction co-localisée assistée par ordinateur, et plus particulièrement dans le domaine de l'art interactif, offre de nombreuses perspectives pour de futurs travaux.

Sur la base des expériences menées, nous pouvons déjà formuler l'hypothèse que les actions individuelles produites par l'interaction avec des dispositifs individuels, pourraient être considérées comme un initiateur, un accélérateur et un catalyseur de l'interaction collective. Par exemple, une fois l'interaction initiée et la phase d'apprentissage accomplie, les téléphones portables, initialement utilisés comme dispositifs d'entrée et de sortie, pourraient progressivement voir leurs capacités de sortie diminuer, et celles d'entrée augmenter — renforçant alors leur rôle d'interface d'entrée — libérant ainsi l'attention des utilisateurs au profit de l'appareil partagé. Cependant, une recherche plus approfondie doit être menée pour vérifier une telle hypothèse.

D'autres recherches pourraient aussi étudier comment les principes d'*affordance*

*perçue*¹ (Norman 2002) et du *feedforward*² (Djajadiningrat et al. 2002) peuvent aider les nouveaux arrivants dans la phase initiale d'apprentissage, leur permettant de se familiariser rapidement avec les possibilités offertes par une installation, et donc de consacrer plus de temps à la construction d'une expérience collective.

Un autre domaine d'exploration possible réside dans l'amélioration de l'attribuabilité grâce à un retour d'information personnalisé et à la demande. En effet, alors que l'attribuabilité du retour d'information était jugée élevée pour un grand nombre d'œuvres, seule une de celles-ci (*Surexposition*) supporte plus de 500 participants, et la haute attribuabilité est largement due au fait qu'un seul message est affiché à la fois. Ainsi, si nous devons concevoir des installations à grande échelle tout en combinant des interfaces utilisateur individuelles et partagées, l'attribuabilité peut devenir un problème majeur. Une éventuelle solution pourrait consister à permettre aux participants de déclencher un retour d'information à la demande, leur permettant de localiser temporairement leur propre représentation dans les interfaces partagées.

La participation active aux activités de conception et de développement autour de futurs projets contribuera à parfaire davantage ma compréhension des défis rencontrés et à élaborer de nouveaux moyens pour les surmonter. Un nouvel événement *Discontrol Party* est prévu en février 2018 dans le cadre de l'événement *Nous ne sommes pas le nombre que nous sommes être* et le festival de danse *Faits d'hiver*³ à la Cité Internationale des Arts à Paris. Cette nouvelle version intégrera des interactions sur smartphones en plus de celles par tags UWB et caméras de surveillance, promettant de fournir des expériences riches et multiples.

¹Un moyen par lequel une interface utilisateur communique la possibilité ou non d'une action

²Principe de design d'interface décrit par Djajadiningrat et al. (2002) comme étant la "communication du but d'une action", donnant ainsi aux utilisateurs la possibilité de comprendre les effets d'une action avant qu'elle ne soit déclenchée

³<http://www.faitsdhiver.com>

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1 Introduction

1.1 Motivation

Interactive art installations that support real-time co-located audience participation emerged as early as the 1960s with projects such as *Kinoautomat*¹ (1967), *SAM - Sound Activated Mobile*² (1968) and *Glowflow*³ (1969). With the advent of personal computers and advanced surveillance and tracking technologies such as computer vision techniques, co-located interactive art projects became more common in the 90s. However, the interaction mechanisms used then were difficult to setup and did not scale well and adapt to the number of participants.

By the early 2000s, projects such as *Dialtones (A Telesymphony)*⁴ and *Blinkenlight*⁵ used widely accessible personal devices — mobile phones — making those projects easier to deploy to a large public.

With the release of the first smartphones in the late 2000s, powerful pocket-sized mobile computing devices have become more and more ubiquitous. The new opportunities offered by the multiplication and interoperability of computer terminals favored the emergence of installations such as *Bloc Jam*⁶ and *Overexposure*⁷, sharing the common objective of deploying original and unprecedented situations of collective

¹<http://www.kinoautomat.cz/index.htm?lang=gbr>

²<http://www.senster.com/ihnadowicz/SAM/sam.htm>

³<http://dada.compart-bremen.de/item/artwork/1347>

⁴<http://www.flong.com/projects/telesymphony/>

⁵<http://blinkenlights.net/>

⁶<http://www.dailytouslesjours.com/project/bloc-jam/>

⁷<http://www.sureexposition.net/>

co-located interactions capable of a profound renewal of forms of the aesthetic experience.

While the large variety of embedded input and output modalities made available by those devices opened up a wide range of new opportunities, it also brought along new challenges when designing interfaces for audience participation. One of those challenges involves the capacity for participants to identify and understand the effects of their actions as well as others' on the system. Another challenge relates to the proper management of the attentional load of the individual and shared interfaces in order to allow a shift of users' focus from the individual to the shared interfaces and thus better promote a common, collective experience.

Indeed, in previous experiments carried out within the framework of the *Discontrol Party*¹ project by Samuel Bianchini in 2009 and 2011, I observed difficulties from the part of individuals interacting within the large group to locate their own actions on the real-time shared graphical representations, and, thus, to distinctly understand their effects on the interactive system.

With particular interest in interactive art installations — which rarely call for the execution of a task or dictate a common objective to achieve in a predefined framework that can serve as a guideline or support for the activity — the research described in this thesis aims at better understanding the various challenges faced by artists in conceiving such works, and the difficulties encountered by participants when interacting with them, towards the goal of proposing a set of tools and design guidelines facilitating the conception of systems that promote co-located interaction within a group for the general public.

1.2 Key research questions

The research project and this dissertation aspire, above all, the establishment of a theoretical and practical design framework that could help guide artists when conceiving art installations for co-located interactions.

The research sets out to gain a better insight into the different attributes and

¹<http://dispotheque.org/en/discontrol-party>

characteristics of co-located interactive art installations that hinder or promote the emergence of collective experiences, with the central research question being:

How to design collective co-located interactions for art installations to promote the emergence of common aesthetic experiences?

In addition to the general question above, the thesis tackles the following significant questions:

- What aspects of interactive art installations affect the nature of the individual, multi-individual and collective interactions?
- What needs to be considered when designing and developing art installations that combine both individual and collective user interfaces to support the emergence of a common aesthetic experience?
- How can we model the human-computer, human-human and/or human-computer-human interactions in such systems, and would that be of any use for artists?

1.3 Conduct of research

The thesis project was conducted jointly in the “Interactivité pour Lire et Jouer” team within the “Médias Interactifs et Mobilité” group at the Cédric¹ laboratory (Centre d’Études et De Recherche en Informatique et Communication) in CNAM (Conservatoire national des arts et métiers) and the “Reflective interaction” group at EnsadLab² (the research laboratory of the École nationale supérieure des Arts Décoratifs - PSL Research University, Paris).

The thesis project was also part of the *CoSiMa*³ (Collaborative Situated Media - ANR-13-CORD-0010) research project, which brought together multidisciplinary teams of several French institutions and companies, with the common goal of developing a software platform facilitating the creation of co-located interaction projects.

¹<https://cedric.cnam.fr/>

²<http://www.ensadlab.fr/>

³<http://cosima.ircam.fr/>

In this context, EnsadLab was responsible for the development of the graphics and data visualization rendering modules of the platform, which was fulfilled by the integration of parts of the *Mobilizing.js* authoring tool (described in section 4.1.2).

Participating in the design and development of those modules as well as prototype projects, the thesis was largely guided by the strict schedule of *CoSiMa* deliverables, and relied on prototypes to perform studies and observations.

In addition to such experiences, this theoretical and practical research builds upon a review of existing projects and literature, as well as design and development activities with students, artists and researchers in hand-on workshops.

1.4 Research context

The thesis primarily addressing interaction design issues, it is in the intersection between computer science, human-computer interaction and design (data visualization, user interface design and interaction design), and is closely related to, and builds on, research in the areas of interactive art, groupware, face-to-face interaction, interaction techniques with public displays, distributed user interfaces, and audience engagement.

The partnership between EnsadLab and the Cédric laboratory as well as the multidisciplinary supervisory team and the diverse thesis jury epitomize the relationship between the fields of human-computer interaction, design and art. While evident in the research at hand, this relationship has seen an upward swing through mutual interest in the different communities related to those fields, exemplified by the special sessions organized in international conferences inviting, for example, artists to submit papers, installations or performances in the *Arts Track* at TEI (the International Conference on Tangible, Embedded and Embodied Interaction) and the *alt.IHM* track at IHM (the French Conference on human computer interaction). In fact, while design, human-computer interaction, and software development are undoubtedly an integral part of interaction design, it being concerned by the quality of the relationships created by the artifacts, the notion of aesthetics, while less evident, is as equally important (see section 2.1.3 for a definition of aesthetic experience).

Also, while cognitive psychology is a common topic in human-computer interaction and interaction design, this thesis project, dealing with interactions within groups of participants, also involves concepts of sociology.

Furthermore, while the primary goal of the research is to expand our understanding of design and interaction challenges in a particular type of interactive art — that which enables co-located interactions — it may be relevant to a wide range of research communities, including that of Computer-Supported Cooperative Work (CSCW), New Interfaces for Musical Expression (NIME), Human-Computer Interaction (HCI), the arts, design and culture (museumography in particular).

1.5 Research approach

I strove in this thesis to reach a balance between both theory and practice. And Research through Design (RtD)¹ has been a guiding methodology throughout the thesis project. In this regard, design has been an integral part of the research tools used when forging tests, experimentations and observations on the various prototypes, tools, and installations created within the framework of the thesis and the *CoSiMa* project.

In addition, discussions and debates with supervisors, artists, and fellow researchers from various fields have been an influential tool in shaping the research's direction.

1.6 Associated works

Conducted throughout the thesis project, the following dissemination activities have contributed to the ideas and material discussed in this dissertation:

¹A term coined by Frayling (1993) to describe a research methodology in which design is used as a tool for research by approaching thought and knowledge from a design perspective

Publications

- Oussama Mubarak, David Bihanic, and Samuel Bianchini. Dispositifs & installations artistiques : étude de la topologie des interactions collectives co-localisées. In *28ième conférence francophone sur l'Interaction Homme-Machine*, alt.IHM, pages 10–19, Fribourg, Switzerland, October 2016.
- Norbert Schnell, Benjamin Matuszewski, Jean-Philippe Lambert, Sébastien Robaszkiewicz, Oussama Mubarak, Dominique Cunin, Samuel Bianchini, Xavier Boissarie, and Gregory Cieslik. Collective Loops: Multimodal Interactions Through Co-located Mobile Devices and Synchronized Audiovisual Rendering Based on Web Standards. In *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '17, pages 217–224, New York, NY, USA, 2017. ACM. ISBN 978-1-4503-4676-4. doi: 10.1145/3024969.3024972.
- Oussama Mubarak, David Bihanic, Pierre Cubaud, and Samuel Bianchini. Art Installations: A Study of the Topology of Collective Co-located Interactions. In *Proceedings of the 8th International Conference on Digital Arts*, ARTECH2017, pages 23–30, New York, NY, USA, 2017. ACM.
- Oussama Mubarak, Pierre Cubaud, David Bihanic, and Samuel Bianchini. Designing Collaborative Co-Located Interaction for an Artistic Installation. In Regina Bernhaupt, Girish Dalvi, Anirudha Joshi, Devanuj K. Balkrishan, Jacki O'Neill, and Marco Winckler, editors, *Human-Computer Interaction - INTERACT 2017: 16th IFIP TC 13 International Conference, Mumbai, India, September 25–29, 2017, Proceedings, Part I*, pages 223–231. Springer International Publishing, Cham, 2017.
- Samuel Bianchini, Dominique Cunin, and Oussama Mubarak. Map, Mapper, Mapping. In Vincent Ciciliato and Karen O'Rourke, editors, *Collecter, cataloguer, cartographier. Pratiques de l'archivage numérique*. Publications Universitaires de Saint-Étienne, Saint-Étienne, 2017. (in press)

Presentations

- Oussama Mubarak. A taxonomy of multi-user co-located interaction environments. In *27ème conférence francophone sur l'Interaction Homme-Machine*, Rencontres doctorales, Toulouse, France, October 2015.
- Oussama Mubarak, *Du repérage visuel de l'information en contexte d'interaction co-localisée*, RES#1 – Recherche en visualisation de données, Tourcoing, France, June 2015
- Oussama Mubarak, *Visual identification in multi-user co-located interaction*, Monthly Visualisers Gathering, Berlin, Germany, June 2015
- Oussama Mubarak, *Du repérage visuel de l'information en contexte d'interaction co-localisée*, Biennale internationale de l'Éducation, de la Formation et des Pratiques professionnelles, CNAM, Paris, France, June 2015
- Oussama Mubarak, *De l'individu au collectif: conception d'interaction co-localisée*, presented in the context of the seminar *Expérimentations et enjeux des interactions collectives (œuvres et dispositifs)*, ESBA TALM, Le Mans, France, September 2016
- Dominique Cunin, Samuel Bianchini, Oussama Mubarak, *Mobilizing.js* and *La Recherche-Création en art* seminar, Design Graduate School of Film and New Media, Tokyo University of the Arts, invited by Takashi Kiriya, Tokyo, Japan, March 2017
- Norbert Schnell, Samuel Bianchini, Oussama Mubarak, Dominique Cunin, Christophe Domino, Uroš Petrevski, Xavier Boissarie *presentation of the results of the CoSiMa project*, festival Manifest, Ircam, Paris, France, June 2017
- Oussama Mubarak, *Interactions collectives co-localisées dans les dispositifs artistiques*, presented in the context of the *Présentation de la réforme design & métiers d'art*, St-Etienne, France, March 2017

Workshops

- Samuel Bianchini and Oussama Mubarak, *À plusieurs tout seul*, École nationale supérieure de la photographie, Arles, France, October 2015
- Dominique Cunin and Oussama Mubarak, preparation workshop for *Espace ^ Espace*, Esbama, Montpellier, France, March 2016
- Oussama Mubarak and Samuel Bianchini, *From spectator to actor: designing for collective audience participation using smartphones*, PROYECTOR16 – 9th International Videoart Festival, Madrid, Spain, October 2016

1.7 Thesis structure

Apart from this introductory chapter, this dissertation is composed of five other chapters, a list of bibliographic references, and appendices.

In the **next chapter** I will go over a few key terms and their definitions before presenting a broad review of related literature in relevant fields, including sociology, human-computer interaction, and art. The review is organized by research themes; starting with interactive art, followed by co-located interaction and mutual engagement.

Building upon previous taxonomies and a review of over a hundred works ranging from 1967 up until 2017, **chapter 3** proposes a taxonomic classification of co-located interactive art installations with a focus on aspects that influence the individual, multi-individual and collective experiences.

In **chapter 4**, I will briefly present the *CoSiMa* platform before examining a central design case around the *Collective Loops* prototype project as well as other peripheral cases, and then discuss the various lessons learned from them.

Chapter 5 is dedicated to an endeavor of creating a domain-specific graphical modeling language for the analysis, comparison and classification of co-located interactive installation, with the aim of facilitating the design and development of such works by artists. In this effort, two radically different approaches will be

examined and reviewed. The first approach is a set of graphical symbols that allow the modeling, at a high-level of abstraction, of the relationships between the different user interfaces of an installation, while the second approach, based on Colored Petri Nets, allows the progressive refinement of a model and takes into account spatial and material resources, human-computer interactions, as well as human-human and human-computer-human interactions.

The conclusion in [chapter 6](#) summarizes the work carried out and the key findings, and discusses further challenges and research perspectives.

The [appendices](#) contain transcriptions of interviews with Usman Haque and Mouna Andraos, as well as questionnaires handed out in user studies.

2 Overview of literature

This chapter clarifies some of the important concepts dealt with throughout this thesis and provides a thorough review of the current state of closely related research.

The concepts brought forward and their definitions served as a guideline throughout this thesis, and the practice-based research undergone (discussed in [chapter 4](#)) strongly relied on insights gained through the critical assessment of the findings.

2.1 Definitions

In this section, I endeavor to highlight the key concepts and find their best suitable definition in the context of my research.

2.1.1 Co-located interaction

Co-located interaction is a gradually emerging topic in the HCI and the CSCW communities.

While the term *co-located interaction* (also spelled *collocated* or *colocated*) has been employed in many publications (some of which will be discussed later in this chapter), it has not, to my knowledge, yet been formally defined. In the CSCW community, the term is usually coined when referring to a, generally small, group of users interacting on a common interface while sharing the same physical space.

Other terms are also often used to describe closely related concepts, yet the term

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co-located interaction seems a better fit in the context of this research.

The term *local multi-player* is, for example, too tightly linked to the notion of video game. It is indeed often used by the computer game industry to identify games designed to be played by multiple users sharing a screen in a local setting, as opposed to the more traditional local area network (LAN) or online multi-player games.

The term *face-to-face interaction*, thoroughly defined by Goffman (1966) in the context of social interactions, seems too restrictive to be used here as it usually implies a small number of participants. It is in fact often employed by the HCI and CSCW community for interactions around interactive tabletops that rarely support over a few users simultaneously.

Contrariwise, the less frequently used term *large-group interaction*, suggests a large number of participants.

And the term *situated interaction*, which is commonly used for environments featuring large public displays, does not specifically imply the concurrent use of those systems.

Thus the term *co-located interaction* seems to be the best fit. However, it is important to bring a precise definition to the term in order to better frame the scope of this research. It is, for example, important to define the type of space in which an interacting group of individuals can be said to be co-located, especially when the group can consist of a large number of individuals. I consequently propose the following definition of co-located interaction:

A group of individuals is in the situation of co-located interaction when all of its members share the same physical space, and each member has the possibility to perceive all the other members of the group directly (i.e without the use of a communication device other than devices used to compensate for a defect or disability such as eyeglasses). Each member of the group must also be able to act on a shared digital platform.

The state of being in *co-located interaction* could thus be regarded as an augmented form of the spatio-temporal conditions of *copresence* as described by Goffman (1966),

in which individuals are not only “accessible, available, and subject to one another”, but also have the ability to interact with a common technological platform.

In this respect it is noted that participants in environments which are spread over several separated physical spaces are considered to be in co-located interaction only with other participants of the same delimited space. Hence, participants of projects such as *Discontrol Party*, in which they can walk freely between several rooms while continuing to interact with the system, are considered to be in co-located interaction only with other participants in the same room.

2.1.2 Interactive art

Cornock and Edmonds (1973) have established a framework for classifying artworks by considering them as systems with relationships between the artist, artwork, environment, and viewer. According to their framework, an interactive artwork — or what they denote as a *dynamic-interactive system* — is one in which the “art object is caused to change with time” by factors that include the participant interacting with the work, creating a “feedback loop”.

In its simplest definition, an artwork can thus be said to be interactive when it requires the participation of its audience to fully achieve its desired purpose as intended by the artist. The viewer, once he becomes an active participant, is thus an integral part of the work. Interactive art differs from performance art, happenings, and action art in that it does not require the presence of the artist while being experienced by the participants (Kwastek 2013).

Bianchini and Verhagen (2016) denote such works as “*practicable*” due to their ability to “accommodate the concrete involvement of their viewers and to generate an activity that may transform the works themselves as well as their audience”.

While interaction in general is not necessarily digital, the term interactive art seems to be strictly used in computer-based art, and I will employ it as such in this thesis. Indeed, according to Kwastek (2008), the notion of interactive art was first coined in the description of the artwork *Glowflow* by his creators in the late 60s, in a period when the use of the term *interaction* tended to be restricted to computer

controlled interactions.

2.1.3 Aesthetic experience

According to Dufrenne (Souriau 2010), the term experience, when regarded from the point of view of the receiver, or viewer of an art work — as opposed to that of the practitioner, or creator — “designates the very effect of living a presence”, and “a certain mode of perceiving, that renders justice to the perceived to accomplish it”. He also notes that an aesthetic, or sensible, experience requires at first some apprehension, and that this experience rests not only on the individual’s past experiences, but also on their social group’s cultural background.

In regards to this thesis’s context, I will refer to the term *aesthetic experience* to designate a user experience that seeks to maintain the right balance between performance, action efficiency, and accurate perception and reflection of the interactive situation, both at its individual and collective scales.

2.1.4 Interface, device, and apparatus

The terms *interface*, *device*, and *apparatus* are often used in the context of HCI and interactive art. The last two terms are even sometimes used interchangeably. As those terms will be frequently employed herein and in order to avoid any misinterpretation, I will attempt to distinguish between them and clarify their intended meaning as used in this thesis.

Interface While the use of the word *interface* can be traced back to the 19th century in the works of James Thomson on fluid dynamics to designate a boundary condition that creates fluidity when differences in energy distributions are present in a fluid (Hookway 2014), it has become a widely used term today, particularly in computing.

Nowadays, the term generally designates a common boundary between two systems by which they can communicate. The exchange of information can be either one-way or two-ways. The term is used, for example, to designate the formal

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description of the entry and exit points of a piece of software allowing it to exchange information with other software. Interfaces also exist in hardware components. Serial ports, for example, allow a computer to communicate with other hardware such as printers and fax machines.

Unless specified otherwise, the term interface will be used hereafter to denote yet another type of interfaces, user interfaces, which are those that allow a human to interact with a machine, to control it or receive feedback from it. It covers various interaction modalities such as graphics, sound, and touch. Some user interfaces, such as a mouse, are used for input, to send information from the user to the machine. Others are used for output to receive information from the machine, such as a monitor. And some even combine both input and output such as a touchscreen, which combines a monitor for output and a touch sensitive surface for input.

This also covers graphical user interfaces, which denote the visible part of a software program that uses icons and other graphics to display control elements (e.g. buttons and drop-down menus) as well as data through text and images.

Device Kwastek (2013) defines the term *device* in the context of interactive art as being “an artifact whose purpose is the active production of objects or information”. It is a “generic term for the various systems used to translate, manipulate, or transform material and information”.

While a user interface is a point of mediation between a human and a machine, a device is a, generally complex, tool or equipment that receives the information or action, processes it, and sends it back in the form of feedback. A device can in fact include multiple user interfaces providing multiple interaction modalities. A smartphone, for instance, provides a touchscreen, integrated speakers, a microphone, a camera, and other input-only, output-only, or input and output interfaces.

The term device will be used in this thesis as such; to designate an equipment used by participants to interact with the artwork, such as smartphones, cameras, video projection systems, etc.

Apparatus According to Kwastek (2013), the term *apparatus* was thoroughly discussed in an analysis of cinema in the frame of the “apparatus debate” and described as the “entirety of the technical and institutional framework, including the conditioning of the viewer”. Kwastek argues that “the apparatus defines the modus operandi of interactive artworks quite accurately” in that the term, as appreciated by Flusser (2013) when discussing the photographic camera, not only portrays the operational capabilities of the system, but also its limitations, which reflects the fact that participants in interactive art are interested in both exploring the operational possibilities of the artwork, and probing its limits.

The term is sometimes used interchangeably with the term device. However, in the remainder of this thesis, the term apparatus will be employed to refer to the entire spatial, technical and material setting of an interactive installation, which can, and often does, include multiple devices.

The apparatus can hence be seen as the complete environment that constrains the interactions of participants with the work, and devices are the objects used to perform their actions and perceive the reactions of the work, while interfaces are the external boundaries of the devices through which the actions and reactions are made possible.

While I will continue to employ the term apparatus herein, it should be noted that the more accurate French term *dispositif* is becoming more frequently used in the art field to “designate various arrangements—material, human, and/or linguistic (for example, protocols)—that organize . . . operating capacities or . . . the way the conditions of a real or potential process are arranged” (Bianchini and Verhagen 2016).

2.2 Related work

Having clarified some of the most important terms in the previous section, I will now review, in this section, the state-of-the-art in research on co-located interaction and interactive art.

With works such as *Kinoautomat*¹ by Radúz Činčera, *SAM - Sound Activated Mobile*² by Edward Ihnatowicz, and *Glowflow* by Myron Krueger (1977), art installations designed for co-located interactions have been created as early as the late '60s. However, little to no research has been performed on the challenges faced by artists as well as participants of such works to enable or promote a genuinely common and collective aesthetic experience.

Some related research has, nonetheless, explored co-located interactions and proposed tools and guidelines for the design and development of systems and interfaces that promote those interactions. As those research areas are vast and treated in various fields such as HCI, CSCW, sociology, cognition, and ergonomics, a great deal of literature has been published on the topic and its fringes. I will thus not attempt to summarize them here, but will focus on the works that are of most pertinence to the research in question.

2.2.1 Interactive art

Artists and researchers have long theorized interactive art. In addition to the work of Cornock and Edmonds (1973) mentioned above, Bell (1991) has analyzed and classified interactive artworks according to different characteristics, some of which will be discussed in the following chapter. And Graham (1997) suggests a reinterpretation of previous taxonomies using a metaphor of conversation, expressing different degrees of interaction and some of the technologies that can afford those various degrees.

Nardelli (2010) has also proposed a classification for interactive art based on the way input is acquired from the participant and transformed to produce the intended output.

Additionally, Winkler (2000) has reviewed four interconnected factors that he deems to impact the audience's experience with interactive art installations that rely on the movements of participants as input: (1) the digital material and transformation algorithms, (2) the physical space and context, (3) the social relationships between the

¹<http://www.kinoautomat.cz/>

²<http://www.senster.com/ihnatowicz/SAM/sam.htm>

audience members, and (4) participants' personal attributes such as mood, personal tastes, and interests.

Others have endeavored to detect, understand and evaluate the public's creative engagement with interactive art. [Edmonds et al. \(2006\)](#) have, for instance, considered three aspects of artworks that have an impact on creative engagement: attractors, sustainers and relaters, which I will revisit in [4.4.1](#). And [Bilda et al. \(2008\)](#) have proposed a model for creative engagement, in which they describe the interactive experience as a “transformative dialogue between the audience and the interactive [art] system”. Their model considers different interaction modes and phases that the participants go through.

2.2.2 Co-located interaction

While research in interactive art has shown great interest in understanding the individual relationship between each participant and an artwork, it has scarcely addressed aspects of co-located interactions and collective experiences. On the contrary, the field of sociology has, undoubtedly, shown great interest in human social encounters and face-to-face interactions. [Goffman \(1966\)](#) has, for example, studied the rules and practices, whether formal or informal, that guide us in our daily social encounters and engagements in public spaces. And [Boudon \(1979\)](#) has discussed how individual actions can, through a bottom-up process, make emerge an unforeseen and unintended collective organization as a result of the aggregation of the effects of those actions. In this social science paradigm, known as *methodological individualism*, it is believed that one cannot, and should not, try to explain or study a collective phenomenon by only considering the social aggregates, but should consider the individuals and their actions and interactions. This paradigm has served as a guideline for the works described further in this thesis.

While those early works focused primarily on non-mediated interactions, more recent research has been concerned with mediated human-human interactions. [Zhao \(2003\)](#) has, for instance, proposed a taxonomy of copresence (i.e. “the conditions in which human individuals interact with one another face to face from body to body”), in the context of technology mediated communication.

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The HCI and CSCW communities have also shown increased interest in systems that support co-located interactions in the past decade. Myers et al. (1998) have, for example, examined the use of PDAs connected to a single PC as a Single-Display Groupware (SDG), allowing multiple users to share notes simultaneously on a virtual whiteboard. Similarly, Greenberg et al. (1999) have studied the use of PDAs with shared displays on individual and group work activities and discussed some design guidelines when managing personal and public contents. The collective use of PDAs was further investigated by Luyten and Coninx (2005), exploring the distribution of user interface elements across multiple PDAs to create larger multi-user interactive spaces.

And more recently, Isenberg (2009) and Anslow (2010) have studied user interfaces designed for co-located collaboration by workmates around multi-touch tabletop displays. And Lundgren et al. (2015) have put together a design framework that can be used when developing co-located mobile interactions, in which they consider aspects relating to the social situation, the technological setting, the physical environment, and temporal conditions. Ardito et al. (2015) have also surveyed existing interactive systems on large displays and proposed a classification based on several dimensions among which are the visualization technology, the interaction modalities, and location.

Research in the above mentioned fields have predominantly focused on systems for the workspace or specialized users. A few have, nonetheless, explored the use of similar systems in walk-up-and-use situations such as museums and public spaces. For example, Kaviani et al. (2009a,b) have examined the concept they denote as “dual displays”, in which mobile devices are used along with large public displays, and how to encourage active participation in aforesaid setups. They discussed, inter alia, the changes in the roles of an individual from passer-by to bystander to actor and some of the properties of interfaces that can promote such changes.

Similar studies were performed by Reeves (2008) and Ludvigsen (2006) in which they discussed issues related to designing interfaces for public spaces. And Bedwell (2010) has reviewed different techniques for coupling mobile devices with public displays, and proposed a design framework with the use of personal trajectories to encourage individual engagement. Furthermore, Brignull and Rogers (2003) have explored ways to entice people to interact with public displays, and have

observed three stages of participation in the interaction process, which they denote as “activity spaces”: peripheral awareness activities, focal awareness activities, and direct interaction activities.

2.2.3 Mutual engagement

Whereas some have tried to address issues related to concurrent individual use of large public displays such as Klinkhammer et al. (2011), who have investigated the use of personal territories in a museum setting, others have explored new interactive approaches to spur users into communicating and collaborating with each other. Krogh et al. (2004) have, for example, investigated the use of a collaborative interactive floor, the *iFloor*, at a public library’s entrance hall. The prototype allowed library visitors to view and discuss questions and answers that were posted by email or SMS. It also featured bodily interaction: user’s positions, which were tracked in real-time, were used to manipulate the position of a shared cursor to unfold a question and its answers. Part of the collaborative aspect of the installations resided in the negotiation that needed to take place in order to move the cursor in a desired direction.

And Maynes-Aminzade et al. (2002) have proposed three techniques for collaborative or competitive audience interaction with a shared display using computer vision: (1) detection of the overall movement of a seated crowd to control an on-screen visual element, (2) tracking the shadow of a bouncing ball to control a shared cursor, and (3) tracking the dots created by laser pointers.

Isenberg et al. (2010) have also reviewed the use of *Cambiera*, a visual analytics system for textual documents, which supports awareness of others’ actions in a co-located setting to enhance collaborative activities.

Studies have also been performed in the New Interfaces for Musical Expression (NIME) community on collaborative musical interfaces. Yet, as in the HCI and CSCW communities, the NIME community has mostly focused on interfaces for non-novices. d’Alessandro et al. (2012) have, for instance, combined *ChoirMob*, a singing synthesis mobile application, and *Vuzik*, a musical composition, visualization and conducting application for large interactive displays, to create a collaborative

musical performance system.

Other NIME projects such as *Tweet Dreams* (Dahl et al. 2011) and *Moori* (Kim 2011) were designed for the general public, but require moderation or orchestration in order to channel users' actions and orient the reaction of the system.

2.3 Brief summary

While my research is primarily conducted within the frame of HCI, a wide variety of fields — from sociology, to HCI, CSCW, and art research — have investigated some of the aspects that can relate to collective co-located interactions in art installations. However, none seem to have specifically addressed the questions at hand.

Indeed, art research and creation in the context of interactive installations — particularly up until the early 2000s — has mostly focused on the individual user experience, as is the case with HCI research around large public displays, while the HCI and CSCW research dealing with co-located interactions has been essentially concerned with interfaces designed for the work environment.

To get a good grasp of the types of apparatus tackled in this thesis, a large survey of existing art installations has been conducted before attempting to bring answers to our questions. The following chapter exposes a list of art installations found to satisfy certain criteria, and later introduces a taxonomy with the dimensions that appear to directly affect the shared and collective experience. The surveyed works will then be classified using this taxonomy in order to discern some of the design patterns.

3

Towards a taxonomy of collective co-located interaction

As outlined in [chapter 2](#), a few taxonomies and classification frameworks have already been proposed for collaborative and multi-display environments ([Grimstead et al. 2005](#); [Ardito et al. 2015](#); [Lundgren et al. 2015](#)) and interactive art ([Bell 1991](#); [Nardelli 2010](#); [Winkler 2000](#)).

They all contribute to a better understanding of aspects of such environments. However, rare are those that consider aspects related to concurrent co-located participation in interactive art systems, and none specifically address the aspects that seem to have an important impact on the emergence of a collective experience on such walk-up-and-use installations.

Thus, based on a thorough review and analysis of a wide range of existing artworks, I propose in this chapter to classify art installations that enable collective co-located interaction by those aspects that intuitively have a significant impact on the emergence of a collective experience.

The chapter begins with a brief description of the criteria used to select the reviewed works amongst others, followed by an exhaustive list of the selected works. It then introduces a set of design dimensions for co-located interactive art installations. Finally, it ranks the works on each dimension and attempts to uncover design patterns that have been used, and identify unexplored combinations of the design attributes that can open up to new possibilities.

3.1 Survey of existing art installations

3.1.1 Selection criteria

In order to outline relevant design dimensions for co-located interactive art installations, a set of criteria has been established for the selection of sampled works. Since this research is specifically interested in co-located interaction in new media art, the works in this review needed to satisfy the following traits:

- **Computer-supported interactive art**

I have chosen in this review to exclusively consider projects designed as interactive works of art created with computer technologies. Projects designed to facilitate collaboration in a working environment such as *Cambiera* (Isenberg et al. 2010) and *iFloor* (Krogh and Petersen 2008) were, for example, not treated in this review. Although the boundaries are not always evident, I have also chosen not to treat projects that are designed as entertainment systems such as PixMob's *LED Wristband*¹, *Cinematix* (Carpenter 1993) and *Opphos* (Marfisi-Schottman et al. 2013).

- **With little to no orchestration**

The research being specifically interested in issues that arise when no guidance or orchestration is given, works that fall under *action art* or *performance art* and necessitate the artist's co-presence, as is the case for *Dialtones (A Telesymphony)*² by Golan Levin et al. (2001) and *TweetDreams* by Dahl et al. (2011) will not be examined here.

- **Pertaining to visual arts**

Additionally, this research is particularly concerned with works exhibiting predominant visual aesthetic elements. Thus projects such as *The Music Room* by Morreale et al. (2014) and *The Sine Wave Orchestra*³ (2002) by Furudate Ken et al. have been excluded.

- **Designed for co-located interaction**

¹<https://pixmob.com/en/products/detail/led-wristband/>

²<http://www.flong.com/projects/telesymphony/>

³<http://swo.jp/yebizo2016/>

To keep with the topic at hand, only projects that are specifically designed to allow the concurrent active participation of multiple individuals in a common delimited space were considered. Thus projects such as *SMShot* (Fischer et al. 2013) and *Pulse Room*¹ do not appear in the list of works as they only allow one participant to interact with the work at any given time. Projects which *can* accommodate multiple participants but do not seem to have been designed with that in mind, such as *Audience*² by Random International, were also not considered here.

3.1.2 Sampled works

Below is the list of projects that have been found to satisfy the criteria above, dating as far back as 1967 with the interactive movie project *Kinoautomat* by Radúz Činčera up until 2017.

While such a compilation can never be exhaustive nor complete, a great effort has been invested to strive to make it as diverse and as representative of the wide range of works as possible. In fact, as indicated in section 2.1.1, different terms are used in the literature to designate co-located interaction, and descriptions of artworks that fit the considered criteria only rarely employ those terms, which renders the hunt for such works a laborious task.

Also, although I have tried my best to depict this information accurately, it was gathered across a variety of sources which do not always clearly describe the work or precisely indicate the date of its first public showing. I thus cannot guarantee the accuracy and completeness of this information.

Some of the sources include printed press (Christiane (2004), Candy and Edmonds (2011), Kwastek (2013), O'Rourke (2013), Bianchini and Verhagen (2016), Fourmentraux (2017) to cite only a few), online resources such as artist portfolios and institutional websites (including those of the ZKM³, the Ars Electronica Archives⁴,

¹http://www.lozano-hemmer.com/pulse_room.php

²<http://random-international.com/work/audience/>

³<http://zkm.de/en>

⁴<http://archive.aec.at>

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and the Daniel Langlois Foundation¹), research papers, and social media (mostly Twitter², YouTube³, and Vimeo⁴).

Table 3.1 lists the sampled works sorted by year in ascending order with the following columns:

- **#**: the row number in the table
- **Title**: the work's title
- **Author(s)**: a comma separated list of the work's author(s)
- **Year**: the year of creation or first public showing
- **Link**: a hyper link to the most relevant online resource found, if any

#	Title	Author(s)	Year	Link
1	Kinoautomat	Radúz Činčera	1967	↗
2	SAM - Sound Activated Mobile	Edward Ihnatowicz	1968	↗
3	Glowflow	Myron Krueger	1969	↗
4	The Senster	Edward Ihnatowicz	1970	↗
5	Videoplace	Myron Krueger	1990	↗
6	The Fruit Machine	Agnes Hegedüs	1991	↗
7	A-Volve	Christa Sommerer and Laurent Mignonneau	1993	↗
8	Tubulophones	Jean-Robert Sédano and Solveig de Ory	1993	↗
9	Bar Code Hotel	Perry Hoberman	1994	↗
10	Resonance of 4	Toshio Iwai	1994	↗
11	Cathartic User Interface (CUI)	Perry Hoberman	1995	↗
12	Hall of Shadows	Luc Courchesne	1996	↗
13	Individual Fancies	Beryl Graham	1997	↗
14	Landscape One	Luc Courchesne	1997	↗

¹<http://www.fondation-langlois.org>

²<http://twitter.com>

³<http://youtube.com>

⁴<http://vimeo.com>

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#	Title	Author(s)	Year	Link
15	Light Around the Edges	Todd Winkler	1997	↗
16	World Skin	Maurice Benayoun	1997	↗
17	Boundary Functions	Scott Snibbe	1998	↗
18	Composition on the Table	Toshio Iwai	1998	↗
19	Text Rain	Camille Utterback, Romy Achituv	1999	↗
20	Autopoiesis	Kenneth Rinaldo	2000	↗
21	Bubbles	Wolfgang Münch and Kiyoshi Furukawa	2000	↗
22	Japanese Whispers	Usman Haque	2000	↗
23	Telephony	Alison Craighead and Jon Thomson	2000	↗
24	You Think, Therefore I Am (Following You)	Siegfried Canto and Magali Desbazeille	2000	↗
25	Blinkenlight	Chaos Computer Club	2001	↗
26	Brainball	Smart Studio	2001	↗
27	Mediamorphose	Peter Hrubesch and Dirk Scherkowski	2001	
28	n-cha(n)t	David Rokeby	2001	↗
29	The Living Room	Christa Sommerer & Laurent Mignonneau	2001	↗
30	Hidden Worlds of Noise and Voice	Tmema	2002	↗
31	Musical/Devices	Jonah Brucker-Cohen	2002	↗
32	Nanoscape	Christa Sommerer & Laurent Mignonneau	2002	↗
33	PainStation	Volker Morawe and Tilmann Reiff	2002	↗
34	Re:MARK	Tmema	2002	↗
35	Silvers Alter	Gina Czarnecki	2002	↗

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#	Title	Author(s)	Year	Link
36	Messa di Voce	Tmema	2003	↗
37	SimpleTEXT	Jonah Brucker-Cohen, Duncan Murphy and Tim Redfern	2003	↗
38	Still	Adad Hannah	2003	↗
39	DO (not) DISTURB	Cécile Babiole	2004	↗
40	Gravicells	Seiko Mikami and Sota Ichikawa	2004	↗
41	Interactive Bar Tables	Tmema	2004	↗
42	Sky Ear	Usman Haque	2004	↗
43	SphèrAléas	Scenocosme	2004	↗
44	Ce qui nous regarde	Thierry Fournier, Emmanuel Mâa Berriet	2005	↗
45	Les errances de l'écho	Jean Dubois	2005	↗
46	Lo-fi	Nell Tenhaaf and Melanie Baljko	2005	↗
47	Subtitled Public	Rafael Lozano-Hemmer	2005	↗
48	Under Scan	Rafael Lozano-Hemmer	2005	↗
49	CellPhone A-Life	Jonah Brucker-Cohen, Usman Haque, Karmen Franinovic	2006	↗
50	Contagion	Gina Czarnecki	2006	↗
51	Footfalls	Tmema	2006	↗
52	Long Harp	Jen Lewin	2006	↗
53	Radicaux libres	Jean Dubois et Philippe Jean	2006	↗
54	Abundance	Camille Utterback	2007	↗
55	Burble London	Usman Haque	2007	↗
56	Evoke	Usman Haque	2007	↗
57	Interstitial Fragment Processor	Golan Levin	2007	↗
58	niform	Samuel Bianchini	2007	↗
59	Tous ensemble	Samuel Bianchini	2007	↗

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#	Title	Author(s)	Year	Link
60	Contact	United Visual Artists	2008	
61	Entanglement Witness	Todd Winkler	2008	
62	Optical Tone	Tsutomu Mutoh	2008	
63	Primal Source	Usman Haque	2008	
64	Still Moving	Maurice Benayoun	2008	
65	Valeurs croisées	Samuel Bianchini	2008	
66	Big Screams	Elie Zananiri	2009	
67	Body Paint	Memo Akten	2009	
68	Discontrol Party	Samuel Bianchini	2009	
69	Lights contacts	Scenocosme	2009	
70	Bloc Jam	Daily Tous Les Jours	2010	
71	People on People	Rafael Lozano-Hemmer	2010	
72	21 Balançoires	Daily Tous Les Jours	2011	
73	Dancing House	Klaus Obermaier	2011	
74	Fluides	Scenocosme	2011	
75	21 Obstacles	Daily Tous Les Jours	2012	
76	Fearful Symmetry	Ruairi Glynn	2012	
77	Growth	Jeffrey Nusz	2012	
78	In order to control	Nota Bene	2012	
79	Photophore	Kollision	2012	
80	PixelPyros	Seb Lee-Delisle	2012	
81	Rain Room	Random International	2012	
82	The Pool	Jen Lewin	2012	
83	Airborne Projection	Rafael Lozano-Hemmer	2013	
84	Illuminations	Vibeke Sorensen	2013	
85	Urban Canvas	Kollision	2013	

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#	Title	Author(s)	Year	Link
86	Cinéma émotif	Marie-Laure Cazin	2014	↗
87	Mini Burble	Umbrellium	2014	↗
88	Overexposure	Samuel Bianchini	2014	↗
89	Unnumbered Sparks	Janet Echelman & Aaron Koblin	2014	↗
90	1984x1984	Rafael Lozano-Hemmer	2015	↗
91	Aspect (white)	Random International	2015	↗
92	Collective Loops	CoSiMa	2015	↗
93	Ego	Klaus Obermaier	2015	↗
94	Mobilisation	Samuel Bianchini	2015	↗
95	Primary Forms	Mark Eats	2015	↗
96	Quantum Space	Igor Tatarnikov	2015	↗
97	The Grid	Abducto	2015	↗
98	Tourmente	Jean Dubois	2015	↗
99	Zoom Pavilion	Rafael Lozano-Hemmer	2015	↗
100	Centon digital	Christophe Domino	2016	↗
101	Crystal Universe	teamLab	2016	↗
102	Espace [^] Espace	Dominique Cunin	2016	↗
103	Infinity	teamLab	2016	↗
104	Let's Play	Kollision	2016	↗
105	Magic Carpets	Miguel Chevalier	2016	↗
106	Mesa Musical Shadows	Daily Tous Les Jours	2016	↗
107	Onda Pixel	Miguel Chevalier	2016	↗
108	People on the Fly	Christa Sommerer & Laurent Mignonneau	2016	↗
109	Flowers Bloom on People	teamLab	2017	↗

Table 3.1 – List of sampled art installations designed for co-located interaction

3.2 Classification dimensions

In this classification I am specifically interested in attributes that influence the emergence of a shared experience and its nature. Following an intuitive conviction that a collective experience can only emerge once individual experiences have been initiated and maintained for a certain period of time, I have mostly focused on the factors and conditions that have an important impact on the ability for participants to understand and follow the effects of their actions.

In this regard, I have chosen to pay particular attention to the following factors: *scale*, *interaction modality*, *input distribution*, *output distribution*, *feedback attributability*, *activity type*, and *participation symmetry*. I will go through each of those seven dimensions below and rank each of the sampled works along their possible values.

3.2.1 Scale

By scale, I refer to the number of simultaneous active participants that are supported by the apparatus. Largely determined by the material and spatial resources available, this factor has an obvious impact on the nature of the collective experience. However, there seems to have been scarce research conducted on the effects of scale on co-located interaction, among which is the work of Ryall et al. (2004) that examines the effects of group size when working on large interactive tables, but was only concerned with small groups of 2, 3, or 4 individuals.

Nonetheless, scale has been discussed by Stephen Bell in his thesis on computer-supported participatory art (1991, p. 21), in which he notes that “attributing the cause of a particular response” can become difficult in installations that support more than two simultaneous participants. Indeed, as the number of participants increase, distinguishing the reactions of the system that are caused by one’s actions from those of others’ — an ability designated as ‘attributability’ by Boden (2010, p. 219) — becomes more difficult.

Another difficulty related to scale resides in the unpredictability of participation in walk-up-and-use installations. Some artists try to cope with this unpredictability

by designing installations that adapt to the number of participants. For instance, the audio-visual installation *Light Around the Edges* (1997) by Todd Winkler, which interprets the location and movements of participants to generate music and abstract visual representations of themselves, adapts its feedback in accordance with the number of participants by lessening the correlation between the actions of participants and the reactions of the system as the number of participants increases.

The bar chart in Fig. 3.1 depicts the scale of each sampled work. While the scale of some of the works can be easily determined by the limited availability of a specific resource, such as the 127 theater seats in *Kinoautomat* (1967) by Radúz Činčera, the 21 swings in *21 Balançoires* (2011) by Daily Tous Les Jours, and the 2 consoles in *Let's Play* (2016) by Kollision, it is more often difficult to gauge. The values presented in the chart are thus mostly estimates.

Furthermore, to ease the comparison of the works based on their scale, I have chosen to categorize the factor into three groups: **small** (≤ 10), **medium** (11 - 100), and **large** (> 100). While various anthropological studies have classified social group sizes from *support clique* to *band*, *clan*, and *tribe* (Zafeiris and Vicsek 2017), such classifications can hardly be used in the context of co-located interactions in art installations due to the ephemeral nature of the experience. The proposed division is thus mostly based on the distribution of the collected data.

Using the chart, it can be noted that most works (94 out of 109) support no more than 100 simultaneous participants. And only five can handle a very large number of participants. The difficulties mentioned above and the high costs and complexities involved in large scale installations are possible explanations.

3.2.2 Interaction modality

Interaction modality refers to the method by which the public interacts with the work, which influences the individual and collective experience as it has effects on attributability and the mobility of participants. It also determines the type of attention required to interact with the work, which, in turn, has an impact on the attention that can be allocated to peers and social interactions.

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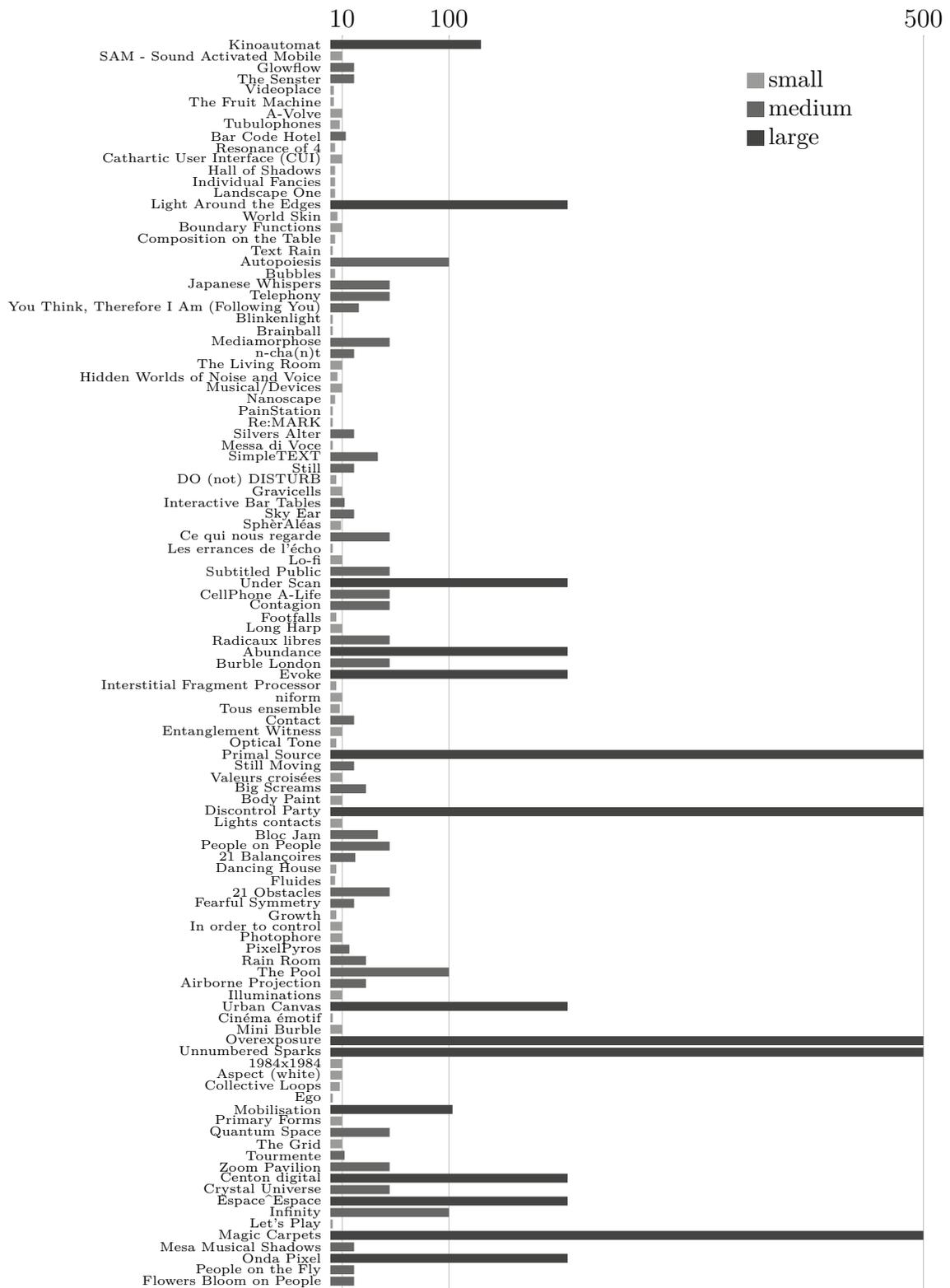


Figure 3.1 – Scale of sampled works

Ardito et al. (2015) have also considered this factor in their survey of interaction with large displays, for which they proposed the following four values: Touch, External device, Tangible object, and Body. And a similar factor, *input directness*, was considered by Rashid et al. (2012b) when studying aspects of multi-display user interfaces that have an influence on visual attention switches. They deemed input to be *direct* when the spatial distance between the motor actions of a user and the feedback is relatively small, and *indirect* when both are separated by a significant distance.

I have, however, preferred to revisit the three modalities identified by Edmonds (Candy and Edmonds 2011, p. 237) for this factor as they more accurately reflect the techniques used in the sampled works:

- **direct:** interaction is done by direct physical manipulation. This is the case, for example, with *Tubulophones* (1993) by Jean-Robert Sédano and Solveig de Ory in which a set of tree-like structures emit sounds when touched by participants, or *Les errances de l'écho* (2005) by Jean Dubois which features a large touch-sensitive mirror that reacts to caresses, and *Long Harp* (2006) by Jen Lewin that emits sounds as the hands or bodies of participants touch a series of vertical laser lights. The lack of physical distance between the actions of the audience and the reactions of the system in this modality considerably eases attributability, it has, however, a tendency to obstruct the free movements of participants and focus their attention on the input device, making it somewhat difficult to pay attention to others and their actions.
- **facilitated:** participants interact via individual remote input devices that communicate with the work. The individual devices might be an integral part of the apparatus such as the voting buttons attached to the seats for *Kinoautomat* (1967) by Radúz Činčera and the joysticks used in *The Fruit Machine* (1991) by Agnes Hegedüs, or brought along by the members of the audience such as the mobile phones used to listen and alter the electromagnetic sounds of the large structure in *Sky Ear* (2004) by Usman Haque or the smartphones used to draw on the suspended net sculpture in *Unnumbered Sparks* (2014) by Janet Echelman and Aaron Koblin. While this modality rarely impedes the free movement of participants, it tends to require constant

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shifts of attention between the individual devices and the shared ones, especially when the former are used both for input and output.

- **ambient**: the positions, movements, faces, or voices of participants are captured using non-invasive technologies, greatly reducing the attentional effort required for interaction without hindering mobility. In *The Senster* (1970) by Edward Ihnatowicz, for example, the robotic sculpture reacts to the public's voices and movements captured using microphones and radars. In *Glowflow* (1969) by Myron W. Krueger, it is the footsteps of members of the public that are detected using pressure sensitive pads to control the flow of phosphorescent particles in transparent tubes and alter the sounds generated by a synthesizer. [Krueger \(1977\)](#) dubbed such immersive interactive environments 'artificial reality'.

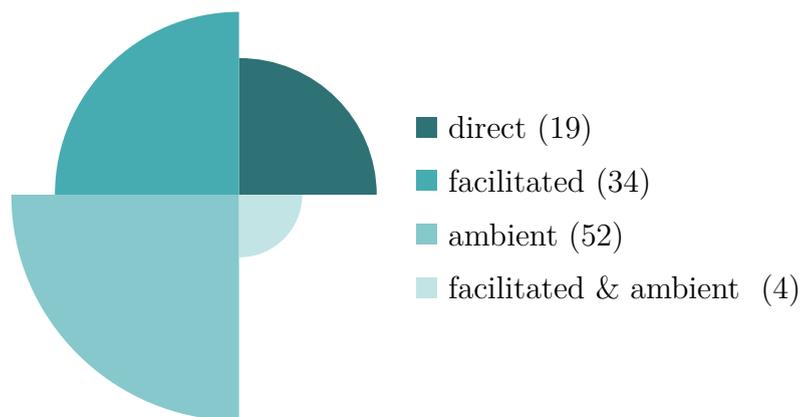


Figure 3.2 – Works per interaction modality

With the help of the graph in Fig. 3.2, it can be observed that most works use an ambient interaction modality, whereas direct interaction is the least used modality.

The graph also shows that some works combine multiple modalities. In fact, four of the sampled works combined both facilitated and ambient modalities, namely *Landscape One* (1997) by Luc Courchesne where participants can communicate with the virtual characters through voice or touch pads, *Mediamorphose* (2001) by Peter Hrubesch and Dirk Scherkowski that tracks visitors movements underneath a large structure made up of mobile phones to trigger ringtones and voices while also accepting calls on two of the phones, the festive installation *Discontrol Party*

(2009) by Samuel Bianchini in which a video-surveillance system and an indoor real-time locating system based on UWB (ultra-wideband) track the movements and faces of partygoers, and *Crystal Universe* (2016) by teamLab in which movements of participants and their interactions via a smartphone application modify a three-dimensional light space.

3.2.3 Input and output distribution

When categorizing groupware, the HCI and CSCW communities tend to use the terms Single-Display Groupware (SDG) (Stewart et al. 1999) and Multi-Display Groupware (MDG) (Wallace et al. 2009) to differentiate between systems that comprise only one shared display from those that combine both shared and individual displays. However, due to the large diversity of setups in the sampled works, it is sometimes difficult or inappropriate to classify the works in those high-level categories. It seems, indeed, more appropriate to go back to some of the essential properties of distributed user interfaces (DUIs).

According to Elmqvist, DUIs can be categorized by their distribution along one or more of five dimensions: input, output, platform, space, and time (Elmqvist 2011, p. 2). As this research is specifically interested in co-located interactions, the space and time dimensions are of no interest here. The distribution of the platform (i.e whether the interface execution is performed on a single computing platform or distributed across multiple platforms) is also of not much interest in our case as it does not have much impact on the individual and collective experience. The distribution of input and output are, however, of great concern. I will regard them as two separate dimensions in this taxonomy with the following possible values for both:

- **centralized:** the input or output is performed on shared devices. Video-cameras are typical centralized input devices. They are indeed used in many works such as *Videoplace* (1990) by Myron Krueger, *Boundary Functions* (1998) by Scott Snibbe, *Still* (2003) by Adad Hannah, *Ce qui nous regarde* (2005) by Thierry Fournier and Emmanuel Mâa Berriet, and *Interstitial Fragment Processor* (2007) by Golan Levin. Microphones are also commonly used as

centralized input devices, as in *SAM - Sound Activated Mobile* (1968) by Edward Ihnatowicz and *Re:MARK* (2002) by Tmema (Golan Levin and Zachary Lieberman). As for centralized output, video-projectors, light-projectors and loud-speakers are some of the most common devices used.

- **partially distributed:** the input or output is split or duplicated on shared and individual devices. The input of all four works mentioned above that combine both facilitated and ambient modalities is partially distributed. The input in *Interactive Bar Tables* (2004) by Tmema can also be deemed partially distributed as the work is composed of several large multi-touch tables that communicate with each other, allowing participants to send virtual creatures from one table to another. And since the tables are also used as output devices, the output is likewise partially distributed, as is the output in *Hidden Worlds of Noise and Voice* (2002) by Tmema in which participants can perceive abstract forms created by their voices through special see-through glasses as well as a shared projection. Additionally, most works that combine smartphones and a shared projection are considered to be partially distributed. Those include *Bloc Jam* (2010) by Daily tous les jours, *Overexposure* (2014) by Samuel Bianchini, *Collective Loops* (2015) by CoSiMa, and *Mobilisation* (2015) by Samuel Bianchini.
- **fully distributed:** the input or output is fully distributed across individual devices. Input is, for instance, fully distributed in works such as *Telephony* (2000) by Alison Craighead and Jon Thomson, in which visitors of a gallery can dial into a grid of mobile phones, or *Blinkenlight* (2001) by the Chaos Computer Club which uses a building's facade as a large shared display and can be turned into a two-player Pong game using mobile phones as controllers. While no projects have been found to only fully distribute output, some fully distribute both input and output, as in *n-cha(n)t* (2001) by David Rokeby and *CellPhone A-Life* (2006) by Jonah Brucker-Cohen, Usman Haque, and Karmen Franinovic.

In some cases, evaluating the distribution of input or output can be somewhat complicated. In *Autopoiesis* (2000) by Kenneth Rinaldo, for example, an array of 15 suspended and interconnected robotic limbs interact with each other and the

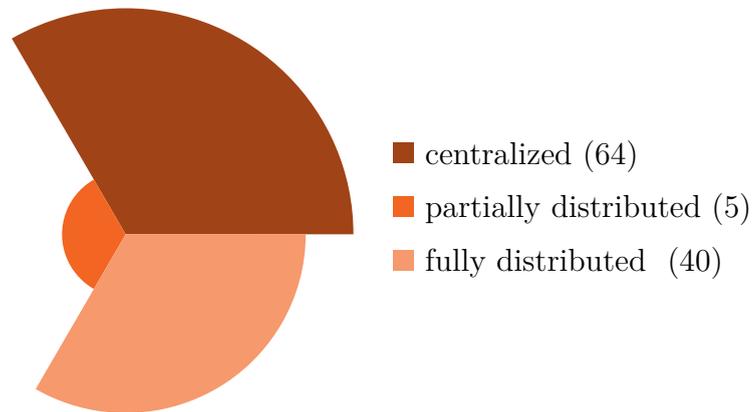


Figure 3.3 – Works per input distribution types

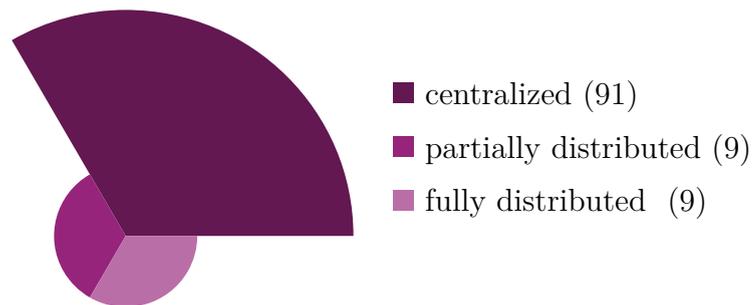


Figure 3.4 – Works per output distribution types

audience. While walking between the limbs, the members of the audience influence the sculptures' movements and the sounds emitted by them. Since each sculpture can be influenced by multiple participants as well as the surrounding sculptures at the same time, it is likely erroneous to designate each one as being an individual device, it seems, nonetheless, appropriate to qualify the input and output as being fully distributed.

The graphs in Fig. 3.3 and Fig. 3.4 illustrate the proportion of the different distribution types for input and output in the sampled works. They clearly indicate that input as well as output are more commonly centralized. Input, however, is more frequently fully distributed than output.

3.2.4 Feedback attributability

The ability of participants to detect that a change in the system is caused by their actions allows participants to feel, in a certain way, in control of the system, which in turn influences the collective and shared experience. In a way, attributability contributes to the subjective self-consciousness during an interactive experience with a work, and is thus closely related to the psychological concept of ‘sense of agency’, which is described by Gallagher (2000) as being “the sense that I am the one who is causing or generating an action”.

While some artists may not deem it important that participants understand the relationship between their actions and the reactions of an interactive work (Boden 2010, p. 219), I argue that, in the context of co-located interactions, this becomes crucial if the work is to promote a shared aesthetic experience. It also seems essential that one not only understands the effects of their own actions, but also those of their peers.

Furthermore, unlike most software and hardware developments that try to follow well-established standards, “there is no direct physical relationship in interactive art between input and output, and, since the mechanisms of transformation are one-off constructs not standardized as specific types of instrument, they are not known to their user” (Kwastek 2013, p. 168), and feedback attributability can play an important role in helping participants understand the mechanisms of transformation at hand.

The importance of feedback attributability was discussed by Krueger following his experience with *Glowflow* in which feedback delays were deliberately introduced to avoid the disruption of the work’s contemplative mood. He acknowledged that this resulted in the work succeeding “more as a kinetic sculpture than as a responsive environment” (Krueger 1977), leading him to the conclusion that “participants should be aware of how the environment is responding to them”.

Due to its subjective nature, I have elected to assess the attributability of feedback on a relative scale of three values: **high**, **medium**, and **low**, where high attributability implies a great ease to perceive and understand the correlation between one’s actions and the received feedback, whereas low attributability implies an increased difficulty

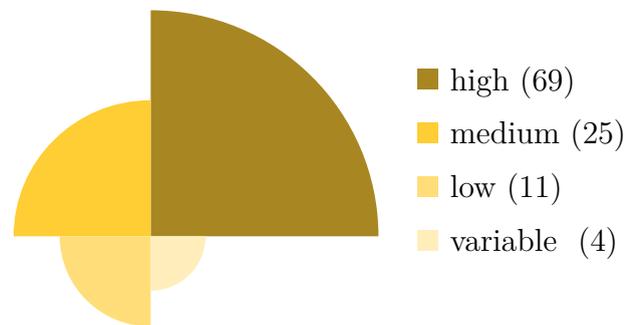


Figure 3.5 – Works per level of feedback attributability

in the perception and understanding of this correlation.

The graph in Fig. 3.5 shows that most works are considered to present a relatively high level of feedback attributability. It also indicates that feedback attributability of four of the reviewed works is variable. Indeed, feedback attributability varies in *Light Around the Edges* (1997) by Todd Winkler according to the different modes of the installation as it adapts to the number of participants. In *Mediamorphose* (2001) by Peter Hrubesch and Dirk Scherkowski, the attributability also varies depending on the interaction mode; it can be deemed to be high when a participant calls into one of the two phones, and low when the sculpture reacts to the movements of the public below. And both *Burble London* (2007) and *Primal Source* (2008) by Usman Haque alternate between multiple interaction modes, some of which can be considered to present higher attributability than others.

3.2.5 Activity type

Whether it is **solitary**, **collaborative** or **competitive**, the type of activity that a work solicits is yet another factor that can shape the individual and collective experience. A work's activity is deemed as collaborative if a certain outcome can only be achieved when participants synchronize their actions or work together. A competitive activity, on the other hand, is involved when multiple participants or groups of participants need to challenge each other and determine a winner. The remaining works, in which none of those two activities were identified, are assumed to support a solitary activity in which each participant acts independently of others.

As depicted in Fig. 3.6, a few works were labeled as promoting a collaborative

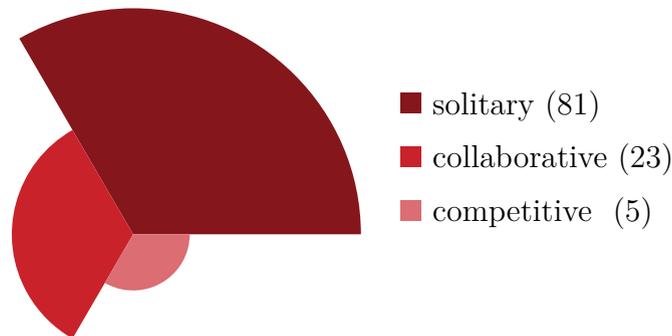


Figure 3.6 – Works per activity type

activity such as *Tous ensemble* (2007) by Samuel Bianchini where participants have to collaborate in order to move an on-screen cursor in a desired direction using ten computer mice connected to a single machine, and *Silvers Alter* (2002) by Gina Czarnecki in which participants collectively choose which virtual human forms get to live or die.

Only a handful were regarded as competitive. Those include *Brainball* (2001) by Smart Studio in which a ball is controlled by the brain waves of two players and the more relaxed one wins, and *Big Screams* (2009) by Elie Zananiri which invites the audience to compete in a screaming game.

3.2.6 Participation symmetry

Symmetry of participation was discussed in Bell’s thesis (Bell 1991, p. 22), in which he considers the “distribution of actions and contributions between participants”. Works in which participants can engage equally in the various activities are considered to be **symmetrical**, while works in which participants play different roles are **asymmetrical**. This factor can impact the collective organization, as it can spur discussion and negotiation between participants of different roles in order to achieve a certain outcome.

As seen in Fig. 3.7, only very few of the sampled works exhibit intrinsic participation asymmetry. In *World Skin* (1997) by Maurice Benayoun, for instance, only one of the participants can endorse the role of the driver while others can take on the role of photographers. Likewise, in *Lights contacts* (2009) by Scenocosme

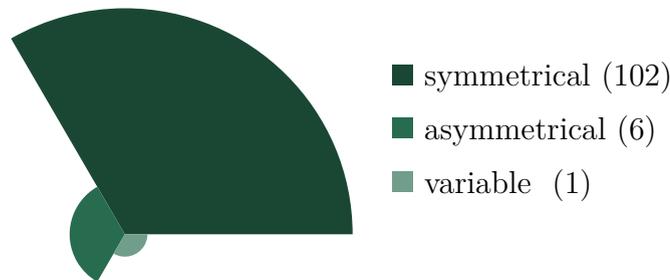


Figure 3.7 – Works per participation symmetry

(Gregory Lasserre and Anais met den Ancxt) only one participant can place a hand on the ball while others are invited to touch this first participant to generate sounds and alter the ambient light's color. And in *21 Obstacles* (2012) by Daily tous les jours, 21 swings allow up to 21 participants to control an equal number of virtual obstacles, while virtual balls are launched on those obstacles by others through SMS. The limited number of available UWB tags in *Discontrol Party* (2009) by Samuel Bianchini also induces participation asymmetry.

While no specific details were found concerning its workings, *SphèrAléas* (2004) by Scenocosme seems to present a special yellow pad among the red ones and the possibility for a member of the audience to endorse the role of a conductor.

In addition, *Videoplace* (1990) by Myron Krueger can operate in two different modes. While the first mode promotes symmetry in participation, the second one is designed for two participants, in which one of them is seated at a desk and takes control over several aspects of the system, and interacts in various ways with the virtual image of the other participant. And *Mini Burple* (2014) by Umbrellium allows participants to draw on a large balloon structure using a custom app on tablets or send in a color through SMS, setting all the balloons to the specified color.

3.3 Design patterns

The graph in Fig. 3.8 and the small multiple in Fig. 3.9 rank each of the sampled works across the seven dimensions. Each dimension is associated to a different color, and the values of the dimension are represented by decreasing saturations in the same order as they appear in the previous section, as indicated in the chart's legend.

To overcome the difficulty of reading such a complex graph, an interactive version is available on-line at the following URL: <http://thesis.semiaddict.com/radial-heatmap>, and an alternative view on the data, in the form of a Sankey diagram, is depicted in Fig. 3.10.

It should be noted that some of the classification dimensions, such as feedback attributability, can only be faithfully evaluated by experiencing the works. Thus, except for the few works that have indeed been experienced by the author, the values depicted in the graph are only estimations based on gathered information.

Using Fig. 3.9a, which sorts the dimensions according to scale in an ascending order, and Fig. 3.9b, which sorts them according to feedback attributability in ascending order, it can be noticed that, surprisingly enough, neither scale nor feedback attributability seem to be directly correlated with any of the other dimensions. In fact, the only distinguishable correlation appears to be the one between the input and output distributions. Fig. 3.9c indicates, indeed, that when input is centralized, output is as well, but the opposite does not hold. The figure also indicates that input is fully distributed when the output is. We can also notice that almost half of the works combine an ambient interaction modality with both input and output centralized.

Fig. 3.9d also reveals that approximately 23% of the treated works share the exact same classification at the exception of scale: ambient interaction modality, centralized input and output, high feedback attributability, solitary activity, and symmetrical participation.

3.4 Summary & perspectives

This chapter introduced a taxonomy with a set of dimensions which I believe to influence the emergence and the nature of a collective experience in art installations. Over a hundred existing works were then classified against the proposed taxonomy revealing some of the dominant design patterns.

Although the taxonomy was specifically intended to address aspects of interactive art installations, the devised dimensions are also applicable to other contexts, such

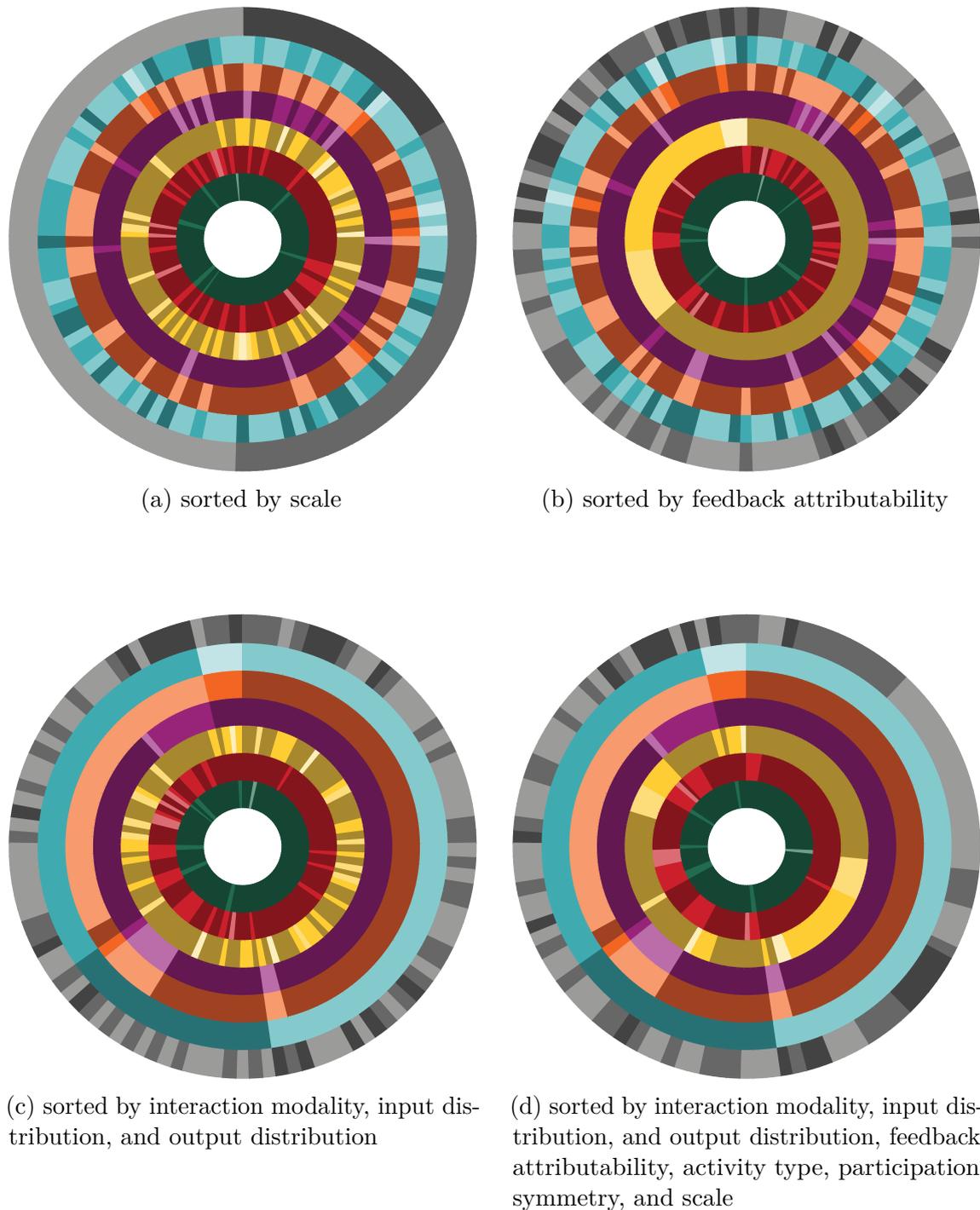


Figure 3.9 – Small multiple of the graph in Fig. 3.8 with various sortings

CHAPTER 3. TOWARDS A TAXONOMY OF COLLECTIVE CO-LOCATED INTERACTION

as systems designed for interactions with large public displays. They can also be used to classify groupware designed for co-located work.

However, additional work needs to be performed to appraise the effect of each factor on the ability for participants to co-construct a shared experience, and the nature and quality of that experience. Supplementary research could also look at the relationships between the different factors, or how artists can balance them to reach a desired type of experience.

Furthermore, dimensions such as the degree of mobility of participants and spatial or material resources allocated, which were not considered here for various reasons — mostly due to the high difficulty of assessing the ranks of works on such dimensions without properly experimenting the surveyed work — could further increase the taxonomy’s effectiveness to classify and compare works.

Nonetheless, there are, hypothetically, several hundred possible combinations of the proposed taxonomy’s dimensions. Yet, only a fraction of them have been explored by the sampled works. And combinations that include a collaborative or competitive activity are by far the less explored ones.

Paying particular attention to the *Collective Loops* prototype specifically designed with collaboration in mind, in the following chapter I will present in more details some of the reviewed works for which I have brought a contribution in the context of the *CoSiMa* research project, and discuss some lessons learned from them.

4 Design cases

The work described in this thesis was realized within the framework of the *CoSiMa*¹ (acronym for Collaborative Situated Media) research project. With financing from ANR, the French National Agency for Research, the project was carried out by a consortium of six actors, three public institutions and three private companies: (1) IRCAM², the Institute for Research and Coordination in Acoustics/Music, (2) EnsadLab³, the research laboratory of the École nationale supérieure des Arts Décoratifs, (3) Orbe⁴, ID Scènes⁵, Nodesign⁶, and Esba TALM⁷, École supérieure des beaux-arts Tours Angers Le Mans.

Conducted by an interdisciplinary team of developers, researchers, designers, and artists during a period of three years, between 2015 and 2017, the main goal of the *CoSiMa* project was the establishment of an authoring platform, bearing the same name, easing the design, development and deployment of collective and collaborative multi-sensory interactive media. Through workshops, prototypes, and user studies, the project also aspired to explore new aesthetic experiences involving the active participation of the general public.

In this chapter, the *CoSiMa* platform will be briefly described, followed by a presentation of a central case study performed on *Collective Loops*, a prototype project of the platform. A few peripheral cases will also be examined. And, in the

¹<http://cosima.ircam.fr/>

²<https://www.ircam.fr/>

³<http://www.ensadlab.fr/>

⁴<http://orbe.mobi/>

⁵<http://www.idscenes.com/>

⁶<http://www.nodesign.net/en/>

⁷<http://www.esba-talm.fr/>

last section of the chapter, some of the main lessons learned through those various experiences will be discussed.

4.1 Context

The *CoSiMa* project aimed, above all, the democratization of collective and collaborative interactive media in co-located settings through a generic and interoperable platform accessible to a wide range of users and institutions. In pursuit of this goal, it took advantage of two technological breakthroughs: (1) the ubiquity of today's mobile devices along with their increased processing power and interaction modalities, and (2) the advances in web standards and their wide implementation in most of nowadays major desktop and mobile web browsers. The two combined allow rapid development and deployment of participatory multimedia installations.

4.1.1 The CoSiMa platform

With technologies such as *DeviceMotion*, *WebSockets*¹, *WebGL*², and the *Web Audio API*³, which are becoming widely supported in most handheld devices carried along by almost each and every one of us, it has become possible to create applications with a great degree of interoperability, and thus allowing anyone to join a collective experience without the need to distribute specialized hardware. Additionally, the open-source and multi-platform JavaScript runtime environment *Node.js*⁴ greatly reduces development time by allowing developers to write server-side code using the same programming language as the one traditionally used for the client-side scripting of HTML web pages.

For those reasons, it was decided to build the *CoSiMa* platform on top of web technologies. The result is comprised of multiple independent and interdependent software and hardware components, and supports a large variety of applications including large multi-user interactive art installations, geolocated augmented reality

¹<https://www.w3.org/TR/websockets/>

²<https://www.khronos.org/webgl/>

³<https://www.w3.org/TR/webaudio/>

⁴<https://nodejs.org/>

soundwalks, and audiovisual participatory performances.

Based on *Node.js*, the platform implements communication, clock synchronization, and scheduling services. It also includes several client-side modules such as the one for audio rendering, which uses *WavesJS*¹ built on top of the Web Audio API.

Constituted of Dominique Cunin, Jonathan Tanant and myself, under the direction of Samuel Bianchini, the EnsadLab team, was in charge of the design and implementation of the graphics engine and modules primarily used to generate the graphical user interfaces. Already in active development at EnsadLab, the software authoring environment *Mobilizing.js*² was used in the *CoSiMa* platform for that very purpose.

4.1.2 Mobilizing.js

Initiated by the artist and researcher Dominique Cunin in 2007 as part of his PhD thesis project (Cunin 2014) and the research program *Formes de la mobilité* on mobile technologies in art practices at EnsadLab, *Mobilizing* was originally designed as a development tool to allow the rapid prototyping of interactive applications for iPhone, facilitating the exploration by art practitioners of the new possibilities offered by those mobile devices. The tool was hence initially developed on top of Apple's iPhone SDK, currently known as the iOS SDK³.

With the advances in web technologies, particularly those brought by *HTML5*⁴, and in an effort to make *Mobilizing* compatible with other emerging mobile platforms such as *Android* and *Windows Phone*, its codebase has been migrated to JavaScript, and is now dubbed *Mobilizing.js*.

While still in beta at the time of this writing, *Mobilizing.js* is approaching its first stable release, and has already become a full blown authoring environment. It, in fact, integrates most of the software tools required to create and deploy large scale co-located collective interactive works. In addition to being a 3D rendering tool

¹<http://wavesjs.github.io/audio/>

²<http://www.mobilizing-js.net/en>

³<https://developer.apple.com/devcenter/ios/>

⁴<https://www.w3.org/TR/html5/>

designed with ease of use in mind, it also simplifies access to device sensors such as GPS, accelerometer, compass, and gyroscope through high-level APIs. It also includes a generic server, built on top of *Socket.IO*¹, that can be used to setup a client-server communication network using WebSockets, as well as a clock synchronization server that uses an approach similar to Network Time Protocol (NTP), allowing precise scheduling of events in a multi-device setup.

Although the *Mobilizing.js* authoring tool and the *CoSiMa* platform might seem equivalent and redundant, they differ in many aspects. They are, indeed, not designed with the same public in mind. The former is primarily focused on graphics. Its core is, in fact, a 3D rendering engine built on top of *three.js*², an open-source and cross-browser JavaScript 3D rendering library that uses WebGL rendering capabilities. The *CoSiMa* platform is, however, designed around the Web Audio API, used in the platform for clock synchronization and event scheduling in addition to audio rendering.

Additionally, *Mobilizing.js* essentially targets artists and designers with little programming knowledge, and even strives to become a learning tool for novices who desire the integration of interactive aspects to their work. It is therefore designed to be as simple and as modular as possible. Its ambitions, for example, to give the possibility to work on different levels of abstraction, depending on the user's programming experience.

Needless to say, only part of *Mobilizing.js* was used in the *CoSiMa* platform, namely the 3D rendering engine, which was combined and interfaced with the rest of the platform.

In addition to this mission, the EnsadLab team was in charge of the design and development of graphical user interfaces of prototype projects, namely that of the very first prototype entitled *Collective Loops*, which served not only as a pilot project of the *CoSiMa* platform, but also as an opportunity to perform qualitative and quantitative user studies.

¹<https://socket.io/>

²<https://threejs.org/>

4.2 Central case: Collective Loops

*Collective Loops*¹ is an experimental real-time collaborative musical 8-step loop sequencer developed as a prototype project for the *CoSiMa* platform.

Participants have access to two user interfaces: (1) an individual interface through their smartphone allowing them to alter the sound emitted from it, and (2) a shared, floor-projected, circular visualization (of approx. 3m in diameter) showing all their choices as well as the current position of the sequencer's reading head.

In the first version of the prototype, the sequencer was divided into 8 time slots, with up to 3 participants per slot; one per instrument. It allowed up to 24 participants to collaboratively create simple melodies using predefined notes of three instruments: percussion, bass, and melody.

As depicted in Fig. 4.1a, the shared, floor projected interface was presented as 12 concentric rings, with each one being divided into 8 equal sectors (one per time slot). Each sector was numbered by a letter of the Roman alphabet displayed in front of it. In addition, a bright translucent sector moved on top of the other sectors indicating the reading head's current position.

A time slot and an instrument were automatically assigned to each newcomer upon joining the experience. The assignment of instruments was done gradually; percussions were given to the first 8 participants, then bass to the following 8, and finally melody to the next ones. A time slot was randomly selected from those in which the given instrument was not already present.

Once a time slot and instrument were assigned to a participant, a cursor was drawn in the corresponding sector in one of three colors representing the given instrument. The participant was then able to modify the note by selecting one out of 12 possible choices by inclining the smartphone back or forth, and the choice was expressed on the shared interface by the displacement of the cursor inwards or outwards; from one ring to another. Cursors of different instruments sharing the same time slot could overlap. When that occurred, their colors were blended using an addition blending mode; adding color values of one cursor with the other. Although

¹<http://cosima.ircam.fr/2015/11/25/collective-loops-forum-workshops/>

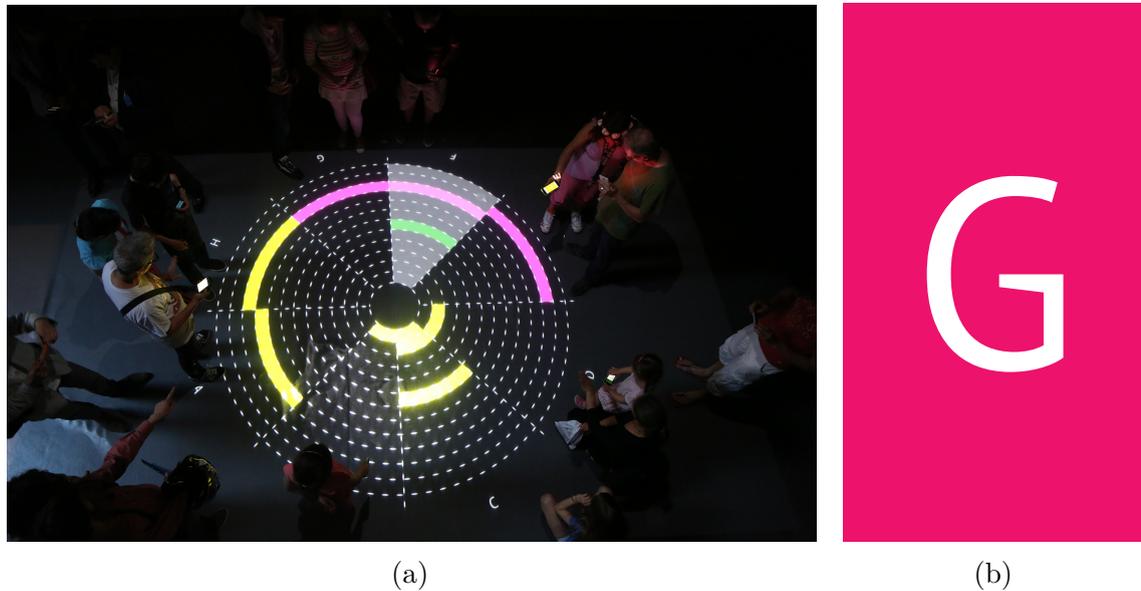


Figure 4.1 – *Collective Loops* v1 interfaces: (a) shared floor projection and (b) individual mobile interface

I could have prevented cursors from overlapping by further dividing each sector into 3 sub-sectors, one per instrument, this division was deemed inappropriate by musical savvies in the team as it could be misinterpreted as temporal information.

The individual graphical interface on smartphones indicated the assigned time slot by displaying the corresponding Roman letter in the center of the screen, while the background color was used to indicate the assigned instrument as seen in Fig. 4.1b. Moreover, the interface signaled when the reading head’s position reached the assigned time slot by temporarily overlaying the other graphical elements with a white foreground.

4.2.1 General technical setup

The installation was composed of three main software components: (1) a local server managing inter-device synchronization and communication, (2) a mobile web application accessible via a local WiFi hotspot handling the individual user interface, and (3) a desktop web application handling the shared interface, which is floor-projected using a 45° inclined mirror to reflect the video projection on to the floor. An overview of the setup is depicted in Fig. 4.2.

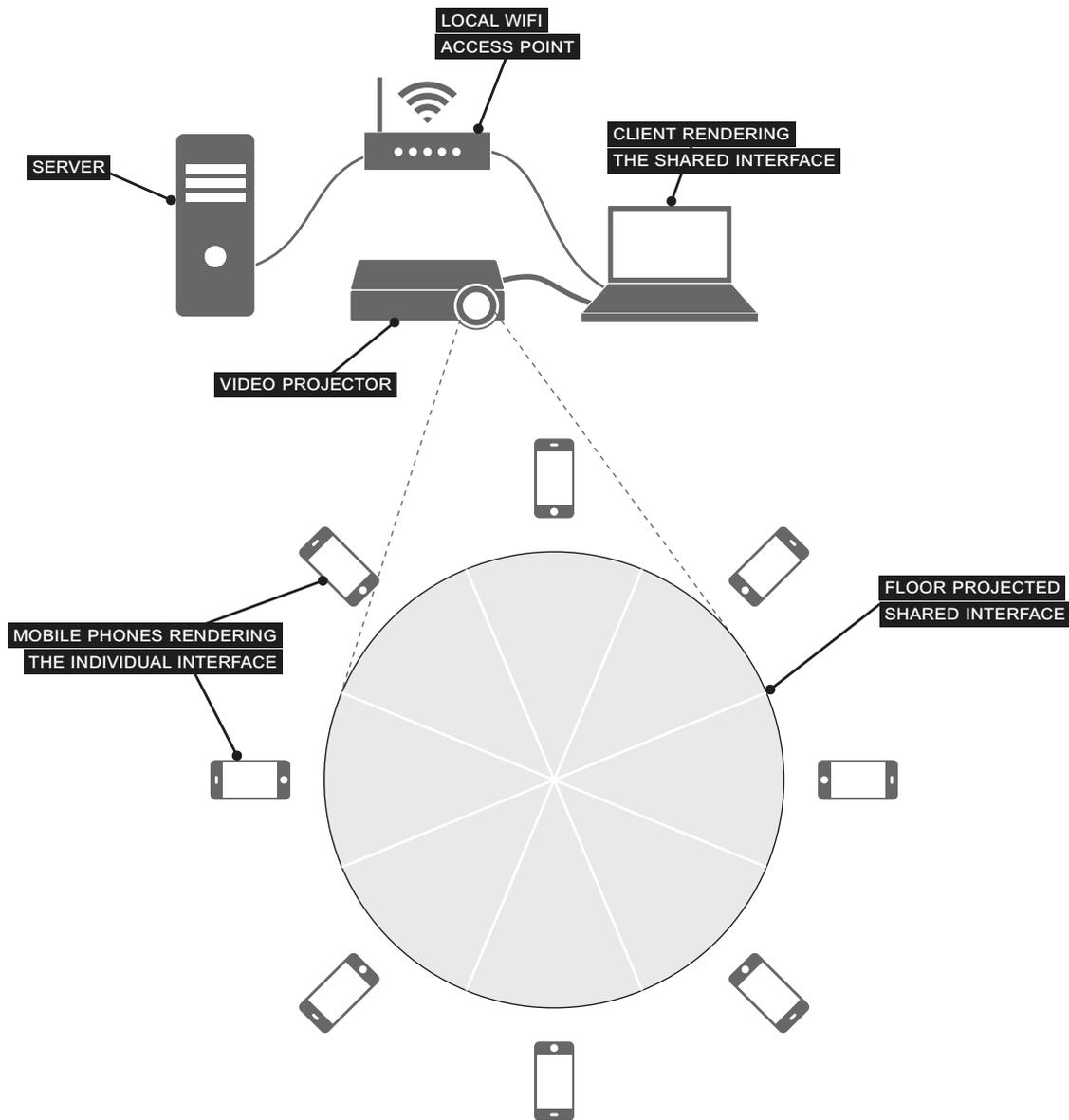


Figure 4.2 – General technical setup of *Collective Loops*

Aspects, such as clock synchronization and the scheduling of audiovisual events were thoroughly described by Schnell et al. (2017).

4.2.2 Design choices

In charge of the design and implementation of the different graphical user interfaces, I made several proposals for the shared floor projection inspired by traditional

sequencers and data visualization techniques such as the polar area chart (more commonly known as coxcomb chart). Some of the initial proposals are depicted in Fig. 4.3.

Through those proposals, I tried to address the different challenges faced for the design of the shared interface. First, it needed to be modular, allowing its rapid adaptation to eventual last-minute changes that could be made on the number of time slots or instruments available. It also needed to allow each participant to easily locate their corresponding slot. Moreover, it had to allow all participants to get a complete view of the current state of the system, particularly the reading head position and all currently selected notes.

The choice of a circular form for the interface seemed a good fit when compared to a linear form. It indeed makes it possible for all participants to get a rapid overview of the system's state while remaining in front of one's corresponding slot. Its concentric shape also gives a better potential for modularity without requiring changes in the complex projection system above.

As for the graphical interface on smartphones, I aspired to make it as simple and intuitive as possible, to try and prevent it from taking up too much attention, distracting participants from the collective experience. In essence, it needed to help locate one's corresponding placement and cursor in the shared interface by indicating the slot and instrument attributed to the participant.

Following several discussions with other team members — particularly those of EnsadLab, IRCAM, Orbe, and ID Scènes — along with intensive development cycles and large scale tests, a first version of the prototype was achieved in mid 2015.

4.2.3 First public deployment

The prototype was deployed to the general public during the Ircam Open Days in June 2015. This first confrontation with the public allowed us to perform a full-scale test of the *CoSiMa* platform and detect technical issues that were difficult to evaluate otherwise. It also allowed us to get feedback on user interface and interaction design aspects of *Collective Loops* through an exploratory study with

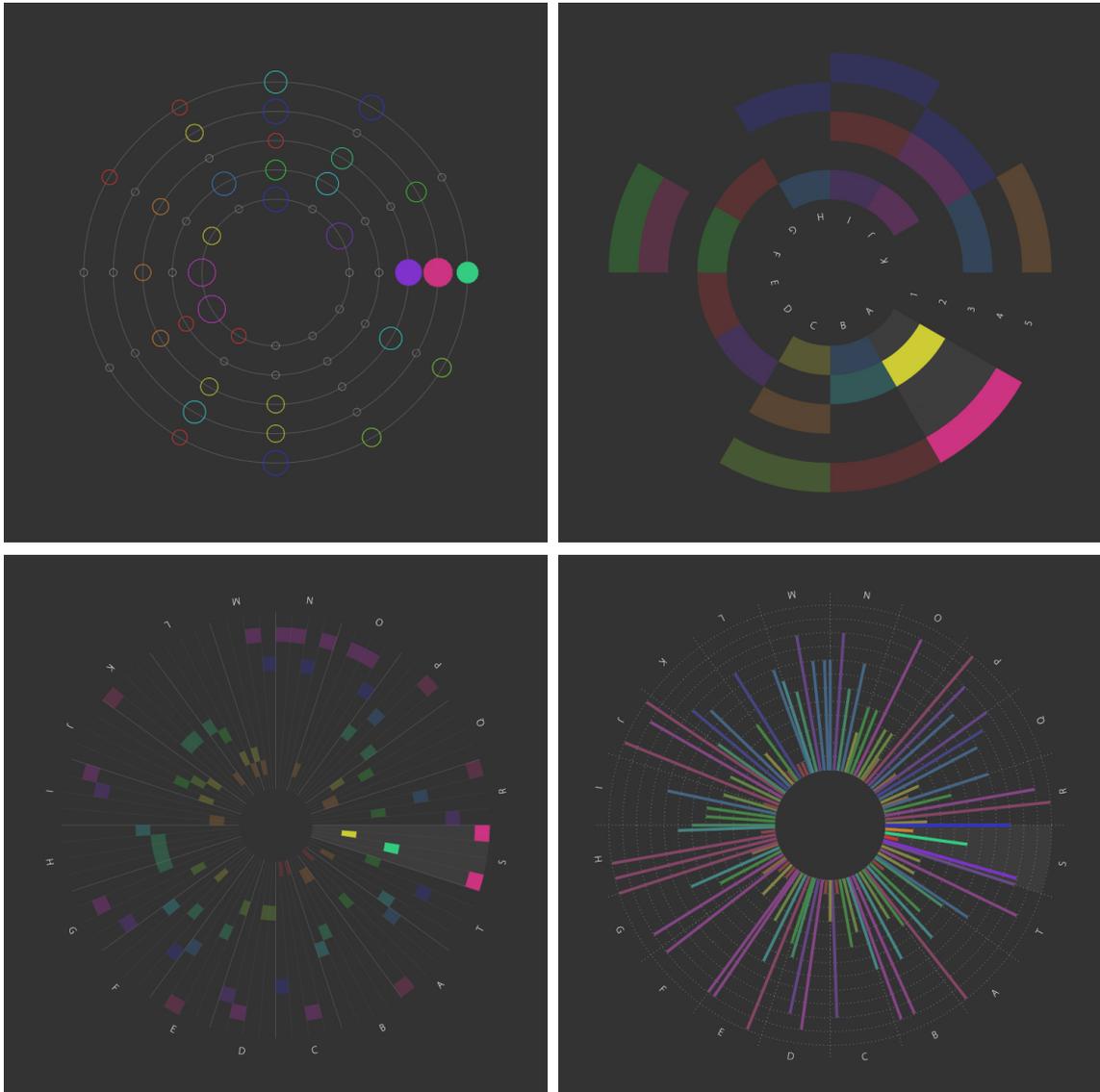


Figure 4.3 – Some graphical proposals for the shared interface of *Collective Loops* v1

interviews, questionnaires (see appendix C), and video recordings.

Unlike my expectations, with little to no prior knowledge of the system and its interactive aspects, most of the participants had a hard time figuring out that their choice of note was done by tilting the smartphone back or forth. Some tried touching the mobile screen, and others jumped or moved their body around, or even walked on the floor projection, likely presuming that a camera system was capturing their movements to control the colored cursors. With the mobile moving along while they

moved or jumped, it often caused the corresponding cursor to move up or down, falsely confirming the participant's intuition. Thus participants spent a considerable amount of time understanding how to interact with the system, and less time in a constructive interaction and musical composition.

Furthermore, some musical-savvy participants, indicated that the Roman letters serving as an identifier for the time slots were somewhat disturbing, as they could (although only for a short time; up until the letter *H* is seen) be misinterpreted as being a note of the chromatic scale.

Also, some of the participants that overcame the first challenges felt that their scope of action was very limited, which had a negative impact on their motivation to fully interact with the system and their peers.

To make things worse, software bugs were experienced as well as incompatibilities with some of participants' mobile phones, causing many frustrations from the part of the public, and ours. For example, cursors of participants who left without disconnecting from the installation, by closing their web browser or leaving the dedicated web page, remained in the shared interface unless the corresponding web client was refreshed. Also, the back button on some of the smartphones, especially those with soft buttons, were sometimes accidentally pressed, causing the web browser to change web pages and get disconnected from the installation.

4.2.4 Improvements

The identified imperfections of the first version impelled us to bring enhancements to the prototype, and the platform in general. Following several weeks of development and bug fixing, a second version of *Collective Loops* was created.

This new version supported up to 8 participants, one per time slot, and touch input was favored over gesture for the selection of notes to better support a walk-up-and-use experience. Also, contrarily to the initial version, each participant could manually choose their time slot from those available, which was done through a first touch interface on the smartphone (see Fig. 4.5a). The participant could then alter the sound emitted from the device by choosing notes from all 3 instruments through

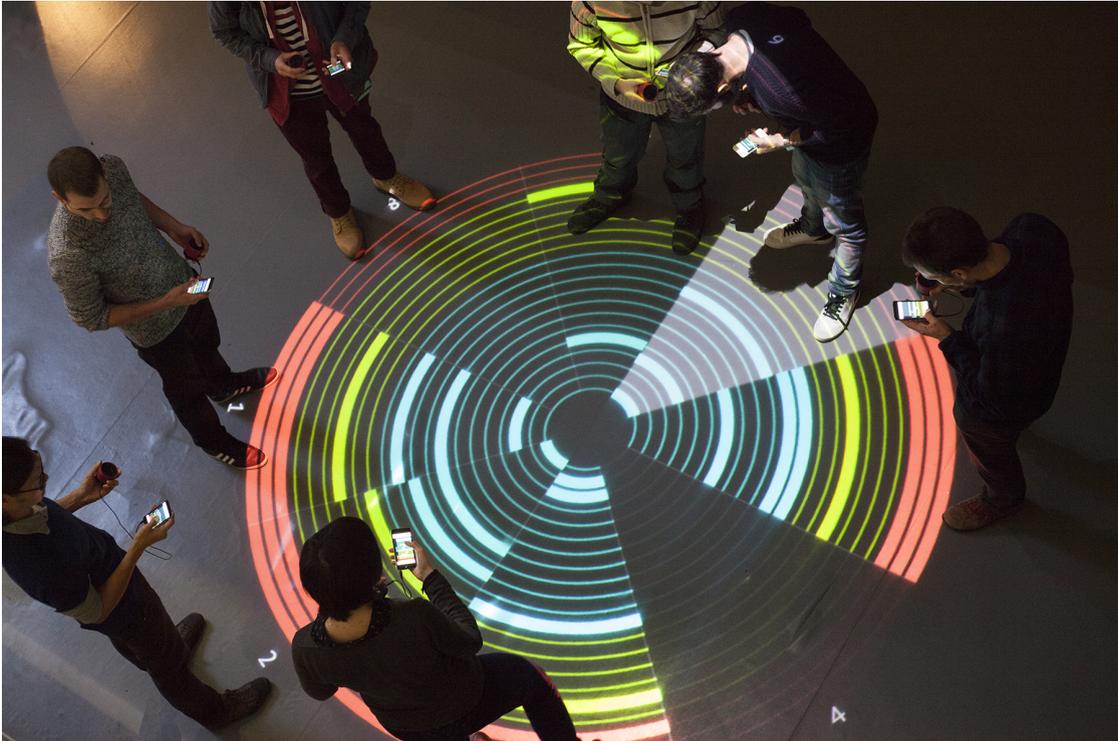


Figure 4.4 – *Collective Loops v2* shared floor projection

a second touch interface, as seen in Fig. 4.5b.

Unlike the first version, only one participant could occupy a time slot, and multiple notes from each instrument could be activated by the same participant within certain predefined limits (3/12 melody notes, 1/6 bass notes, and 3/3 percussion notes). The Roman letters were also replaced by Arabic numerals (see Fig. 4.4), and more consistent graphical design choices were done by making the individual interface as close a replica as possible of the corresponding sector on the shared one.

The tilting of the smartphone was still used as an interaction mode, but for a less important, auxiliary, function. It controlled the cutoff frequencies of a low-pass filter, modifying the intensity of the emitted sound; damping the sound when the device is tilted in vertical position — with the screen towards the participant — and opening it up when brought into a horizontal position.

Additionally, an echo effect was added to make the overall sound more interesting even with a small number of participants.

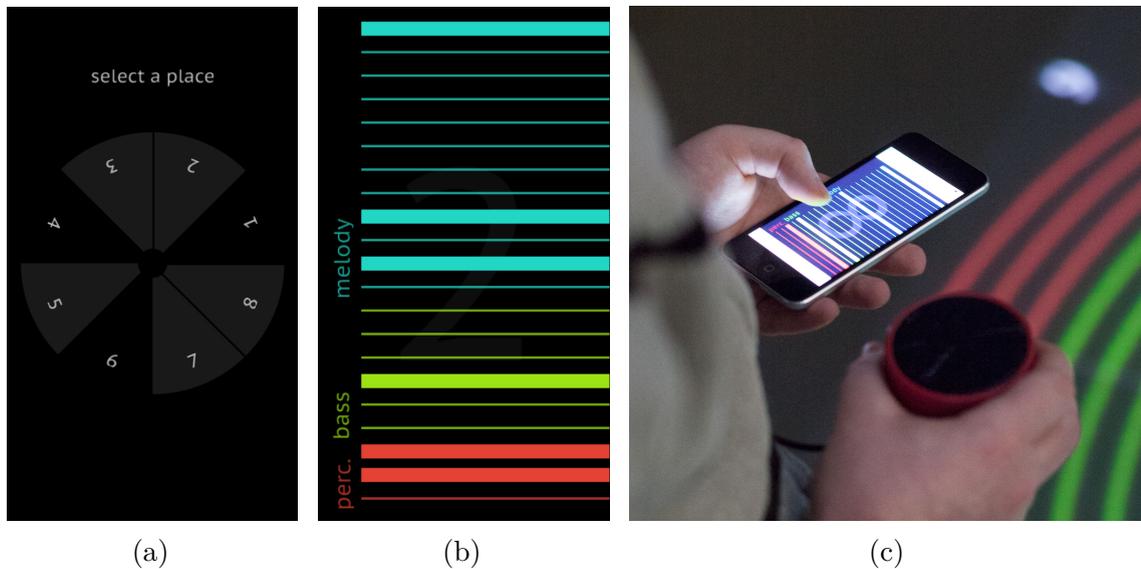


Figure 4.5 – *Collective Loops* v2 individual interfaces: (a) place selection (b) and (c) notes selection

4.2.5 User Study

With those improvements carried out, a new public deployment was planned for the audience of the workshops and presentations held during the International IRCAM Forum Workshop in November 2016.

Based on the notion that “the site of exhibition can be seen . . . [as] the central site for interactive art research – the necessary starting and finishing point for any study that aims to understand how meaning is produced by an interactive artwork” (Edmonds et al. 2006), I took advantage of this opportunity to study the impact of the shared interface on the collective experience. This decision was also influenced by the high costs involved in setting up such installations. Indeed, the setup of *Collective Loops* requires a non-negligible amount of time and man power, and the floor-projection requires the mounting of a complex video-projection system.

While previous studies have shown that revealing teammates’ progress to each other can improve collaboration in distributed problem solving situations (Balakrishnan et al. 2008; Paul and Morris 2009), to the best of my knowledge, no studies seem to have been conducted to understand the role of mutual awareness, through shared visualization, on an autotelic collaborative activity in a leisure, walk-up-and-use

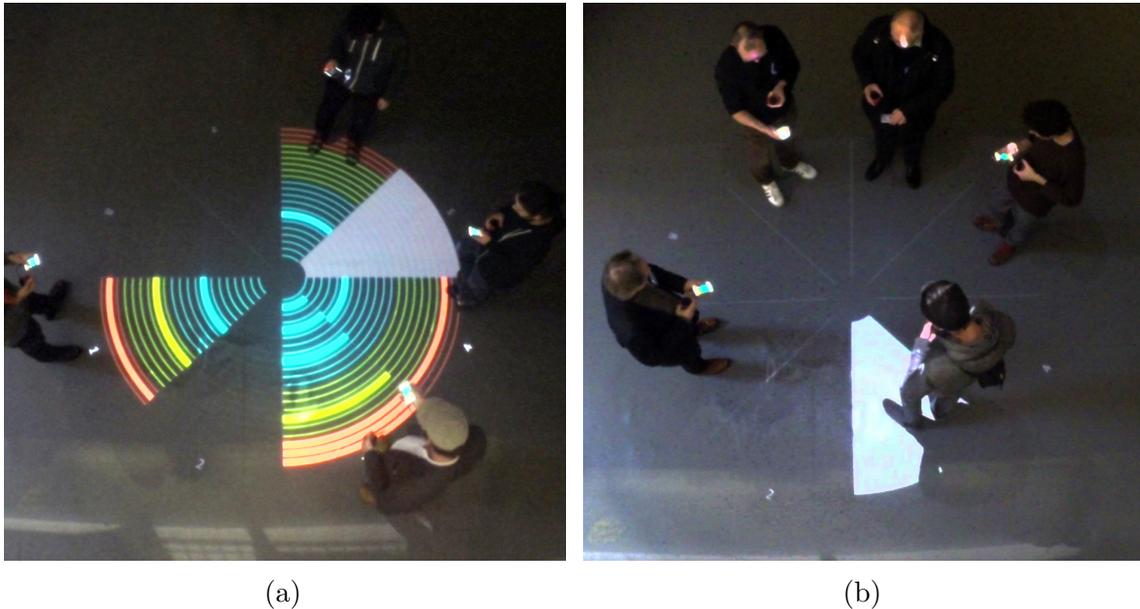


Figure 4.6 – Comparative study interfaces: (a) NSloop and (b) RHloop

co-located setting. I thus devised an experiment in order to test the hypothesis that revealing all users’ choices on the common, shared interface would promote a more collaborative experience.

Since the quality of creative collaboration that is not guided by a predefined outcome is subjective, the study was based on participants’ impressions concerning their engagement in the collective process and their ability to create a common satisfactory result. Participants were expected to build a better sense of collaboration and engagement when they are able to view each other’s choices, and thus enhancing the collective experience.

Two different designs for the shared, floor-projected interface (shown in Fig. 4.6) were tested in this comparative user study: (a) participants’ choices were displayed on the interface as well as the reading head’s current position, (b) only the reading head’s current position was displayed. I will refer hereinafter to the first interface as “NSloop” (for Note Selections) and the second interface as “RHloop” (for Reading Head).

Subjects & Procedure The audience of the workshops were invited to freely experience the installation during lunch and coffee breaks which lasted between 1 and 2 hours. Starting with NSloop, the shared interface was switched before each break, alternating between NSloop and RHloop.

As noted during the first deployment, although the *CoSiMa* platform aims to be compatible with most smartphones, the current state of web standards' implementations still requires lending compatible devices to participants. Thus, to facilitate the participation and improve the user experience, users were encouraged to borrow preconfigured smartphones with small portable speakers attached to them as shown in Fig. 4.5c.

Human mediation was limited to lending a preconfigured device, or assisting during the connection process on a participant's own smartphone. Participants had thus no prior knowledge of the system and its musical collaborative possibilities.

After their participation, users were asked to volunteer in the study by filling out a questionnaire. As non-French speaking participants were expected due to the international nature of the event, two versions of the questionnaire (one in French and another in English) were made available (see appendix D and appendix E). With none of the participants having experienced both interfaces, 36 questionnaires were collected (18 per interface). The subjects who experienced NSloop were comprised of 5 women and 13 men varying in age from 19 to 68 years old (mean: 38.9, σ : 13.1), whereas those who experienced RHloop were comprised of 5 women and 13 men varying in age from 19 to 69 years old (mean: 36.2, σ : 14).

Data Collection The questionnaires consisted of two general profile questions (age and gender), ten 5-point Likert scale questions eliciting the participant's impressions on the individual and collective experience, and a final open-ended question allowing the expression of general feelings and suggestions. I also video-recorded all sessions from above, and stored detailed system communication logs.

Results & Analysis The diagrams in Fig. 4.7 visualize the self-reported impressions of the subjects in the individual and collective engagement in the real-time musical composition with both interfaces. Although many of the comments left in

experience ones (bottom-right), implying that participants were globally satisfied with the individual experience, but did not manage to fully exploit the collective and collaborative aspects of the installation.

Indeed, the charts reveal that most participants deemed that they were able to follow their own actions, but were not fully aware of others' actions and did not pay attention to others' choices very often. They also indicated that they rarely communicated with their peers and did not quite feel engaged in a collaborative process.

Data collected from system logs, illustrated in the diagrams of Fig. 4.8, reveal that the average number of simultaneous participants was slightly lower on NSloop (2.8) than on RHloop (3.1). And, against my expectations, the total time spent per participant on the installation was on average shorter on NSloop (4'27") than on RHloop (7'05"). This might have been a consequence of the lack of shared information on RHloop forcing one to spend more time to apprehend the system. No significant difference was, however, observed on the number of note selections made by participants per minute between NSloop (mean: 25; σ : 17) and RHloop (mean: 22; σ : 17) when compared using a T-test (t-value: 0.65; two-tailed p-value: 0.52).

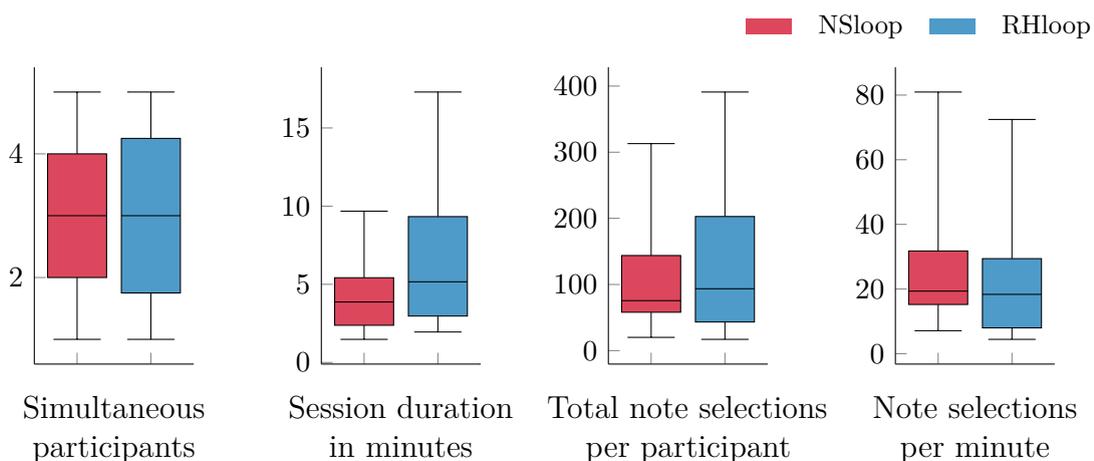


Figure 4.8 – Means from system logs

Furthermore, several participants indicated that the acoustic aspect of the system was not engaging enough, and would have appreciated to have more choices and control over the sounds emitted:

“I would expect to have more variations, such as speed, deviation... That will feel more fun to me”

“J’aurais aimé plus de variations possibles dans le “vocabulaire” mis à disposition: du son plus contrasté, des samples rythmiques plus variés, etc”

“On aurait envie de pouvoir contrôler plus de paramètres, surtout des paramètres “global”, comme la vitesse de loop”

“I want to have more influence rather than just choose between limited pre-tab sounds”

“It would be nice to be able to manipulate parameters beyond those given”

“I would enjoy access to more steps”

One also noted that the shared projection on NSloop was too prominent, dissuading discussion and collaboration with others:

“During my session most people did not seem to be utilizing the projection on the floor, however, it did keep their eyes glued there so I felt less connected to others due to lack of eye contact. However I listened carefully to the sounds others were making rather than personal contact with them”

And others indicated that collaboration was difficult as the sounds emanating from devices of their peers were not always audible:

“Je n’entendais pas très bien ce que faisaient les autres participants”

Based on the participants’ subjective evaluation of collaboration, this study did not succeed in demonstrating a statistically significant improvement in the shift of focus from the individual to the collective when all users’ choices are exposed on the shared interface. Additional research will be required to verify the results of this study and better understand the role of individual and shared graphical

user interfaces in promoting collective experiences around multi-display co-located interactive environments.

Despite all the difficulties and obstacles experienced during the two encounters of *Collective Loops* with the public, the overall experience was very fruitful, especially for the *CoSiMa* project and my research. It indeed gave us a better understanding of the challenges faced by participants (more particularly non-musicians and non-tech-savvies, but not exclusively), to engage with walk-up-and-use installations in an individual interaction, let alone a collective and collaborative one.

4.3 Peripheral cases

In this section, I examine some of the other cases for which design or development activities in the context of this thesis have, in one way or another, contributed to it. While no formal studies have been performed on the described cases, they have all strengthened my understanding of the various challenges faced in the conception processes for systems that support co-located interaction.

4.3.1 Multimouse & CoCursor

In the early months of research, before the *CoSiMa* platform reached its alpha phase, I put together smaller toolkits to easily create and deploy simple prototype projects in order to better understand and conceptualize the design and development process of co-located interactive systems.

Multimouse The first of those toolkits, which was dubbed *Multimouse*, allowed controlling several mouse pointers in a web browser by connecting multiple mice to the same machine. Without the use of such a toolkit, all the mice would control the same unique cursor.

The toolkit, developed with *Node.js*, intercepts and forwards the USB communication data of connected mice to the browser, allowing the creation and control of custom cursors.

In addition to being used as an experimentation tool, *Multimouse* was used in October 2016 for a workshop led by Samuel Bianchini with my collaboration and technical direction at the École Nationale Supérieure de la Photographie in Arles (ENSP-Arles)¹. During this five-day workshop, groups of students were tasked with designing interactive images that could be controlled by multiple co-located users simultaneously using five mice. Three projects were developed and then exposed to the public in an exhibition at the school.

The first prototype, titled *Brouhaha*, is a series of five videos depicting the same character reciting a different quote or phrase invoking silence and meditation (see Fig. 4.9a). Each video plays in a loop until the button of the corresponding mouse is pressed, causing the video to pause. The video continues playing once the button is released. Thus, in order to be able to listen to the quote in a particular video, the other four videos need to be paused using the four corresponding mice, urging participants to collaborate.

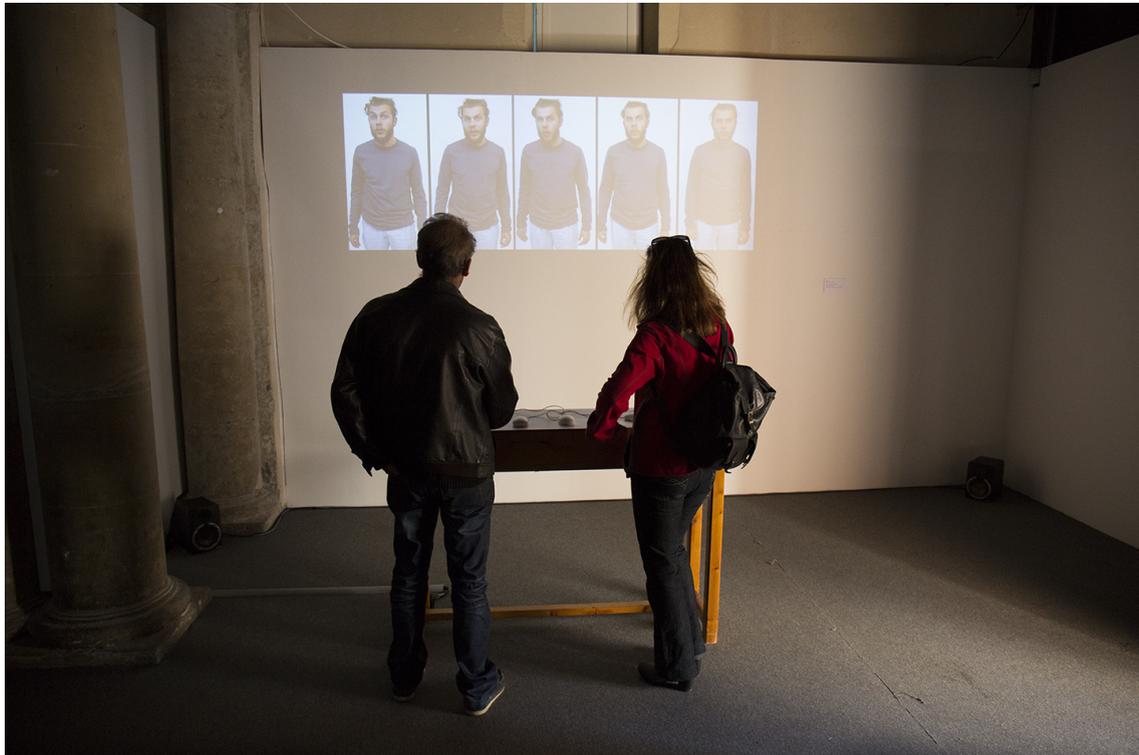
In the second prototype project, *À table*, mice represented a set of cutlery by which participants could make appear or disappear parts of an image depicting a prepared meal. Participants needed to coordinate their actions in order to reveal the entire image. Indeed, while the different traces created by the cutlery unveil parts of the image, those traces are gradually erased by the machine, requiring participants to act as quickly as possible to be able to see the image in its entirety.

Curseurs, the third prototype project, featured a cloud of several hundred cursors, initially aligned in a grid. Once in use, each mouse controls a randomly selected cursor, which in turn attracts or repulses surrounding cursors, depending on the number of participants.

CoCursor While *Multimouse* allowed fast prototyping and helped get acquainted with the research subject, it did not scale well to large groups. This led to the creation of a second toolkit, *CoCursor*, which allowed several mobile devices to control cursors on a shared screen; each cursor corresponding to one device.

CoCursor was then used to develop a simple multi-player game, which was in

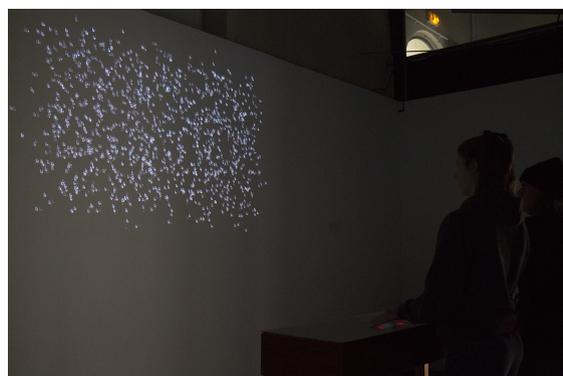
¹<http://www.ensp-arles.fr/>



(a) *Brouhaha*



(b) *À table*



(c) *Curseurs*

Figure 4.9 – Prototype projects created during the ENSP-Arles workshop

turn used to illustrate the research subject in conferences such as the RES conference¹ held in Tourcoing, France in June 2015, as well as a data visualization meetup² that took place in July 2015 in Berlin, Germany. Later on, the toolkit was used as a base for a network module in *Mobilizing.js*.

¹<http://www.res-conference.com/>

²<http://www.meetup.com/Data-Visualization-Berlin/events/223329956/>

4.3.2 Overexposure

In a much different register, *Overexposure*¹ (or *Surexposition*), described in more details in section 5.1.2, is a project by Orange (a French telecommunications corporation) and EnsadLab, under the direction of Samuel Bianchini, which features a large monolithic structure that transmits Morse encoded messages written by participants synchronously into the sky using powerful light projectors as well as within the crowd via the flash lights of mobile phones.

One of the major difficulties faced in the design and development of this installation resided in the management of the received messages. Indeed, only one message could be transmitted at a time, and, to avoid damaging the custom made shutters of the light projectors used in the first version, the transmission rate needed to be set to a relatively low value. Thus, while participants were free to send as many messages as they wanted using the dedicated mobile application or via SMS, a special queuing mechanism controlled the flow of those messages.

The mechanism, illustrated in Fig. 4.10, was conceived to prevent congestion and give an opportunity for the last received messages to be chosen for transmission. Indeed, although messages were limited to 60 characters, the transmission of a single message took approximately one minute on average, thus if a simple FIFO (first in, first out) queue management had been implemented, the messages of participants that arrived an hour or more after the start of the event would have likely never gotten a chance to be transmitted, considering that several hundreds of participants could potentially send out messages.

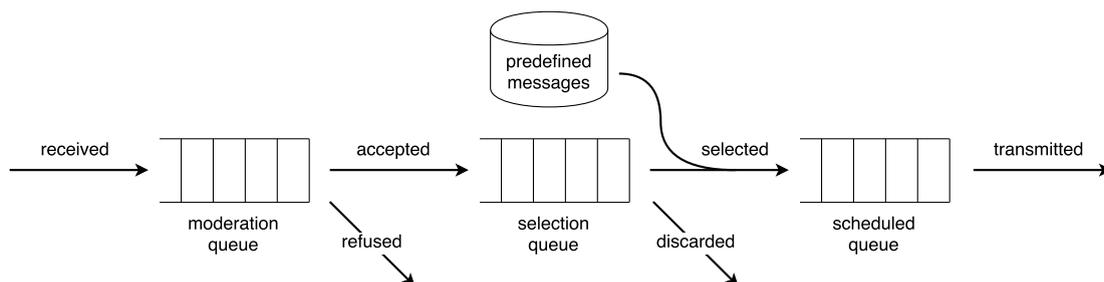


Figure 4.10 – Message queuing mechanism of *Overexposure*

¹<http://www.surexposition.net/>

Each received message is handled by the message management server. The message first undergoes a profanity check, which tags it as potentially profane if specific words or expressions are detected. The message is then added to a first manual moderation queue, and assigned to one of the human moderators connected to the server through a custom web application. The moderator then has a limited time to accept or refuse the message. Messages that are not moderated on-time are automatically refused by the system.

If accepted, a message goes through a second queue. Every few minutes, the server randomly selects a set of three or four messages from this queue and discards the other ones. The selected messages are then scheduled for transmission and added to a final queue. The items of this last queue are periodically retrieved by all instances of the mobile application as well as the monolith to be synchronously transmitted. The number of selected messages depends on their calculated transmission time, insuring that a sufficient number of messages are always available in all devices. Also, if not enough messages have passed the selection process, additional messages are randomly picked from a list of predefined ones.

A first version of *Overexposure* was deployed at the Festival of Lights in Lyon, France between the 5th and 8th of December 2014, during which over 4000 messages were received, and approximately 850 were transmitted out of the approximately 2000 accepted ones.

While this mechanism seemed to have well functioned during this first showing, a change in the speed of the shutters used in a second version and a lower participation rate had an important, rather negative, impact on the overall participatory experience. Indeed, deployed in February 2016 at the Palais de Tokyo in Paris, the new version of *Overexposure* employed different light projectors. The shutters of the new projectors were, contrary to the first ones, an integral part of the projectors, and could be opened and closed in a much faster rate.

Most relevant parameters of the queuing mechanism had been revised to take this into consideration, with the exception of the parameter that regulated the number of messages stored in the queue of scheduled ones. Due to this minor oversight, this change in shutter speed, which should have normally been an asset, resulted in an abnormally high proportion of predefined messages being transmitted, and a large

number of participants' messages were automatically discarded by the system, which led to the frustration of participants.

4.3.3 Espace^Espace

Created in the context of the *CoSiMa* project, *Espace^Espace*¹ is an experimental installation by Dominique Cunin which explores the projection of a 3D virtual model of an architectural construction on its real-life counterpart and at original scale via video projection mapping techniques. Using a specially designed web application on their mobile phones, participants can collectively interact with the virtual model, detaching it from the real one, creating rather surreal sensations.

The project was initially conceived for the opening of the 36th edition of the Montpellier Danse festival, and was shown at the Agora, an international dance academy, in June 2016. It was also presented on a second occasion during a *CoSiMa* seminar, which took place at Esba TALM² in September 2016.

The installation proposes different scenarios of interaction, which are synchronously alternated on all mobile phones through a remote administration interface. One of those scenarios invites each participant to balance a special spirit level, which is both displayed on their mobile phone and projected on the surrounding walls (see Fig. 4.11). Once each and every participant has managed to balance their individual spirit level, a virtual tour in the projected space is triggered.

While the scenario was devised with collaboration in mind, it was observed that the exposure of each spirit level on the shared projection spurred competitive behavior. Some participants were, in fact, eager to finish balancing their spirit level before others, and would then yell or scream at the ones lagging behind. Collaboration did occur, but at a later time; only once most participants, but one or two, had managed to balance their spirit level. Some of the other participants would then encourage the remaining ones or help them solve their puzzles.

¹<http://www.mobilizing-js.net/en/#espace-puissance-espace>

²The Ecole supérieure des beaux-arts Tours Angers Le Mans

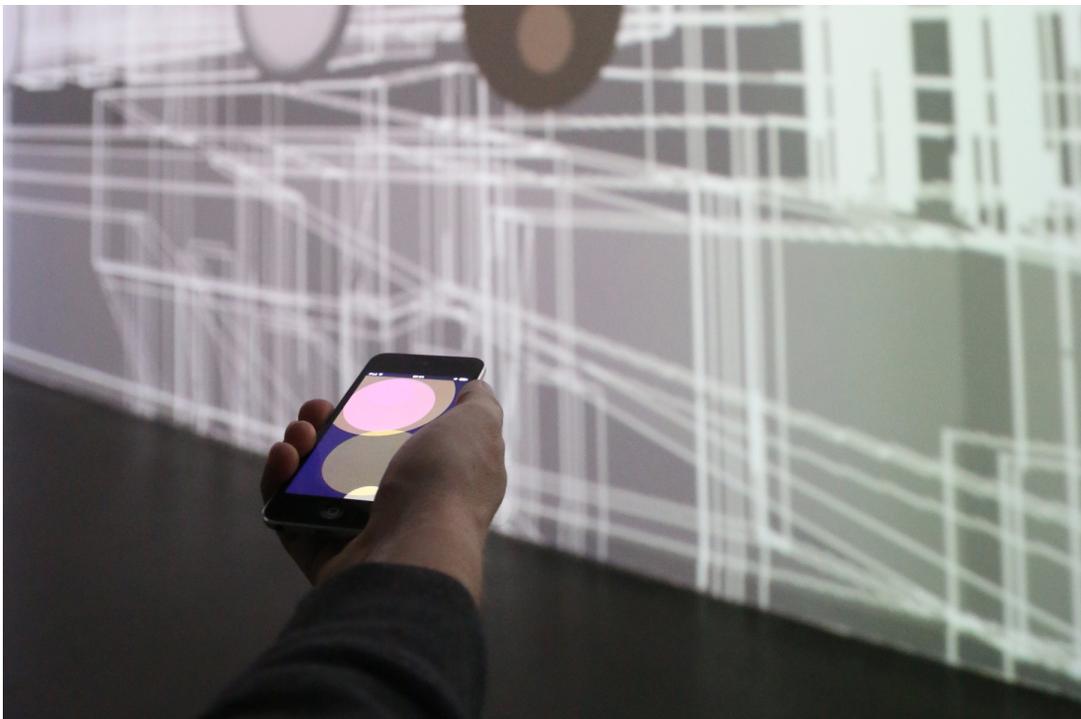
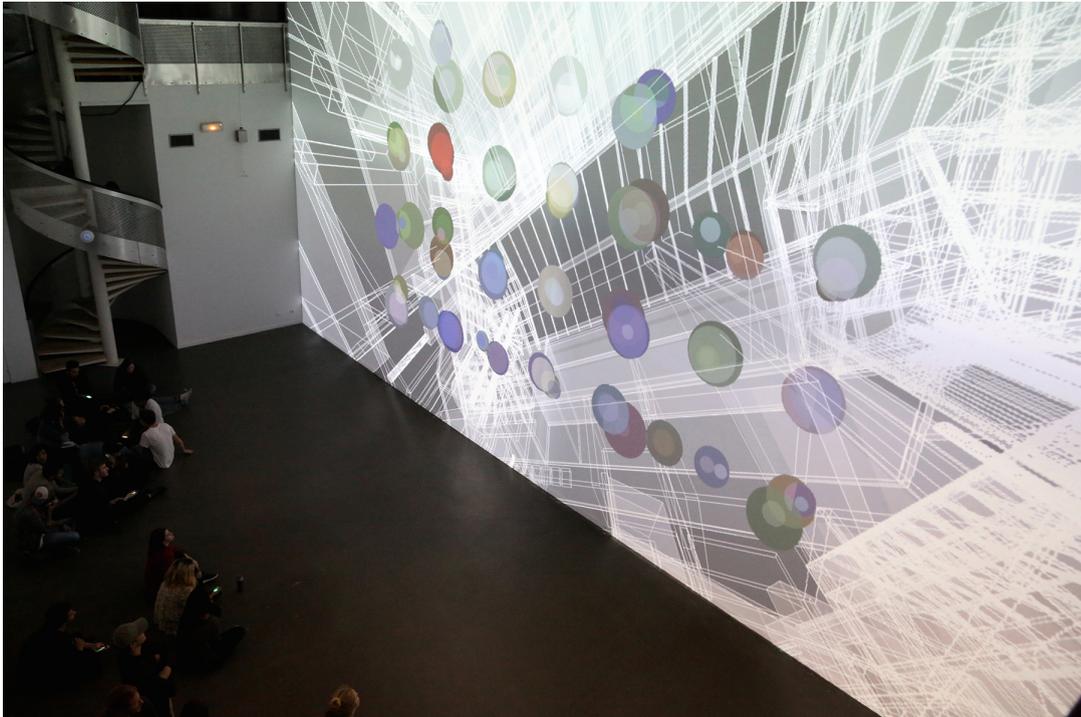


Figure 4.11 – *Espace^Espace* at Esba TALM, Le Mans, France in September 2016: shared video projection (top) and mobile web application (bottom)

4.3.4 PROYECTOR2016 workshop

Other prototype projects were conceived by students, designers, and filmmakers in a hand-on workshop led by the author with Samuel Bianchini as special guest. Held as part of the 9th edition of the international video art festival *Projector*¹ in Madrid, Spain, the workshop, dubbed *From spectator to actor: designing for collective audience participation using smartphones*, proposed to explore co-located interaction in interactive video art.

Several prototype projects were developed using *Mobilizing.js* and presented at the end of the festival. With varying scenarios, the prototypes consisted of short movies requiring the collective action of the participating public at specific times to resume playback, and, as depicted in Fig. 4.12, unusual interactions via the mobile phones were imagined: pressing the lips against the touchscreen to initiate the famous kiss scene in the *Casablanca* movie (1942), shaking the device up and down to mimic the stabbing of Marion in *Psycho* (1960), or repeatedly pressing it against one's chest to reanimate a female assembly worker.

4.4 Lessons learned

Along with other *CoSiMa* and *EnsadLab* projects and workshops, *Collective Loops* has taught us many lessons. The most significant ones will be discussed in this section.

4.4.1 Attractors, sustainers, relaters ... and facilitators

It was observed that participants were more likely to take the first step towards an engagement in an interaction if others were already engaged. This phenomenon known as the *honeypot effect* (Brignull and Rogers 2003; Wouters et al. 2016), which describes how the presence of participants can influence passers-by to become passive or active participants, has gained interest in HCI research around public displays (O'Hara 2003; Müller et al. 2010; Veenstra et al. 2015; Wouters et al. 2016).

¹<http://projectorvideoartfestival.blogspot.de/>



Figure 4.12 – Demonstrations of two prototype projects created during the PROYECTOR2016 workshop

This allowed newcomers to explore the possibilities offered by the installation through the interaction of others before joining the experience themselves, thus bypassing part of the initial learning phase, which can be a source of discomfort for some.

It was also observed that sounds emitted from active participants in *Collective Loops* and the light emitted by the monolith in *Overexposure* acted as an attractor for passers-by, who would have otherwise not heard of the installation or would not have shown interest in it.

Additionally, it was found that participants of *Collective Loops* who spent less time figuring out the workings of the system and how to interact with it, and found their time slot rapidly, were more apt to engage in an extended involvement with the work and their peers.

Thus, for a collective collaborative experience to emerge, an installation must not only attract passers-by and entice them to become active participants, but also make the initial encounter as smooth as possible, and then prolong the interaction by sustaining the participants' interest, who then become greater attractors for newcomers, allowing the progressive creation of a collective experience. A collaborative one could then potentially emerge as participants gain more experience and share thoughts and ideas with their peers.

Some of those aspects were discussed by Edmonds et al. (2006) in what they denote as the attributes of creative engagement: attractors, sustainers, and relaters. According to the authors, *attractor* attributes are the aspects of an installations that initiate the encounter with the audience, directing their attention towards the work. *Sustainers*, on the other hand, are those aspects that prolong the engagement during the encounter, while *relaters* help build a more lasting relationship with the work, inviting the audience to revisit it on other occasions.

Although their work was not specific to collective or collaborative experiences, but more generally concerned with creative engagement in interactive visual art, most of the attributes (with the exception of *relaters*) seem particularly important for the emanation of a collective and collaborative aesthetic experience.

It seems, however, that we could add a fourth attribute to those mentioned above:

facilitators, which would come after attractors, but before sustainers, and are those aspects of a work that simplify or ease the initial encounter in its early stages. Those are tightly related to interface intuitiveness and perceived affordance. To later make place for sustainers, it might be necessary to progressively fade out those aspects, by slowly increasing the complexity of the interaction, or augmenting the interactive possibilities of the system, without which the experience could become somewhat humdrum.

To attract the first passers-by and help increase the chance of encounters in *Collective Loops*, I had imagined having virtual participants playing preconfigured rhythms, who would slowly disappear as real ones joined the installation. This was unfortunately never achieved as it was deemed too difficult to setup in the short period of time available for the design and development of the prototype.

4.4.2 Conflicts in interaction pace

In art installations that support concurrent interactions, participants are usually free to join and leave the experience at any given time, which has a direct impact on the likelihood of emanation of a collaboration and its nature. As discussed by O'Hara (2003), conflict in pace can be dealt with in remote settings by using each user's display to throttle the effects of other's interactions. This is, however, more difficult to deal with in a co-located setting.

This is particularly problematic in walk-up-and-use installations that are specifically designed with collaboration in mind, as is the case with *Collective Loops*. Indeed, a collaborative effort can be greatly disrupted by the joining of a newcomer or the leaving of an active participant, requiring other participants to readapt.

While facilitators and sustainers can increase the chance of collective interactions by helping the first participants get a rapid grasp of the offered possibilities and prolonging their engagement, how can we manage the differences in interaction pace of participants?

More research is required to evaluate the impacts of the joining and leaving of participants on the collective and collaborative engagement, and how to reduce or

regulate those impacts.

4.4.3 Attentional weight of interfaces

In multi-display and multi-sensory environments, yet another design challenge is involved: the management of participants' attentional focus. Indeed, participants of *Collective Loops* were confronted with no fewer than four sources of attention throughout their participation: (1) the individual interaction on their smartphones, (2) the visualization of all the interactions on the shared projection, (3) the sounds emitted from all the individual devices, and (4) their collaboration with other members of the public. While we wished to promote the fourth one by means of the individual and shared interfaces, all four seemed to be in competition with each other. They all solicited, in different ways, the user's attention. It, in fact, seemed difficult for participants to pay attention to others if their mind was already occupied by one, let alone two or even three other sources of attention.

While this major difficulty needs to be overcome if we are to design such collective and collaborative experiences, it is a very challenging one, and was, in fact, even faced by the video game giant, *Nintendo*, when they tried, and failed, to provide a dual-screen gaming experience with the *Wii U*'s GamePad, which featured an integrated touchscreen. The dual-screen approach was first used in the *Star Fox Zero* video game, which resulted in the disorientation of players (Kohler 2016).

Some related research has investigated the use of multi-display environments and their effects in collaborative systems (Wallace et al. 2009, 2011; Khan et al. 2005; Biehl et al. 2008). However, they mostly deal with groupware designed for collaboration in a working environment. In walk-up-and-use installations such as *Collective Loops*, the challenge is exacerbated, as participants are not already acquainted with each other, and, as noted earlier, the pace of their arrivals and departures is usually unpredictable. It is thus hardly conceivable to rely on techniques imagined for the workplace such as *spotlight* by Khan et al., in which a region of a large shared display is made more prominent to direct the attention of the audience towards it, or the *IMPROMPTU* framework by Biehl et al., which allows co-located users to share opened applications with others for modification or viewing purposes on a large display, but requires the user to have prior knowledge of the framework. Other approaches such as *Gazemarks*

(Kern et al. 2010), in which the user’s last gaze position is highlighted to be used as a visual reminder, easing attention switching when resuming an interrupted visual search task, are also unsuitable for the context at hand.

Therefore, more research needs to be undertaken to find a balance between concurrent sources of attention. We could, for example, consider attentional weight of the individual and shared interfaces to balance them, or to dynamically manage their ability to retain or release users’ attention, and thus better control which type of interaction we would like to privilege in order to support the emergence of a collaborative situation.

Such research could build upon that of Witka (2016), in which they evaluated the importance of different perceptual properties such as color, brightness, field of vision, and attention on different types of multi-display environments, amongst which are those that combine large displays with mobile devices.

4.4.4 Shared display angle: horizontal vs. vertical

One of the first choices that needed to be made for *Collective Loops* regarded the positioning of the shared interface. It was intuitively decided very early on to have it floor-projected. While this choice had a negative impact on the complexity of the projection system — requiring the installation of an angled mirror — it revealed to be a good choice when regarded from the interaction perspective. The projection being in a contiguous visual field with the individual hand-held devices, it facilitated the switch in visual focus between the two interfaces as depicted in Fig. 4.13a and Fig. 4.13b. Whereas the vertical angle of the shared display in *Overexposure* and *Mobilisation* (described respectively in sections 5.1.2 and 5.1.3) require participants to raise their head when switching their attention from the individual device to the shared one (as in Fig. 4.13c), and, as a consequence, participants using the application on their smartphones seem to be, albeit momentarily, pushed to the fringes of the collective experience.

While the benefits offered by floor-projected interfaces seem to outweigh the disadvantages of the complex projection setup in a co-located installation that support a relatively small number of participants, such as *Collective Loops*, this

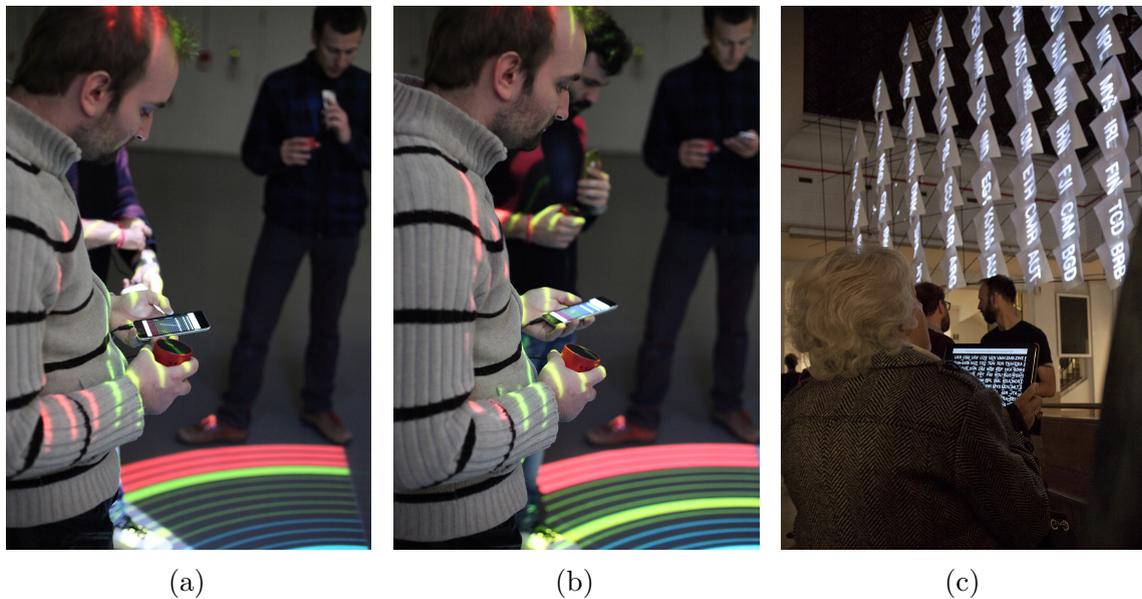


Figure 4.13 – Attentional focus of participants in *Collective Loops* (a and b), and *Mobilisation* (c)

would likely not apply in larger installations that can support dozens or even hundreds of participants.

Previous studies have been performed on the effects of the display angle in individual and group activities. Inkpen et al. (2005) have, for example, explored the effects of different display factors on co-located collaboration. Among those factors was the angle of the display, which they found to be more comfortable when in a horizontal position compared to a vertical one, but the vertical position had other advantages such as making work more time-efficient.

And Potvin et al. (2012) compared the use of horizontal and vertical interactive surfaces in collaborative tasks, and found, against their expectations, that more face-to-face contact was made with vertical displays, and that discussion time can be overall equivalent in both settings, but is more affected by the different arrangements of users (side-by-side, opposite one another, or kitty-corner). While Rashid et al. (2012b) have proposed a taxonomy of factors that influence shifts in visual attention with multi-display environments such as display contiguity.

Ichino et al. (2016) have, for their part, investigated the effects of display angle on the social behavior of museum visitors, and revealed that changing the angle incurred

different impacts on the way visitors gathered around the display and interacted with it. They observed, for example, that a horizontal or vertical display had a positive impact on the honeypot effect, when compared to a tilted display.

Another study by Rashid et al. (2012a) compared three different user interface distribution configurations on mobile and large displays when performing a set of tasks, and showed a significant decrease in performance in individuals' visual search tasks when displaying the same contents across a mobile device and a vertical large display.

Yet more related studies were performed, including those of Tan and Czerwinski (2003), Rogers and Lindley (2004), Su and Bailey (2005), and Cauchard et al. (2011). However, to the extent of my knowledge, little to no studies seem to have addressed the effects of the angle of the shared display in a co-located collective multi-display environment when combined with individual hand-held devices, and especially around art installations. Therefore, complementary studies need to be conducted to further understand the effects of different arrangements of heterogeneous displays on such setups to help guide their design.

4.4.5 Designing for queues

Whether they regulate access to spatial resources or material ones, queues are an integral part of many installations. As recognized in section 4.3.2, the way they are handled can deeply affect the participatory experience.

Although usually perceived to be an undesirable effect of resource limitations, it is sometimes possible to design around the queuing experience in order to ameliorate the overall user experience.

In an interview with the architect and artist Usman Haque (see appendix A for a more exhaustive extract of the interview), he revealed how the queuing experience was used as a facilitator in one of his projects:

“It’s a project called *Assemblance*, where deep down a dark theater, underneath at the Barbican in London, we knew that the queues would be very long, and that people could potentially be waiting an hour to come

in and experience it. And that it would be quite a complex interaction that they would be then faced with once they got inside. So we built a window into the installation that was big enough that you'd be next to it probably for about 5 minutes as you were going past, where you would see the installation and people [interacting], but it then disappeared as you walked on the last 10 minutes before you'd get in. So we were consciously thinking about that effect of teaching people by giving them that kind of fragment.”

This strategy can be very efficient for installations that exhibit physical queues with passive participants standing in line waiting for their turn to interact. Other strategies, however, need to be envisaged in apparatus similar to *Overexposure*, in which the limited resources lie mostly in its output capacities, not in its input.

Would rendering the queuing and selection process more transparent to participants of *Overexposure* decrease their frustrations or entice them to collaborate?

4.5 Summary & perspectives

In this chapter, I presented the *CoSiMa* platform and the *Mobilizing.js* authoring environment which was partly used in the platform for graphics rendering. I then described *Collective Loops*, a prototypical audiovisual installation, on which I performed a comparative user study to verify a hypothesis regarding the role of the shared interface on promoting the user engagement in a collaborative process around a collective musical experience. Although the results obtained through the study did not allow us to draw reliable conclusions and more questions were raised than answers, the prototype project along with other diverse *CoSiMa* and EnsadLab projects helped us forge a better understanding of the numerous challenges that need to be addressed when designing co-located interactions to allow the emergence of a collective and collaborative aesthetic experience, and some of the most important challenges were discussed above.

Most of the above described works combine both individual and shared interfaces. While this combination — especially when the individual devices used are powerful

hand-held ones that offer both input and output capabilities such as smartphones — enables us to provide highly rich and diverse experiences, it can result in attention overload for participants, greatly hindering their ability to engage in and pursue a constructive experience with their peers. It thus seems reasonable to say that, once the interaction initialized and the learning curve overcome, the output capabilities of the individual devices could be gradually restricted, increasing that of their input, and hence reinforcing their role as an input interface, and consequently releasing some of the user’s attention to the benefit of the shared apparatus.

This design pattern has been employed by some of the surveyed works presented in the previous chapter such as *Tourmente* (2015) by Jean Dubois, which invites passersby to interact with a series of facial portraits exhibited on a large public display by dialing a special phone number and then blowing into the microphone of their personal device. However, can this be applied to complex collaborative installations such as *Collective Loops*, which relies on a touch interface to try and give away as much control as possible to participants? Could special menu techniques such as the *Wavelet menu* (Francone et al. 2009) or haptic feedback techniques (while not yet available on today’s smartphones) such as *programmable friction* (Potier et al. 2016) be used to reduce the visual attention solicited by the individual interface once participants become familiar with it?

Another related strategy could consist in a better separation and distribution of the interactive modalities of the individual and shared devices, preventing or limiting the concurrent use of the same modality on different sets of devices; using a modality on only one set, whether individual or shared. For instance, if a visual modality is used on the shared device(s), it should be avoided on the individual ones, and another modality, such as audio or haptics, should be privileged.

Much research remains to be carried out to further investigate such solutions and bring answers to the numerous questions raised.

In the following chapter, yet another challenge will be tackled: that of modeling co-located interactive apparatus. I will unveil and review two distinct, yet complementary, approaches to a graphical modeling language, that could further help in their design by providing tools for their description, comparison and classification.

“The most that can be expected from any model is that it can supply a useful approximation to reality: All models are wrong; some models are useful.”

— George Box

5

Modeling co-located interactions

As discussed in previous chapters, the type and quality of the aesthetic experience in art installations that enable co-located interactions is determined and influenced by many different factors, making the design of such systems a complex and challenging undertaking.

In order to help guide artists and designers in this task, I have endeavored to put together a domain-specific graphical modeling language. As an abstraction of a system, a model allows, in fact, the extraction of essential aspects and characteristics from the rest of the system’s details. The system can then be analyzed, compared or evaluated in a time and cost effective way.

In this chapter I will introduce two different approaches at a graphical modeling language. The first one mainly focuses on the visualization of the relations and arrangements of user interfaces through very high-level abstractions. The second one is, on the other hand, human-centered, and focuses on the user experience, with an adjustable level of detail. Built on top of an existing graphical and mathematical modeling language, the later approach not only allows the visualization of some characteristics of the system and its comparison with others, but can also be used as a simulation and performance analysis tool.

5.1 Relational Graph of Interfaces: first approach at a graphical modeling language

My first approach at a graphical modeling language was initially created as a visual aid in a study of the topology of collective co-located interactions (Mubarak et al. 2016, 2017).

The study reviewed and analyzed four interactive art installations which were conceived within the framework of research on "Large Group Interaction" at EnsadLab: *Discontrol Party*, *Overexposure*, *Mobilisation* and *Collective Loops*. I examined the possible configurations of the interactive space according to the actions and relations between its agents, both humans and machines.

Inspired by works on groupware such as that of Courbon and Tajan (1999), the language presented in the study helped visualize the relations between the individual and shared interfaces and facilitate the comparison between the different configurations.

The language is composed of two main symbols: (1) a square one representing individual interfaces with an indicator specifying whether they are input interfaces, output ones, or both as seen in Fig. 5.1a, and (2) a hexagon symbol for shared interfaces with the identical indicators for input and output as depicted in Fig. 5.1b. Furthermore, the number of each interface supported by the system is represented by a small "badge" icon overlaid on the top-right corner of each symbol (see Fig. 5.1c), the arrangement or organization of the individual interfaces can be indicated using one of the icons in Fig. 5.1d, and the direction or nature of the flow of interaction data between the individual and shared interfaces is illustrated by the different arrows of Fig. 5.1e.

In the remainder of this section, I will briefly describe each of the four installations, and then demonstrate how the modeling language can be used to depict the arrangements and relations of the system's various user interfaces.

I will then conclude this section by discussing the strengths and weaknesses of this approach.

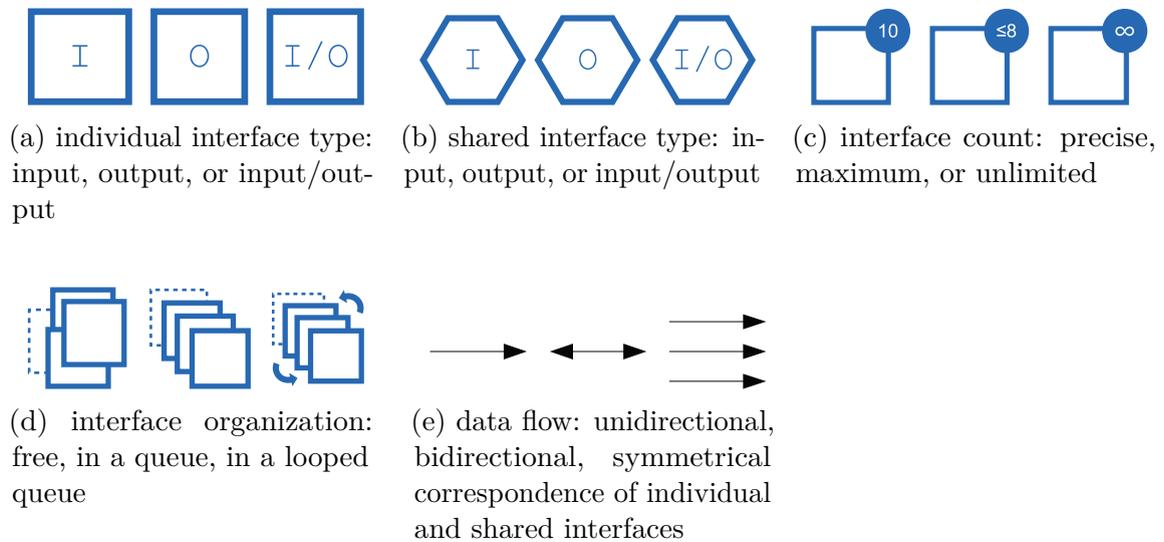


Figure 5.1 – Symbols of the interface relational graph system

5.1.1 Case 1: *Discontrol Party*

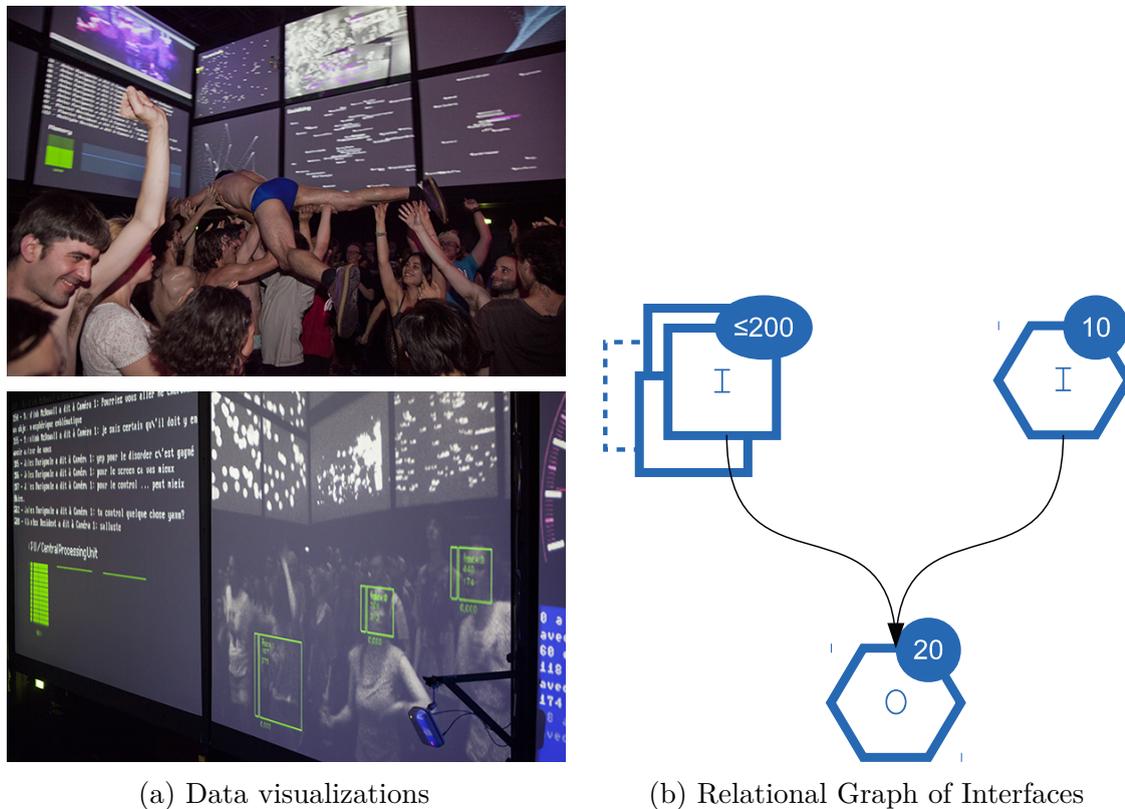
Developed by EnsadLab, with several partners, the interactive festive installation entitled *Discontrol Party*¹ unites the two, usually opposing, worlds of state-of-the-art surveillance technologies and partying. A dance floor appears in the dual spotlight of a party and a data-driven control and surveillance system with computer vision and indoor geolocation.

Participants of the event are encouraged to carry one of the 200 available UWB tags, allowing the system to track their every move. Additionally, 10 video surveillance cameras are installed throughout the space to perform blob and face detection. While partying, the crowd is confronted with multiple real-time visualizations of the collected and analyzed data.

Though the system does its best to track and analyze the behavior of participants, their rapid movements and the crowd's high density makes it almost impossible to distinguish the individuals from each other.

The graph in Fig. 5.2b visualizes the individual and shared interfaces of *Discontrol Party* and the data-flow between them according to the system described in Fig. 5.1. The top-left symbol in the graph represents the individual input interfaces (the UWB

¹<http://dispotheque.org/en/discontrol-party>

Figure 5.2 – *Discontrol Party*

tags), which are freely positioned in the installation space, and indicates that the installation supports up to 200 of them. The symbol at the top-right, on the other hand, represents the 10 shared input interfaces (the surveillance cameras), and the bottom one represents the 20 shared output interfaces (the video projections).

5.1.2 Case 2: *Overexposure*

Overexposure (version 2) is an interactive work bringing together a public installation and a smartphone application.

On an urban square, white dots and dashes scroll from bottom to top on a large black monolithic structure. Each time one reaches the top of the monolith, a bright beam of white light is projected by the structure into the sky. Visible all over the city, the light beam is transmitting short messages sent by participants using the mobile application or via SMS. The text messages are encoded into Morse code and

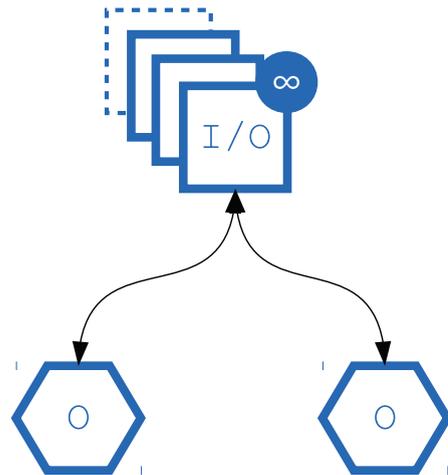
made visible, one at a time, to everyone for a few moments, marking the installation with their rhythm.



(a) Monolith and mobile application



(b) Floor-projected map



(c) Relational Graph of Interfaces

Figure 5.3 – *Overexposure*

On a completely different scale, we see the same dots and dashes scrolling across the smartphone screens of the participating public following the same rhythm. Here, it is the flash of the smartphones that synchronously releases light in accordance with the coded language.

Returning to the very essence of Morse, the messages are also transformed into a sound composition, broadcast by the monolith and the smartphones. In addition, a map of the real-time activity of the mobile phone network, is floor-projected around

the monolith and available through the smartphone application, giving access to the pulse of an even larger community: that of the city.

From individual devices the size of a hand to a shared device at the scale of the city, a momentary community forms and transforms, sharing a space and a pace, through a type of communication whose ability to bring people together by a sensory experience is more important than the meaning of the messages it transmits or their destination.

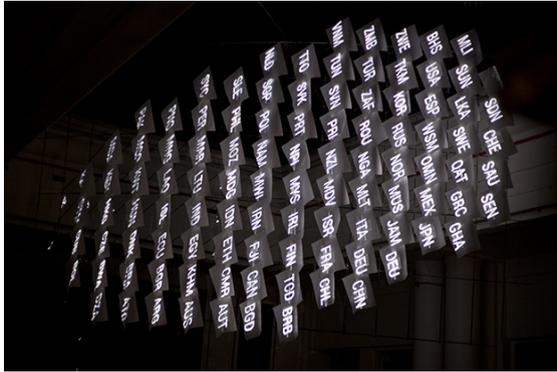
We can represent the interfaces of *Overexposure* and their relations as in Fig. 5.3c. The queue for the individual input/output interfaces (the smartphones) is indicated by the symbol at the top, and the two shared output interfaces (the monolith and the floor projection) are indicated by the symbols at the bottom. Since the two shared interfaces differ in nature from each other, each one is represented by its own symbol. The arrows between the individual and shared interfaces indicate that information flows back and forth, as smartphones send the messages, and the selected message is displayed on all the individual and shared interfaces.

5.1.3 Case 3: *Mobilisation*

In *Mobilisation*¹, a mobile sculpture, moving with the slightest breeze, is suspended from the ceiling of the lobby of Sciences Po (Paris Institute of Political Studies). The sculpture is composed of over a hundred flags, on which textual information is video projected using projection mapping. When the sculpture and the flags move, under the effect of wind, the video projection seeks to adapt to the movement in real time. It only succeeds to do so to a certain extent, especially if the movements of surrounding objects or people disrupt its environment.

Each blank white flag is initially coated by three letters representing the name of one of the countries (e.g., FRA for France) that contributed to the IPCC, the Intergovernmental Panel on Climate Change. Although a world map is not quite formed, the arrangement of the flags corresponds to the global organization of the territories.

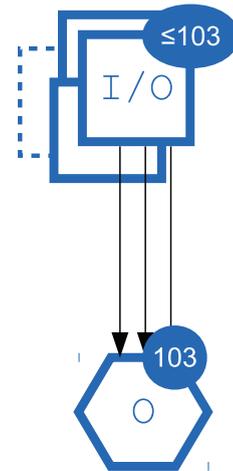
¹<http://dispotheque.org/fr/mobilisation>



(a) Flags



(b) Mobile application



(c) Relational Graph of Interfaces

Figure 5.4 – *Mobilisation*

We can perceive on certain flags, behind the three initial letters, some more or less dense texts in the background. These typographic aggregates reveal the degree of participation of each country in the various IPCC reports and indicate an information space to be explored. The public facing the sculpture can indeed act on it through a dedicated application on their mobile device. After choosing a flag, and thus a country, they explore this information by traveling in the typography laid out in a three-dimensional space. The information revealed by the interactions varies according to the data available in the IPCC database (report, role, participation chapter, working group, etc.). By seizing this information and adopting a country's perspective, the interactions of the participant on the mobile device are reproduced in real time on the corresponding flag to be seen by all. Each participant thus momentary becomes a representative of the chosen country.

Caught between the actions of the participants and the slightest air movements,

the information attempts to mobilize us through an uncommon and collective aesthetic experience.

Fig. 5.4c outlines, by the parallel arrows, the direct correspondence between the individual and shared interfaces. It also indicates that the individual interfaces are both input and output ones freely distributed in space and limited in number to 103, corresponding to the total number of shared output interfaces.

5.1.4 Case 4: *Collective Loops*

In accordance with the thorough description of the *Collective Loops* installation in section 4.2, the diagram in Fig. 5.5 indicates, by the upper symbol, that the individual input/output interfaces are in a looped queue, and that the system supports a maximum of 8 of those interfaces. It also specifies that there is only one shared interface, *Collective Loops* and that it is an output-only one. The one-way arrow signifies that the interaction data are not returned to the individual interfaces, and therefore the choices of the other participants are only visible on the collective floor projection.

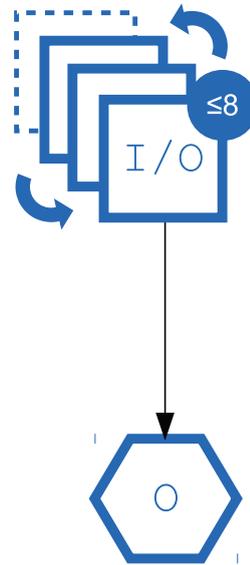


Figure 5.5 – Relational Graph of Interfaces for *Collective Loops*

5.1.5 Review

Designed with ease of use in mind, the proposed modeling language is constituted of a small set of symbols of a very high level of abstraction. As I have shown above, this language has already proven to be of value in sketching out the relational graph of interfaces of different, more or less widely used, setups. Revealing some of the topology of each installation, the models can help review, classify, and compare the works.

Such an approach could also be used as a visual programming language facilitating the setup of software components for an installation. A server's network configuration, for instance, could be handled automatically through the interpretation of a model's

server-client communication requirements.

The expressive power of the language as a modeling tool is, however, very limited. At its current state, it cannot, for example, be used to model peculiar cases like *SMSlingshot*, in which an individual interface, the handheld digital slingshot, is passed from one participant to another (Fischer et al. 2013). The language also does not provide a means to indicate fixed or predefined placements for individual interfaces as is the case in *Kinoautomat*, *Dialtones (A Telesymphony)* and *PixelPhones*. Modeling such cases would require augmenting the language with new interface organization symbols.

Throughout the next section I will present a second, radically different, approach to modeling co-located interactions in art installations which aims, among other things, to address some of the above mentioned limitations by building on top of an existing graphical and mathematical modeling language with a large expressive power, Petri nets.

5.2 CoPN: towards a human-centric approach based on Petri nets

The shortfalls and weaknesses detected in my first approach at modeling co-located interactions prompted me to explore a new one, and the following set of desired properties were identified:

- capable of modeling human-machine, human-human, and human-machine-human interactions
- capable of modeling spatial and material resources
- supports different levels of abstraction and the progressive refinement of a model
- convenient for the description, comparison, and classification of co-located interaction systems
- precise enough to be eventually used in verification, specification, and implementation processes of the modeled system
- accessible for non-computer scientists

- facilitates the dialog between artists, designers and software engineers in the conception process

For convenience, I have chosen to base this new approach on an existing modeling language with a solid foundation. I will therefore proceed in the next section by evaluating a set of commonly used languages in accordance with the goals above.

5.2.1 A brief overview of commonly used graphical modeling languages

In view of the existence of a wide range of general-purpose and domain-specific graphical modeling languages (such as Flowchart, EXPRESS-G, and Southbeach Notation), only those supporting the modeling of interactive aspects of systems were considered. I will briefly review each one below.

UML Originally designed by the computer scientists and software engineers Grady Booch, Ivar Jacobson and Jim Rumbaugh in the mid-'90s, the Unified Modeling Language (UML) (Glasson 1999; Rumbaugh et al. 2004) is a very widely used modeling language. It is commonly used for specifying and visualizing object-oriented software systems. The language includes a variety of diagram types, some of which are used to model the structure of a system (such as component and class diagrams), while others are used to model its behavior (such as activity, sequence, and use case diagrams), and some behavior diagram types (namely interaction diagrams) can be used to model interactions within the system.

While UML is a de-facto standard for system modeling, the diagram types are very specific to the software industry, and are not particularly suitable for modeling human-human interactions. Furthermore, the language is composed of many constructs, and its notations are complex, which can greatly hinder its adoption by artists, who do not always have previous experience with modeling languages.

SysML A dialect of UML, Systems Modeling Language (SysML) (Huang et al. 2007; Specification 2006) was designed to support the modeling of complex systems. It extends a subset of UML with two diagram types: requirement and parametric. In

addition to being able to model software components of a system, it can also be used to model its facilities, personnel, and other physical resources.

With its smaller set of constructs and diagram types, SysML is considered easier to learn than UML. Furthermore, its ability to model spatial resources as well as human actors, and the existence of tools allowing the simulation of SysML models (such as *Enterprise Architect*¹ from Sparx Systems, and *Papyrus*² developed by the French Alternative Energies and Atomic Energy Commission) makes it a more suitable solution for our needs than UML.

Petri net Both a mathematical and graphical modeling language, the concept of Petri nets was originally described by the mathematician Carl Adam Petri in his PhD dissertation (Petri 1962). In essence, a Petri net is comprised of two kinds of nodes, and arcs connecting nodes with each other. The simple, yet powerful notation of Petri nets and their precise formal definition have facilitated their adoption in a large variety of domains, from software engineering (Bastide 2000) to ergonomics (Sperandio and Wolff 2003), workflow management (Van Der Aalst and Ter Hofstede 2000), and biology (Mura and Csikász-Nagy 2008).

The underlying mathematical models of Petri nets and the various analytical techniques applicable for them allow them to be used to analyze, verify and simulate systems with “concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic” processes (Murata 1989). Petri nets can thus be used to model a large diversity of complex systems and their components with a minimal set of graphical elements. Additionally, besides being well-fitted for modeling hardware and software components, Petri nets can be used to model human-machine and (Ortega et al. 2013) human-human interactions (Khaddaj and Makoond 2010).

As with UML, there exists many extensions or variants of Petri nets, denoted as high-level Petri nets, such as Colored Petri Nets (Jensen and Kristensen 2009), Queueing Petri Nets (Kounev and Buchmann 2008), and Hypernets (Mascheroni 2010).

¹<http://www.sparxsystems.com/products/ea/>

²<http://www.eclipse.org/papyrus/>

COMM, CIAN, ... A multitude of graphical notations that address groupware issues have been proposed, but were deemed to be too specific and inappropriate for our intentions. Those include *Collaborative and MultiModal* (COMM) (Jourde et al. 2010), *Collaborative Interactive Application Notation* (CIAN) (Molina et al. 2013), and *Mobile Collaboration Modeling* (MCM) (Herskovic et al. 2009).

Based on my review, Petri net seems to be the best candidate for our purposes.

In the following section, I will recall the basic concepts of elementary, or traditional, Petri nets. For a more complete description and formal definition, one can refer to Reisig (1985, 2013); Kordic (2008); Murata (1989).

5.2.2 Informal introduction to elementary Petri Nets

A Petri net, also referred to as Place/Transition net, is a weighted directed bipartite graph. It is constituted of two distinct node types: (1) places, symbolized by circles or ellipses, (2) transitions, depicted by squares or rectangles. Places usually represent passive components, such as conditions, of the modeled system, and transitions represent active components, such as events.

Moreover, the nodes of a net are interconnected by directed arcs, drawn as arrows, which show the flow direction. An arc can only go from a place to a transition, or vice versa; it cannot connect a place with another place or a transition with another transition. Arcs also have a non-zero numerical weight attached to them, defaulting to the value 1.

In addition, tokens are used to indicate the current state, called marking, of the system. A net's marking M_i is usually denoted by a multiset of its places, e.g. $M_0 = \{P_1, P_1, P_2\}$, and the notation $M(P)$ is used to denote the number of tokens in place P in marking M .

Only one transition can fire at a given time. For a transition to be enabled, and thus ready to fire, the number of tokens in each of its input places (the ones connected to the transition by an outgoing arc) must be at least equal to the arc's weight. When a firing occurs, tokens are consumed from input places and produced in output places according to arc weights, altering the net's marking. In elementary,

Petri nets, tokens are traditionally symbolized by black dots.

Fig. 5.6 illustrates a transition firing of a simple Petri net. The initial marking $M_0 = \{P_1, P_1, P_1, P_2\}$, as depicted in Fig. 5.6a, indicates that place P_1 contains 3 tokens, and place P_2 contains 1 token. Transition T_1 is thus enabled, i.e., it can fire, as all its input places, namely P_1 and P_2 , contain at least as many tokens as indicated on their outgoing arcs.

After the firing of transition T_1 , two tokens are consumed from place P_1 , and one from place P_2 (according to arc weights), and only one token is added to the output place P_3 . Such a sub-structure is usually used to model the synchronization of two or more processes.

Fig. 5.6b illustrates the net's marking after the firing of transition T_1 . With no more tokens in place P_2 , transition T_1 is no longer enabled, and can therefore no longer fire. However, transitions T_2 and T_3 are now enabled as P_3 , their only input place, is now marked with a token. If transition T_2 is fired, three tokens will be produced in place P_4 according to its incoming arc's weight, and transition T_3 will no longer be enabled. If, however, transition T_3 is fired, then only one token will be generated in place P_5 , and transition T_2 will no longer be enabled. Such a sub-structure can be used to model decision making.

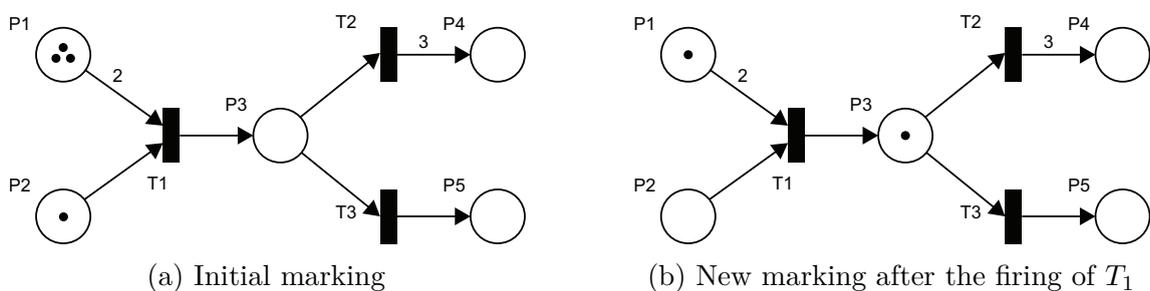


Figure 5.6 – Example of an elementary Petri net and the firing of a transition

In the next section, I will show how elementary Petri nets can be used to model human-human interactions. I will focus particularly on human face-to-face conversations, as they are the most common type of human-human interactions that occur in the systems we are here interested in.

5.2.3 Modeling human-human interactions

In order to validate my choice for the graphical modeling language which I will use to build upon to model art installations designed for co-located interactions, I opted to first attempt the modeling of human face-to-face conversations. This decision was motivated by the fact that human-human interactions are much less commonly modeled with Petri nets than computer systems or human-computer interactions. My aim here is to be able to simulate the amount of time a person spends in a conversation with peers; time which is consequently not spent in direct interaction with the art installation.

Some related studies have already managed to model human conversations using Petri nets, particularly that of [Khaddaj and Makoond \(2010\)](#). Their study was motivated towards a better understanding of conversational dynamics in order to apply some of the concepts in communication models to distributed systems. It was hence mostly focused on the protocols and policies that govern human conversations. I am, on the other hand, mostly interested in a model of human conversations which can simulate the time spent in a conversation, thus taking into account the starting and ending of a conversation, as well as the joining and leaving of participants in or out of an ongoing conversation. I am not interested, for example, in the changes that might occur in a participant's conversational role within a conversation.

To ease the design and analysis of the desired nets, I chose to use *PIPE2*, a free and open source “Platform Independent Petri net Editor” ([Dingle et al. 2009](#)). While several other tools (e.g. *ORIS Tool*¹, *PNEditor*², *Snoopy*³, and *Wolfgang*⁴) were examined, *PIPE* was identified as having one of the most simple and user friendly interfaces, whilst producing nets with sufficient readability. For a list of Petri net tools and editors, a database, maintained by researchers of the University of Hamburg in Germany, is made accessible through a web interface⁵ on the *Petri Nets World* website⁶. Although the latest version of *PIPE* at the time of this writing is number

¹<http://www.oris-tool.org/>

²<https://github.com/matmas/pneditor>

³<http://www-dssz.informatik.tu-cottbus.de/DSSZ/Software/Snoopy>

⁴<http://doku.telematik.uni-freiburg.de/wolfgang>

⁵<https://www.informatik.uni-hamburg.de/TGI/PetriNets/tools/db.html>

⁶<https://www.informatik.uni-hamburg.de/TGI/PetriNets/index.php>

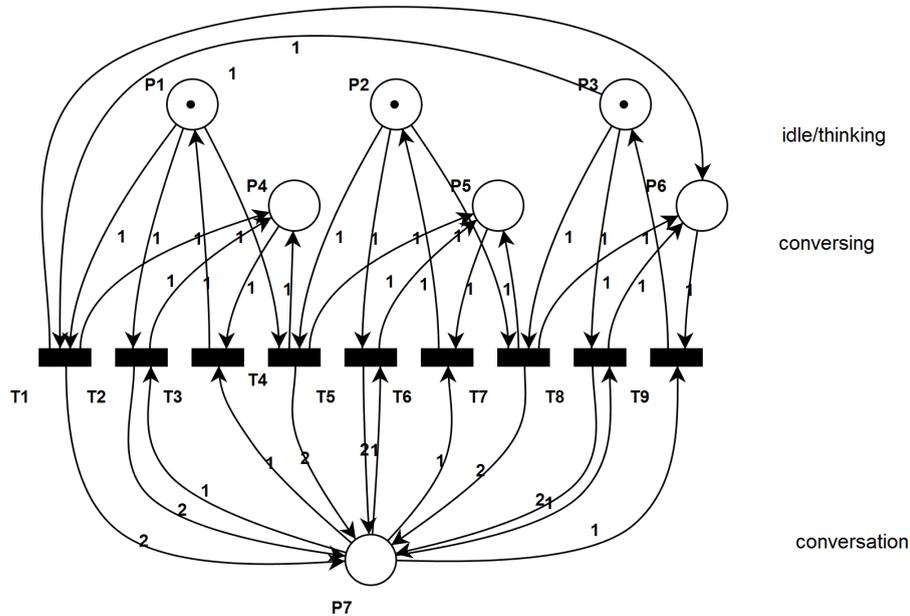


Figure 5.7 – A first try at modeling two and three-way human-human conversations

5¹, it is still in beta and seems to be affected by several bugs. I have thus opted for the use of the previous version: 4.2.1².

Also, to keep the size and complexity of the graphs manageable in my initial attempts at modeling conversations with elementary Petri nets, I chose to limit the number of individuals who could engage in a conversation to a maximum of three. This number is sufficient to be able to model the starting and ending of a conversation by two individuals, as well as the joining and leaving of an ongoing conversation by a third individual. Essentially, the model needed to satisfy the following conditions:

- allow two individuals to start a conversation
- allow a third individual to join an ongoing conversation
- allow any individual to leave a conversation

Fig. 5.7 depicts a first attempt at modeling a three-way conversation. Each of the top three places (P_1 , P_2 , and P_3) represent the idle or thinking state of an individual, whereas places P_4 , P_5 and P_6 represent a conversing state. Place P_7 is a counter, indicating the number of individuals engaged in the conversation.

¹<http://sarahtattersall.github.io/PIPE/>

²<http://pipe2.sourceforge.net/>

The initial marking, $M_0 = \{P_1, P_2, P_3\}$, indicates that all three individuals are in an idle state. Transitions T_1 , T_4 and T_7 are enabled. If T_1 fires, the tokens in P_1 and P_3 are consumed, a token is produced in P_4 as well as P_6 , and two tokens are produced in P_7 . The marking thus becomes $\{P_2, P_4, P_6, P_7, P_7\}$, indicating that a conversation has been started by the first and third individuals, while the second individual remains in an idle state.

The second individual can join the conversation with the firing of T_5 . Then any of the three individuals can leave the conversation through the firing of T_3 , T_6 , or T_9 .

In the initial marking, the starting of the conversation could have been initiated by the first and second individuals (by the firing of T_5) or the second and third individuals (by the firing of T_7). Then the remaining individual could join the conversation through the firing of T_8 or T_2 respectively.

This net satisfies the above given conditions. However, it also allows an individual to withdraw from a two-way conversation, leaving his peer in a soliloquy. As this is unusual behavior in real-life conversations, we might want to add a condition preventing a single individual to leave a two-way conversation. For one to leave such a conversation, all engaged parties must leave together, consequently ending the conversation. We could also extend this to three-way conversations, thus enabling the ending of any conversation, by allowing all participants to leave it simultaneously. We could thus add the two following conditions to the initial ones:

- allow all participants engaged in a conversation to leave it simultaneously
- do not allow only one participant to leave a two-way conversation

Fig. 5.8 is a revised version of the two and three-way conversation model which also handles the supplementary conditions. In this variant, the counter place is no longer required. Places P_4 , P_5 , and P_6 are now used for two-way conversations; two tokens are output in one of them when a new conversation is started by two participants. When a third participant joins in, the two tokens are consumed and three are output in place P_7 . The transitions T_1 , T_2 , and T_3 allow the starting of a two-way conversation, whereas transitions T_4 , T_5 , or T_6 ends it. Transitions T_7 , T_8 , and T_9 allow a third participant to join an ongoing conversation, and T_{10} , T_{11} , and T_{12} allow one of the participants to leave a three-way conversation. Finally,

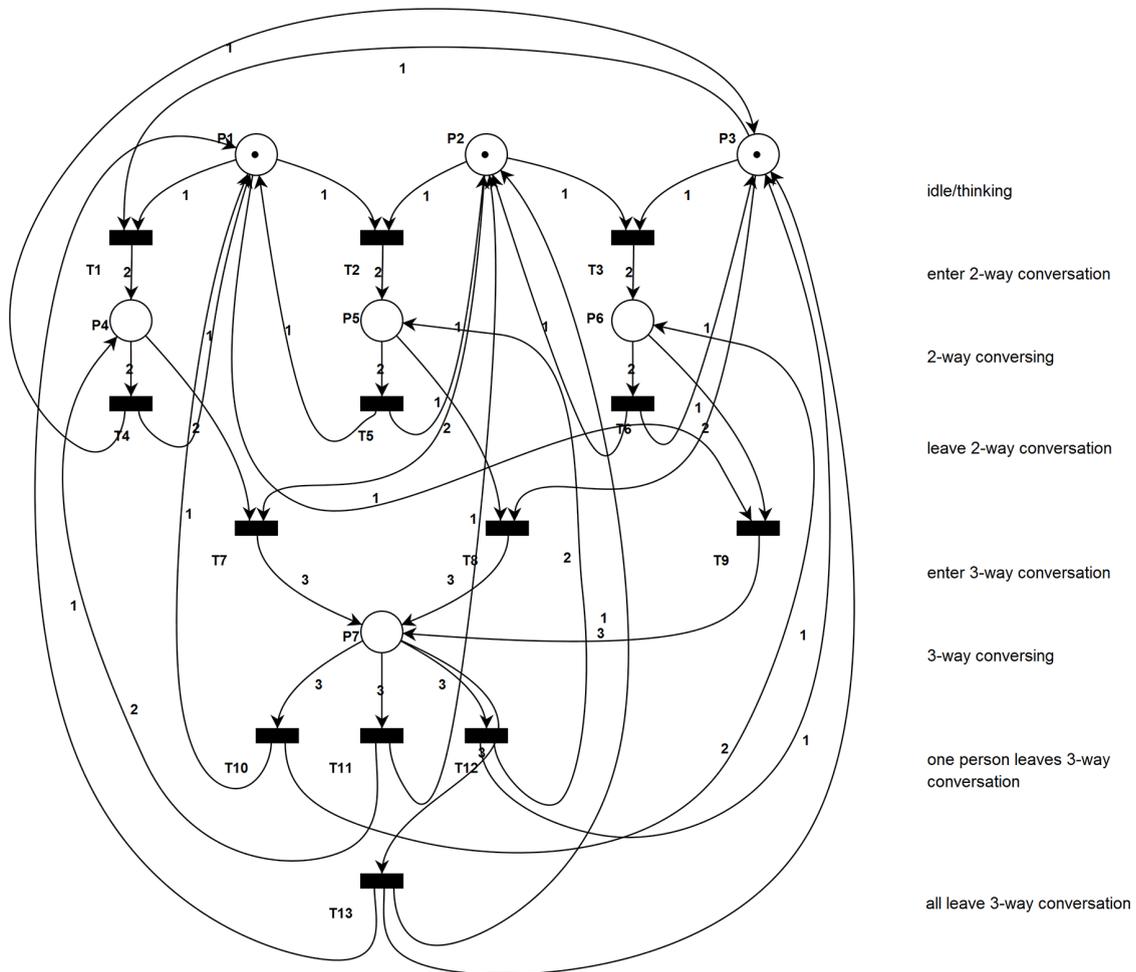


Figure 5.8 – A revised model for two and three-way human-human conversation

transition T_{13} allows the ending of a three-way conversation with the leaving of all participants.

By means of this graph, we can validate, at least for our purposes, the feasibility of using Petri nets to model two and three-way human conversations. It can also be assumed that modeling conversations with a larger number of participants would be possible, but would potentially create nets that are exponentially larger, thus greatly hindering their readability.

Before tackling such readability issues, I took up the modeling of some of our installations (focusing particularly on *Collective Loops*) using elementary Petri nets. For this task, I took advantage of one of the features of Petri nets: the possibility to

refine a model. Starting from a high level of abstraction by breaking down a system to abstract components, we can then progressively add details to each component until the desired level of abstraction is reached.

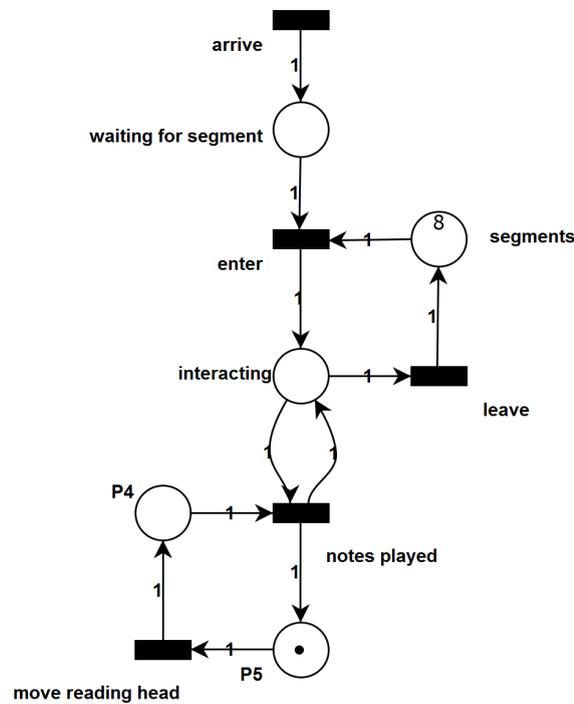


Figure 5.9 – A basic model of *Collective Loops*

Fig. 5.9 illustrates an elementary model of *Collective Loops*. Place *segments* serves as a counter for available segments. Upon the arrival of a participant (handled by the transition *arrive*, which is always enabled as it does not have any input places), the participant, represented by a token, has to wait for a segment to be available. If a segment is available, the transition *enter* can fire, reducing by one the number of available segments as well as the number of individuals waiting for a segment, and then outputs a token in the *interacting* place. An interacting participant can leave the installation with the firing of transition *leave*, restituting a segment into the *segments* place.

The reading head's movement is humbly depicted by a loop at the bottom of the model. When the token representing the reading head's position is in place P_4 , the notes of one of the interacting participants can be played by the firing of transition *notes played*.

We can refine this rudimentary model by adding details to most of its components. As the net can rapidly grow in size and complexity, I elected, once more, to limit the number of participants handled by the model to a maximum of three by limiting the number of available segments.

Fig. 5.10 is a possible refinement of the previous model in which each component has been expanded. The *interacting* place of the original net has been split into three sub-nets, one per participant. We can also notice that the general interaction activity has been developed to several human-machine and human-human interactive activities, represented by the places *observe others*, *choose notes*, and *observe floor projection*. The reading head loop has also been developed. It's position is now clearly identifiable. It can advance regardless of whether the corresponding segment is in use or not. If the corresponding segment is being used by a participant, the updating of the reading head's position triggers the playing of notes of the corresponding segment, otherwise only the updating of the reading head's position occurs.

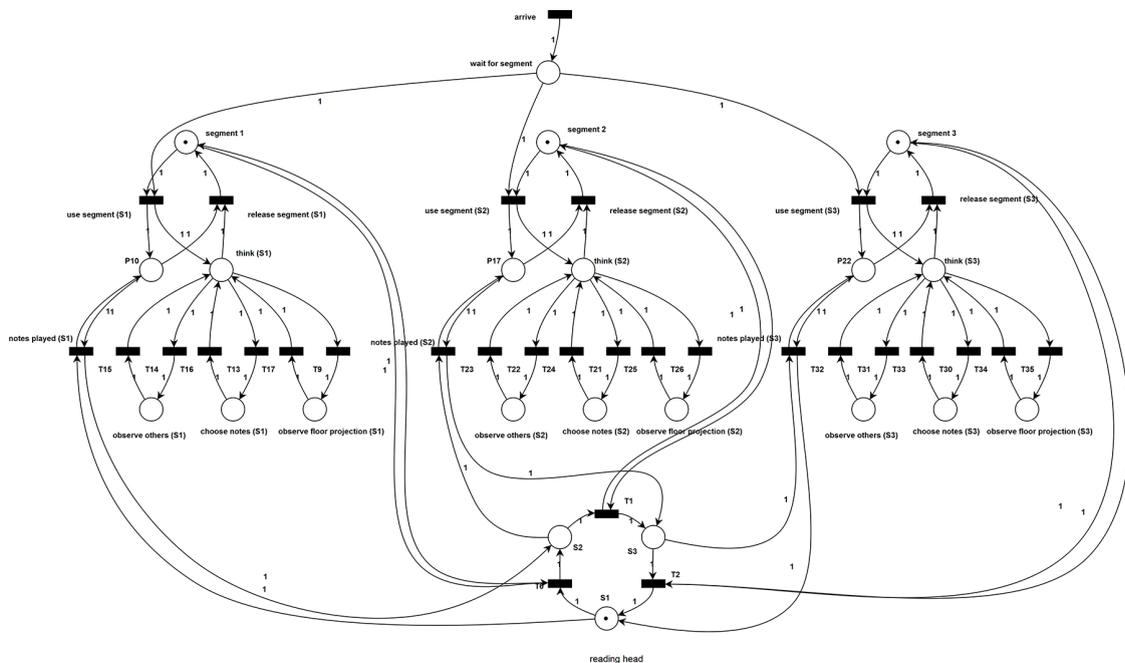


Figure 5.10 – A refinement of the simple model of *Collective Loops*

We can further refine this model to handle passive participants (i.e. those who are not using the mobile application), as well as those waiting for a segment (i.e. having engaged in an interaction with the mobile application, but are waiting for a

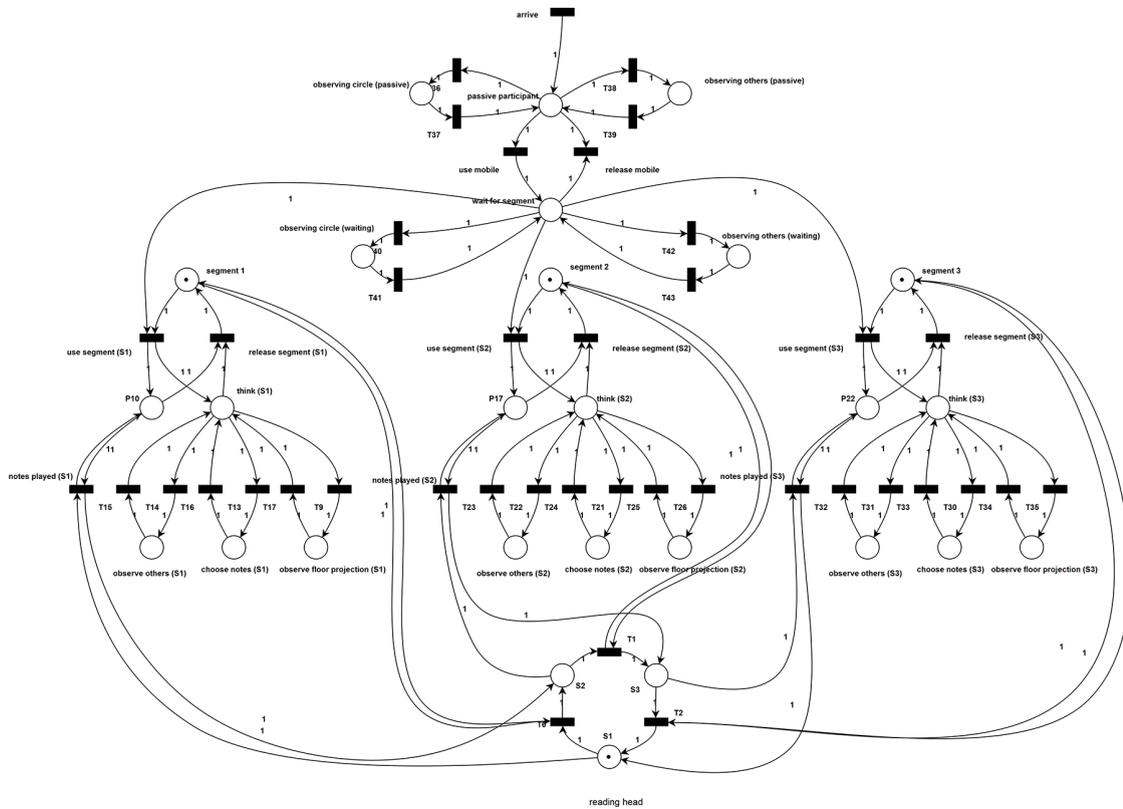


Figure 5.11 – A further refinement of the model of *Collective Loops*

segment to become available). Indeed, while those participants cannot fully engage with the installation, they can nonetheless perform some activities with others, or observe the shared floor projection.

We could certainly combine this latter model with the one in Fig. 5.8 to allow participants to converse with their peers, but, although both models only handle up to three participants, we can already imagine how the resulting model would become too complex. Yet, the models are not complete. Indeed, some activities such as paying attention to the played notes have still not been incorporated into the model.

It is thus clear that, although the modeling of such systems is possible with elementary Petri nets, the models become rapidly too large and complex. Thankfully, there exists several extensions to Petri nets which can help remedy such issues and render the modeling of complex systems more convenient. Most extensions are subsumed under the term *high-level Petri nets*. Some extensions, such as Colored Petri nets (Jensen 1998), are backward-compatible, preserving valuable properties

of elementary Petri nets, while others (e.g. reset arcs, inhibitor arcs (Lakos and Christensen 1994; Verbeek et al. 2010), and Timed Petri nets (Boyer and Roux 2008)) truly extend the expressive power of Petri nets.

In the following section I will demonstrate how some extensions can greatly reduce the size and complexity of my models, rendering them easier to manipulate, and so allowing me to get closer to the goal of establishing a graphical modeling language that can be used by artists, designers and developers in the design and development processes of art installations for co-located interactions.

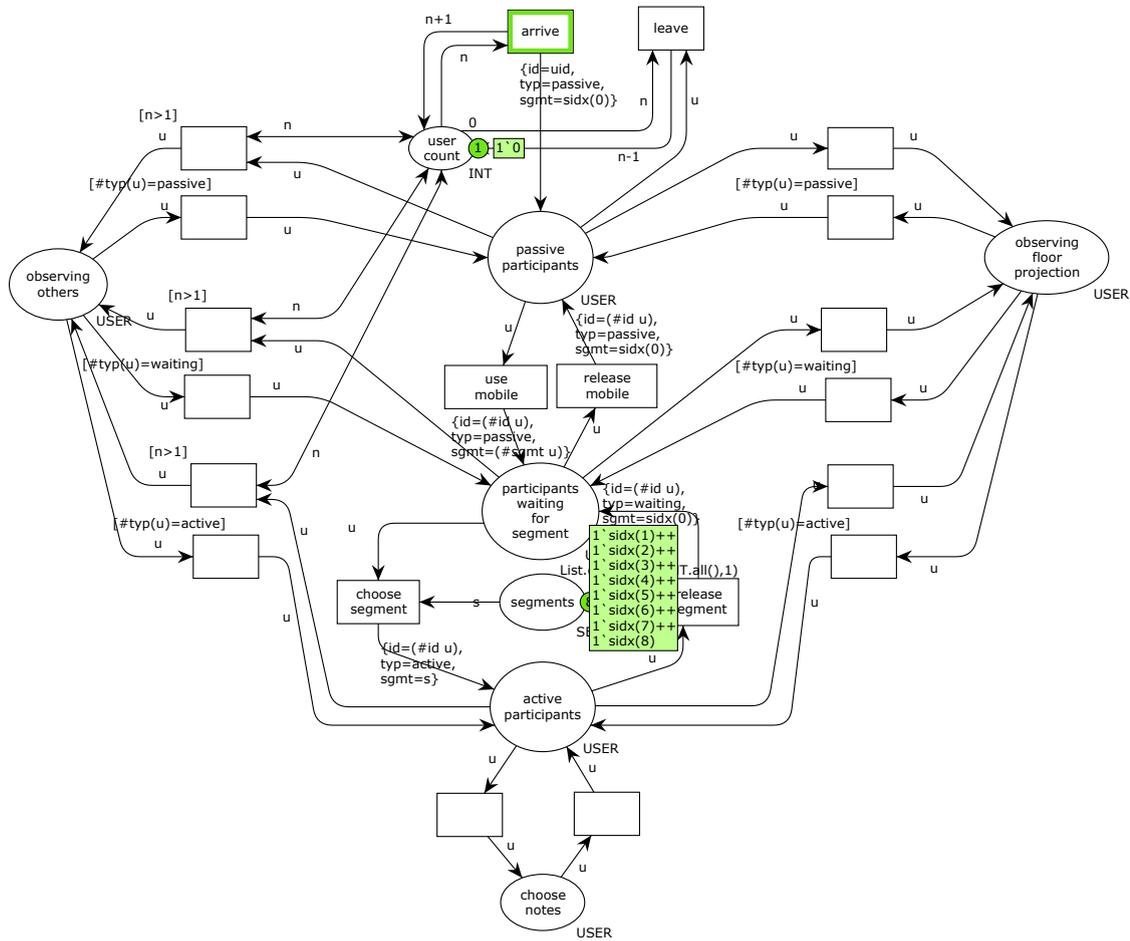
5.2.4 From low-level to high-level nets

While there exists a large number of extensions for Petri nets, I have mostly examined those that appeared to be adapted to my intentions: (1) colors, (2) hierarchy, and (3) time.

Color While all tokens in elementary Petri nets are black and do not have any data attached to them, in Colored Petri nets, CP-nets, or CPNs, tokens can carry data values of different, arbitrarily complex, data types, called color sets. CPNs are, in fact, an association between Petri nets and a programming language. The programming language allows values of tokens to be read and altered through net inscriptions, which are written as expressions on arcs and transitions. An expression used on a transition, called a guard, must be a boolean expression, and acts as a means to further condition the enabling of the transition. An expression attached to an input or output arc can also be used to determine if the transition is enabled, and can even alter a token's value.

The concept of colored tokens was initially presented by Zervos (1977), however, the most well-known colored extension is that of Jensen (1981). For a brief introduction to CPNs, one can refer to Jensen (1997). As for more detailed descriptions and formal definitions, Jensen (1998); Jensen et al. (2007); Jensen and Kristensen (2009) are valuable resources.

CPNs can help us better manage participants. By representing them using tokens of a relatively complex color type that can hold a unique identifier, the current role



```

colset INT = int;
colset UID = index uidx with 0..99;
colset USER_TYPE = with passive | waiting | active;
colset USER = record id:UID * typ:USER_TYPE * sgmt:SEGMENT;
colset SEGMENT = index sidx with 0..8;
var n : INT;
var uid : UID;
var u : USER;
var s : SEGMENT;

```

Figure 5.12 – A first attempt at modeling *Collective Loops* as a CPN

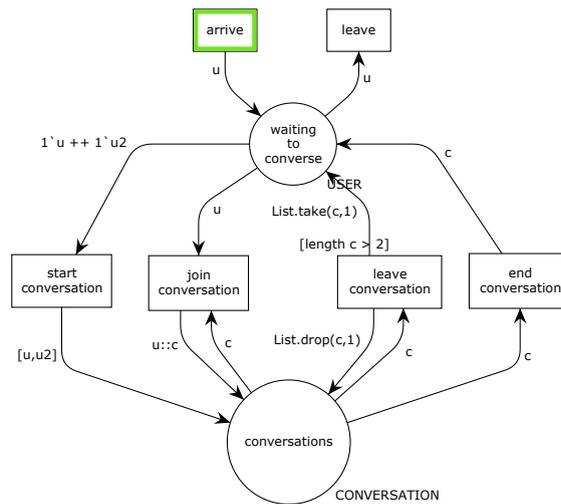
(passive, active, etc) as well as any held resources (such as the segments in *Collective Loops*), we can merge activity places in Fig. 5.11 into a single place per activity.

Due to the limited support of *PIPE* for colored tokens, I have moved to *CPN Tools*¹, a well-known software tool for the design, simulation and analysis of CPNs (Jensen and Kristensen 2009). *CPN Tools* is a major revamp of the widely used tool

¹<http://cpntools.org/>

*Design/CPN*¹ (Beaudouin-Lafon et al. 2001), and uses the *CPN ML* programming language to declare color sets and specify net inscriptions (see Jensen and Kristensen 2009, chap. 3). The language is an extension of the functional programming language *Standard ML* (Milner 1997).

Using *CPN Tools*, we can construct the net in Fig. 5.12. The color sets and all variables we declared in *CPN Tools* and used in the net are presented within the figure, below the net.



```
colset UID = index uidx with 0..99;
colset USER = record id:UID;
colset CONVERSATION = list USER;
var u, u2 : USER;
var c : CONVERSATION;
```

Figure 5.13 – The conversation model revisited as a CPN

This CPN handles up to 8 active participants, one per segment. It also handles an unlimited number of passive participants as well as ones waiting for a segment to become available. All participants can engage in the activities *observing others* and *observing floor projection*, but only active ones can engage in the activity *choosing notes*. Note that the incoming transitions of place *observing others* are only enabled if at least two participants are present; the place *user count* keeps track of the current total number of participants for this very purpose.

We can also revisit the conversation model to allow an unlimited number of participants to engage in one or more conversations, such as in Fig. 5.13.

¹<http://www.daimi.au.dk/designCPN/>

Although both nets do not seem to be more compact than the originals, let's not forget that the original ones only supported up to three participants, and would have become much larger if they were to support as many participants as the new CPNs.

Hierarchy As depicted in Fig. 5.14, we can further refine the *Collective Loops* model by merging the three places *passive participants*, *participants waiting for segment*, and *active participants* into a single place which would hold all *idle* or *thinking* participants, who are not currently engaged in a particular activity. This allows us to minimize the number of transitions between this place and the different activities. Indeed, in the previous net, a transition to start an activity and one to end it were required per user type, while now only one of each transition is needed for all user types.

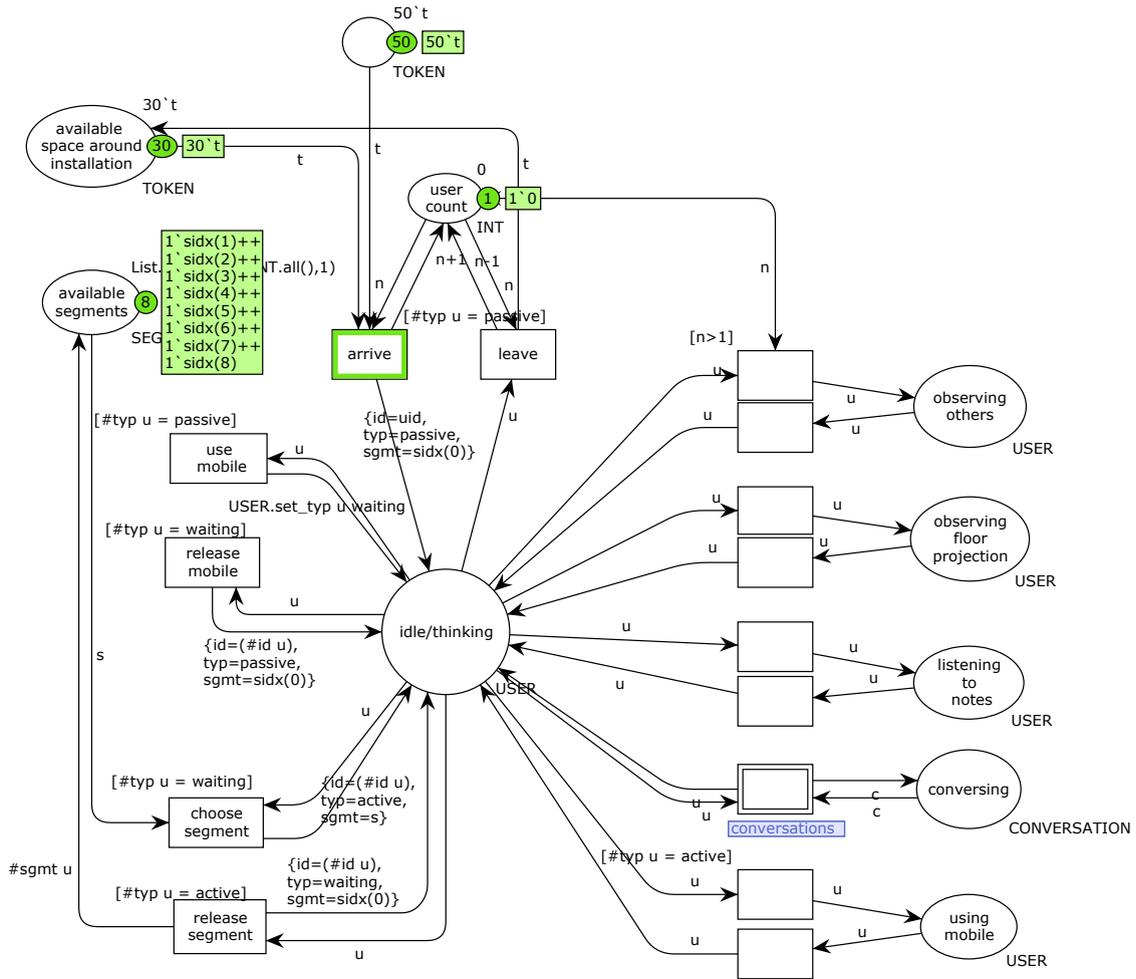
I have also incorporated various activities which were not yet handled in the previous models including *conversing*.

However, to prevent the addition of the conversation net from making the model too large and hide its readability, I took advantage of another high-level extension supported by *CPN tools*: hierarchy.

Hierarchy enables the construction of nets with a modular approach by allowing a set of nets to be used, and reused, as subnets (referred to as *subpages*), of another net (referred to as a *superpage*). Different hierarchical concepts exist for CPNs, including *substitution transitions* and *fusion sets for places* (see Jensen and Rozenberg 1991, chap. 7 for details and more concepts), which are supported by *CPN tools* (see Jensen and Kristensen 2009, chap. 5).

The subnet for conversations illustrated in Fig. 5.15 was embedded into the *Collective Loops* net of Fig. 5.14 in the form of the substitution transition *conversations*.

Time If we are to be able to analyze and measure the performance of an installation, it is crucial to define the metrics, or criteria, used in the evaluation (Jain 1991). While the metrics can change from an installation to another according to the artist's intentions, time (e.g. the time passed in the different activities by participants, or the time required for the system to process data and give feedback) can be used in



```

colset INT = int;
colset TOKEN = unit with t;
colset UID = index uidx with 0..99;
colset USER_TYPE = with passive | waiting | active;
colset USER = record id:UID * typ:USER_TYPE * sgmt:SEGMENT;
colset CONVERSATION = list USER with 2..10;
colset CONVERSATION_LENGTH = int with 2..10;
colset SEGMENT = index sidx with 0..8;
var n : INT;
var uid : UID;
var u, u2 : USER;
var c : CONVERSATION;
var cidx : CONVERSATION_LENGTH;
var s, s2 : SEGMENT;

```

Figure 5.14 – Further refinement of the *Collective Loops* model

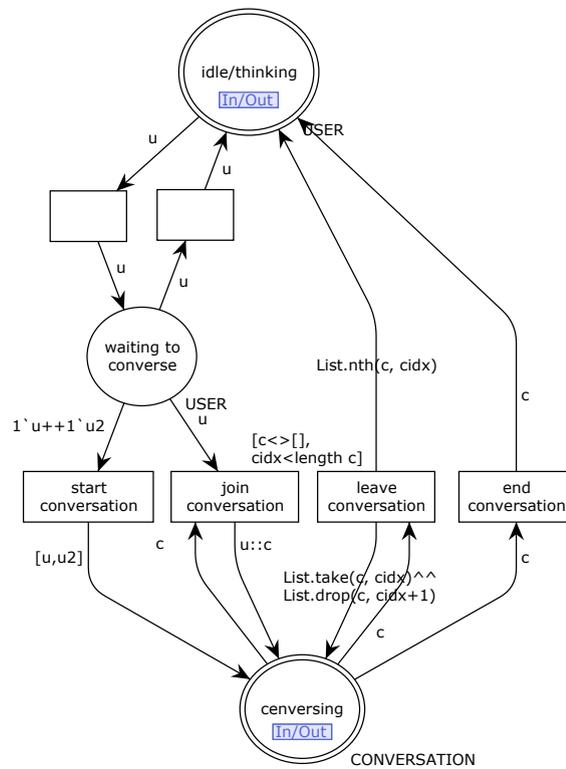


Figure 5.15 – The conversations subnet, or subpage, of the *Collective Loops* model in Fig. 5.14

most cases to assess performance. In *Overexposure*, for example, we could use the time spent waiting for one’s message to be broadcast as a metric for performance. In *Discontrol Party*, we could consider the time it took for participants to create enough disorder, preventing their accurate tracking by the surveillance system as a metric.

I, in fact, argue that the quality of the collective aesthetic experience could be evaluated by regarding the fluidity of the token game and average time spent in each activity. For instance, if a work is designed with a strong emphasis on collaboration, time spent in collective activities, such as conversations, could be used as an evaluation metric or criteria.

In the models above, however, there is no notion of time and no assumptions are made on the duration of an activity. Thus, if we are to use time as a unit of a performance metric, we need to be able to add the notion of time in our models.

There exists different concepts of time in high-level Petri nets such as *Time Petri*

Nets and *Timed Petri Nets*. Due to the extensive literature on the matter (Bérard et al. 2005; Louchka 2013), I will not go into details on how to use such extensions. It can, however, be noted that *CPN Tools* supports one of the concepts of time (see Jensen and Kristensen 2009, chap. 10).

It is also noteworthy that if a model is to be created for performance analysis and time is used as a criteria, then time can serve as a guide when establishing the appropriate level of abstraction for a model. In most cases, it is, for example, not necessary to go into details as to how a participant performs a certain action, as long as the time spent performing it is known at the current level of abstraction.

5.2.5 Modeling the effects of feedback

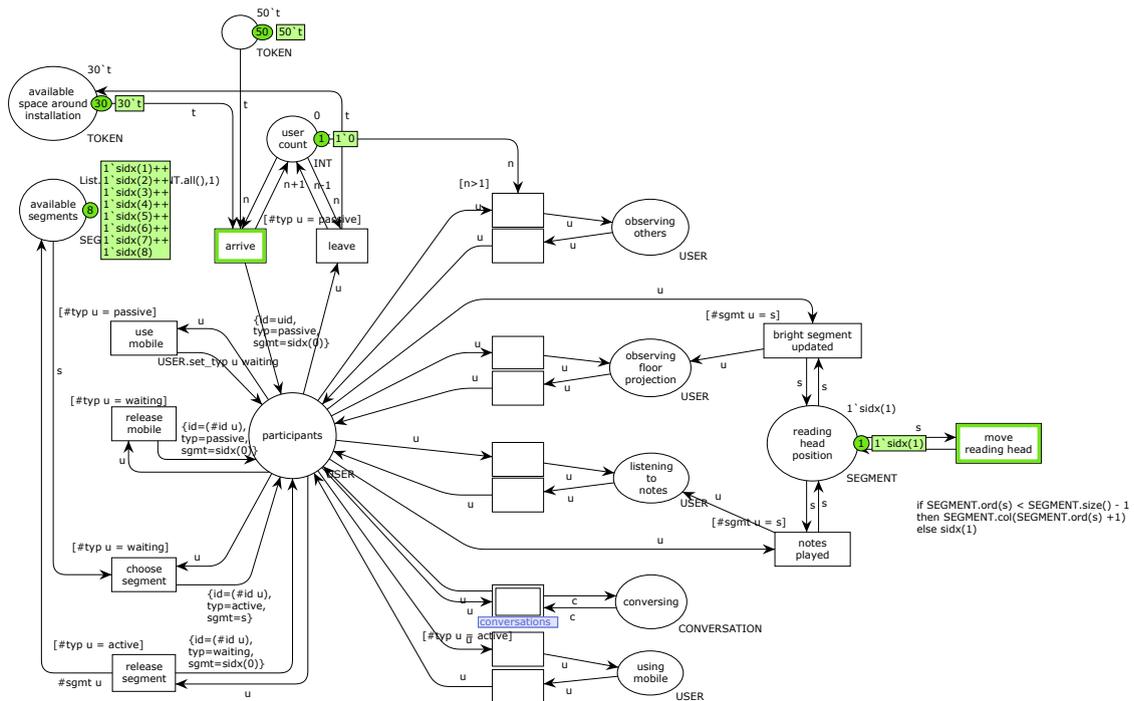


Figure 5.16 – Adding feedback to the *Collective Loops* model

As discussed in earlier chapters, feedback is a highly important aspect of the type of art installations we are interested in. Participants’ behavior is indeed affected by the system’s various feedbacks, which can help foster the emergence of a common aesthetic experience. It is hence crucial to be able to include the notion of feedback and its effects in our models.

In *Collective Loops*, the reading head's movement triggers several feedbacks including the sounds emitted from the phones and the movement of the reading head indicator on the floor projection. When sound is emitted from one's smartphone, the participant might be more inclined to engage in the *listening to notes* activity, on the other hand, the movement of the bright reading head indicator might stimulate the engagement in the *observing floor projection* activity.

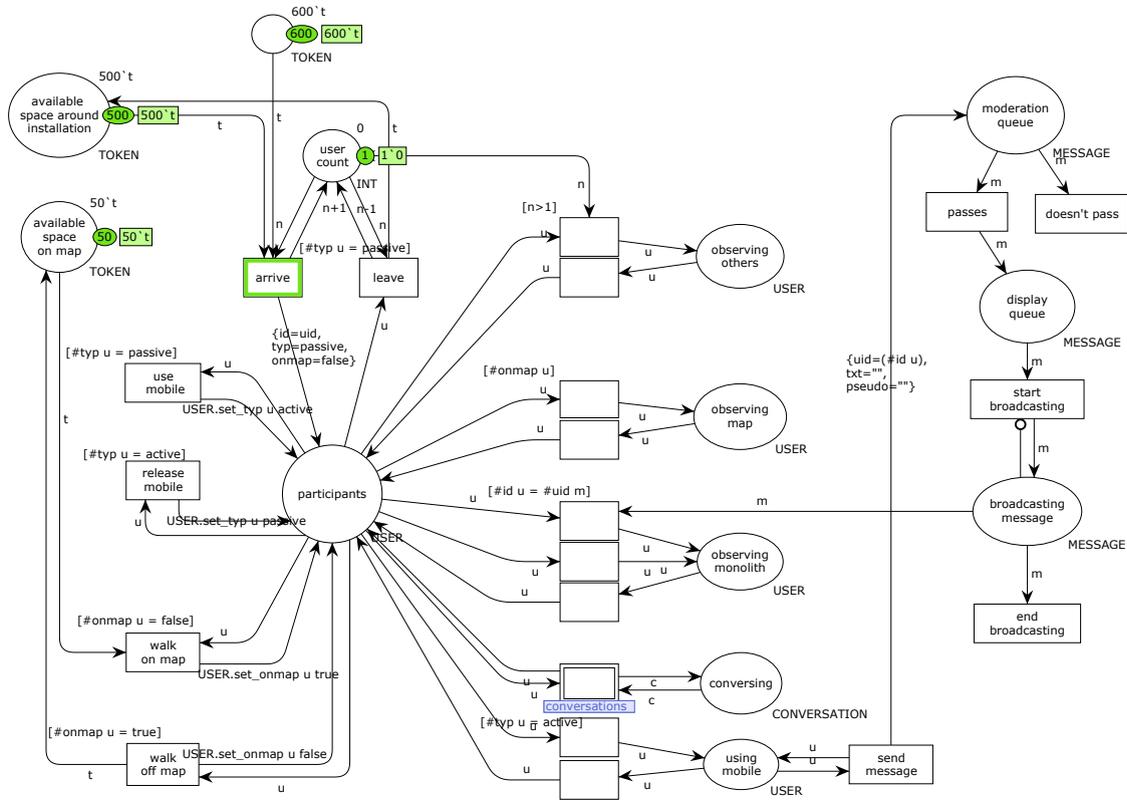
Building on the previous model and its declarations, we can add the reading head's movement as well as its effects on participants' behavior as in Fig. 5.16. Although concepts such as *firing weight*, which "specify the probability of firing a transition relative to the weights of all other conflicting transitions" (see Zimmermann 2008, chap. 5) are not supported by *CPN Tools*, we could very well imagine using them to assign a different firing probability for each transition in order to fine-tune the model.

A similar model could be constructed for *Overexposure* as depicted in Fig. 5.17. Here, the broadcasting of one's message entices the participant to observe the monolith. Note that a different arc type, dubbed *inhibitor arc*, connects the *broadcasting message* place and the *start broadcasting* transition. The arc is used to insure that only one message is broadcast at a time. Indeed, with an inhibitor arc, it is the absence, not the presence, of tokens in the corresponding input place that enables the transition (Billington 1988; Christensen and Hansen 1993; Lakos and Christensen 1994).

5.2.6 Towards a domain-specific language

I have shown in the previous sections how CPNs can be used to model co-located human-human, human-machine, as well as human-machine-human interactions around art installations. The models also integrated notions of spatial and material resources and their management. Therefore, although the presented models are not complete, they demonstrate the ability to achieve most of my modeling goals.

However, while CPNs and the *CPN Tools* software strongly facilitate the creation, simulation and analysis of the models, they can still be difficult to interpret, let alone manipulate, especially for artists or designers who might not have any prior experience with the tools or the underlying programming language.



```

colset INT = int;
colset BOOL = bool;
colset STR = string;
colset TOKEN = unit with t;
colset UID = index uidx with 0..99;
colset USER_TYPE = with passive | active;
colset USER = record id:UID * typ:USER_TYPE * onmap:BOOL;
colset CONVERSATION = list USER with 2..10;
colset CONVERSATION_LENGTH = int with 2..10;
colset MESSAGE = record uid:UID * txt:STR * pseudo:STR;
var n : INT;
var uid : UID;
var u, u2 : USER;
var c : CONVERSATION;
var cidx : CONVERSATION_LENGTH;
var m : MESSAGE;

```

Figure 5.17 – A CPN model for *Overexposure*

Furthermore, in *CPN Tools*, unlike in elementary Petri nets, a model's tokens are represented in a textual notation as seen in Fig. 5.18, greatly impeding the model's readability as well as the tracking of tokens.

To render the modeling more accessible, one could build on top of the tools used so far to create a domain-specific graphical modeling language. That is, in fact, the

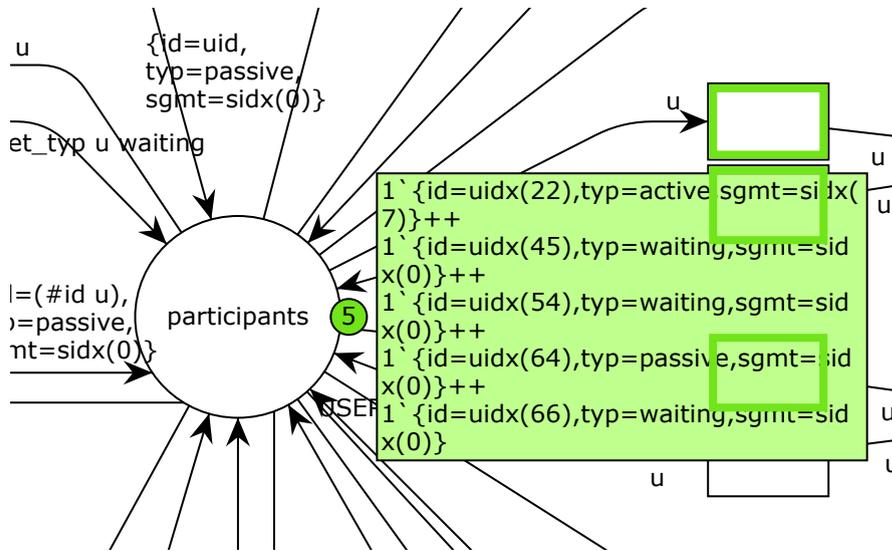


Figure 5.18 – Representation of tokens in *CPN Tools*

approach I have chosen with what I have named *CoPN*, and will refer to herein as such.

The difficulty here resides in allowing users with little to no modeling experience to create models of their works and analyze them, while preserving as much of Colored Petri net’s graphical and mathematical modeling power as possible.

As an initial step towards that objective, we could use graphical notations for tokens with different shapes and colors, easing their identification and tracking. The use of graphics within commonly used elements could also ease the differentiation between the various activity types (observing, listening, acting on a device, etc).

In addition, by taking advantage of hierarchical concepts, we could provide a set of predefined elements with a high level of abstraction, allowing artists to create a first draft of the model with ease, and then progressively add details with the collaboration of developers.

While the substitution place concept has been neglected by several Petri net tools including *CPN tools* in favor of *substitution transition* — possibly due to some unsuitable semantics in the original proposal identified by Lakos (1993), who also propose an enhancement — the former concept is more adapted to our needs for two main reasons: (1) we are more concerned about analyzing the states of participants

rather than the actions they perform to move from one state to the other and (2) substitution places are more flexible as they allow each of their input and output transitions — those used as an interface to their superpage — to be used multiple times.

Thus, we could, for example, use general constructs for the different queuing mechanisms using a substitution place as depicted in Fig. 5.19c, which uses the graphical notation proposed for *Queuing Petri Nets* (QPNs) (Bause 1993), in which the place is divided into two parts: a queue and a depository. The highly generic definition of queues in QPNs allows them to be used for arbitrarily complex queuing and scheduling strategies.

Using such a generic queuing place and some of the other graphical notations depicted in Fig. 5.19, the model for *Overexposure* might resemble Fig. 5.20.

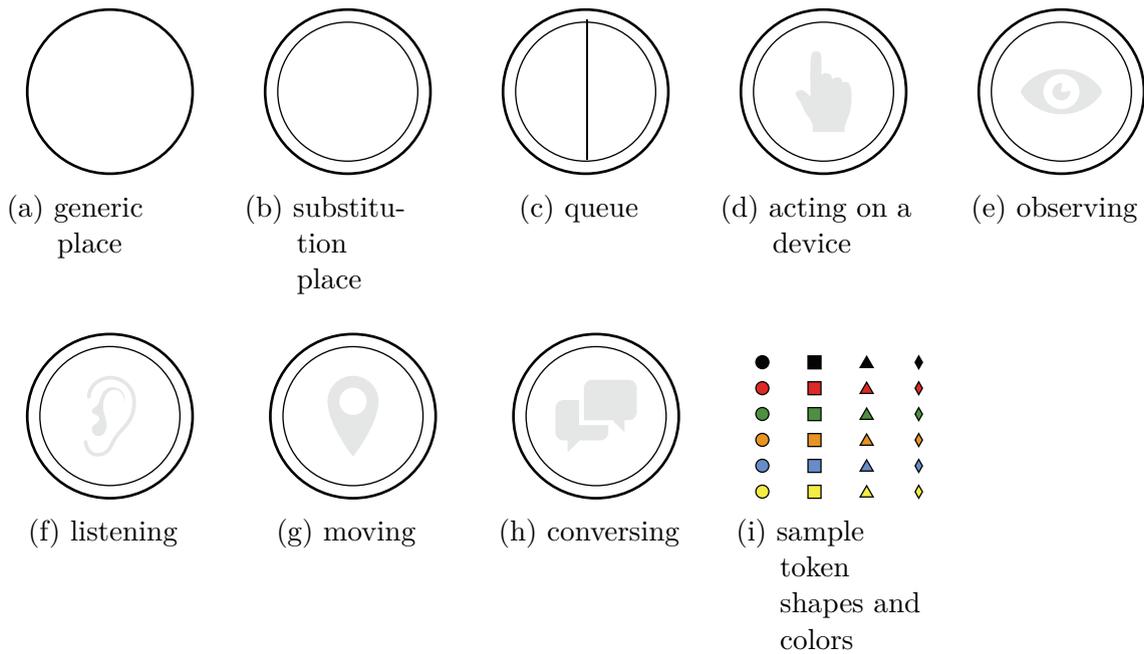


Figure 5.19 – A set of graphical elements for *CoPN*

5.2.7 Review

While this second approach to a graphical modeling language for co-located interaction has mostly been exploratory, it has a much greater potential than the first

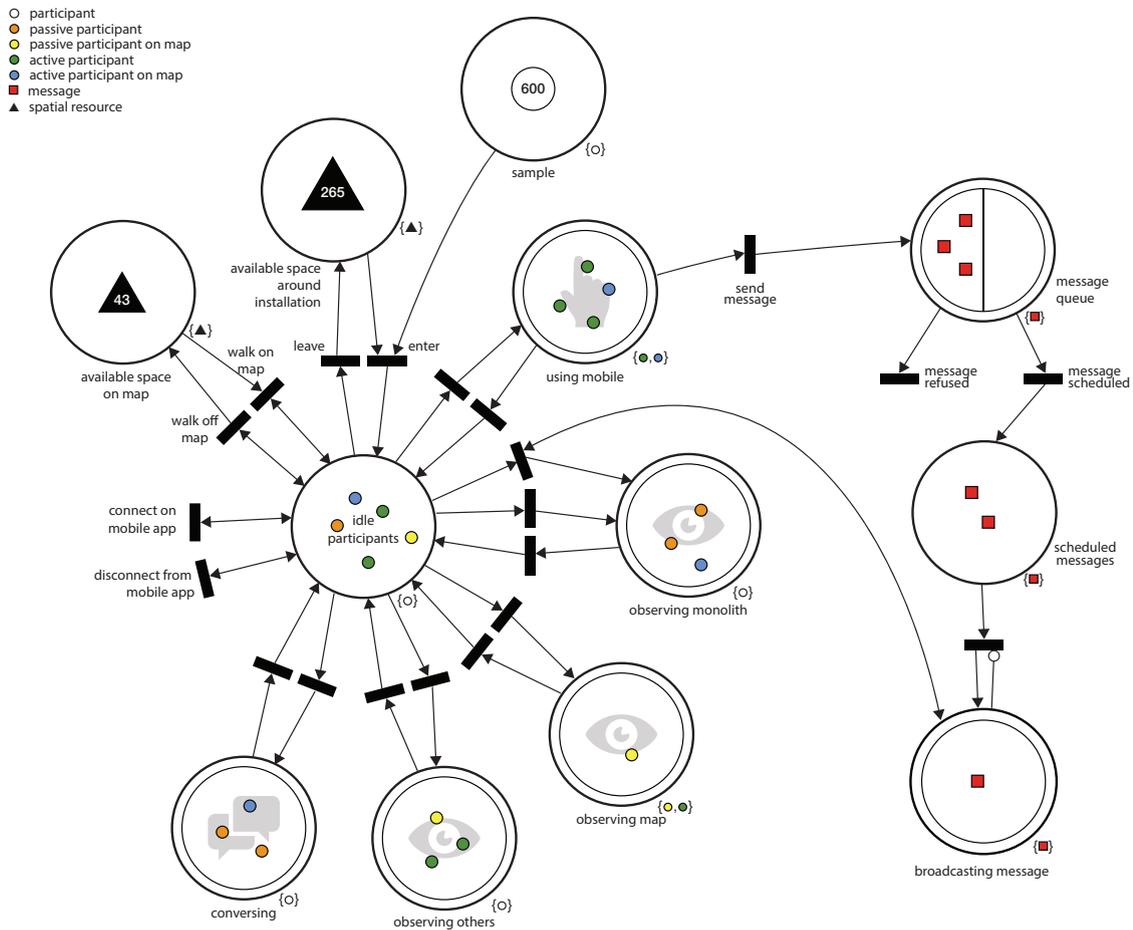


Figure 5.20 – A CoPN model for *Overexposure*

one. The ability to model most aspects of an apparatus, whether they are spatial, material or human, at varying levels of abstraction makes this approach extremely flexible. And, being based on Petri nets, it can be used not only for the description and comparison of installations, but also for their simulation and analysis. However, much work remains if we are to create a functional tool and making it truly accessible for artists.

With inspiration from constructs available in *Workflow-nets* (Van Der Aalst and Van Hee 2004) and the *Mobile Collaboration Modeling* (MCM) language (Herskovic et al. 2009), domain-specific transitions could be introduced to reduce the necessity for writing inscriptions. High-level transitions could, for example, indicate by their graphical notation that a participant’s token needs to be in a specific state or possess a resource for the transition to be enabled, thus drastically reducing the need for

transition guards.

Another enhancement could reside in the choice of the programming language used to define the data structures and write inscriptions. Indeed, while the CPN ML language is not very complex and can be apprehended by most software developers, the use of a more widely exploited programming language in the interactive art domain, such as Processing or JavaScript, might facilitate the adoption of the tool by artists and the developers they collaborate with.

Additionally, if we are to conceive a modeling language capable of providing analysis and simulation tools for co-located interactions, it needs to take into account frameworks that describe social aspects related to such contexts, such as *F-formations* (Kendon 1990), the *Audience Funnel Framework* (Michelis and Müller 2011), or the *Creative Engagement Model* (Candy and Edmonds 2011, p. 168), and integrate models of visual attention (Borji and Itti 2013) and social dynamics (Starnini et al. 2013).

Interviews

Before pursuing further efforts, the validity of this approach needs to be verified. The most adequate verification method in the current stage of research seemed to entail the surveying of practitioners. To do so, a few artists were contacted with requests for interviews, to which Usman Haque, London-based architect, artist and founder of *Umbrellium*¹, as well as Mouna Andraos, artist and co-founder of the design studio *Daily tous les jours*² in Montréal have responded positively.

To give them the possibility to better prepare for the interview, two short documents were made available to them a few weeks in advance, with the main interview questions, information on the general research undergone, a short introduction to Colored Petri Nets, details regarding the modeling approach along with simplified models of one of their installations in both *CPN tools* and *CoPN* graphical notations. However, due to their busy schedules, they were not able to take full account of those documents beforehand.

The first interview question dealt with the type of aesthetic experience that the

¹<http://umbrellium.co.uk/>

²<http://www.dailytouslesjours.com/>

artists generally aim for, followed by four questions aimed at better understanding how a change in interaction modality affects the participatory experience by comparing two closely related installations per artist; one in which the interaction modality is direct, and the other one facilitated. The next four questions revolved around the performance evaluation criteria of their works and the artists' impressions concerning the graphical modeling language. The interview concluded with a question regarding the impact that the discussion might have had on the way they considered their works.

The interviews, conducted respectively by video-conference and phone, were transcribed as accurately as possible with minor modifications induced by the transformation from oral to written language. Excerpts of the transcriptions are available in [appendix A](#) and [appendix B](#).

Both, Usman Haque and Mouna Andraos, have indicated that their main goal when designing their interactive installations resides in the empowerment of the public, and giving them the sense that they can have an impact on the environment around them. If their projects succeed in becoming an excuse for people to go out on the streets, exchange with each other, and work together on something larger than them, at the scale of architecture, then both artists consider that their work would have achieved its goal. They have also pointed out that the collective and collaborative aspects are a very important part of their works. In fact, both try to reward collaborative efforts in a way or another. In Umbrellium's *Assemblance*¹ installation, light sculptures created collectively by several participants last longer than those created by a single individual, and in *21 Balançoires*² by *Daily tous les jours*, more music is generated when participants manage to synchronize their swinging.

When confronted with the modeling language and the sample model of *Mini Burble*, Usman Haque was somewhat skeptical at first due to the formal nature of the modeling language. He was however intrigued by the approach, and the fact that human-human conversation was integrated into the model. He, in fact, felt that “the more conversational the system can be, the better”.

¹<http://umbrellium.co.uk/initiatives/assemblance/>

²<http://www.dailytouslesjours.com/project/21-balancoires/>

He later showed increased enthusiasm for the modeling language and indicated that it could have been useful for some of his projects. However, he pointed out that if such models are needed, he would rather entrust part of the modeling task to a specialized person who is more proficient at system modeling and analysis. He also pointed out that he would then want to use it as a “shared canvas”, to collaboratively create and design a model with other team members.

Already familiar with Petri Nets and somewhat accustomed to viewing such models, he also felt that the icons used in the high-level substitution places are of minor importance, but did recognize their benefits to others who might be less comfortable with such models.

Mouna Andraos seemed less enthusiastic about our modeling approach. Partly because she deems that if a work becomes complex enough to require such modeling, then that would usually be an indicator of a design failure. She indeed indicated that “simplicity is actually key”, and that installations which combine multiple interfaces on shared and individual devices, as in *21 Obstacles*, is not something she would necessarily want to pursue. She, nonetheless, expressed some interest in the modeling approach, while arguing that the learning curve required to model should not be too high in order to be a practical tool for her and teammates.

Furthermore, while both artists do create models, maps or sketches as part of their design process, they both tend to privilege prototyping over modeling and simulating, by building things as early as possible.

While modeling the entire apparatus of an installation including the human-human interactions might be a far-fetched goal, and, overall, the *CoPN* modeling approach appears to have been met with lukewarm enthusiasm — the fact that the interviews were conducted remotely via video-conference and phone, and the language being in an early stage of development might be partly to blame — I argue that the approach could benefit artists, designers, and developers, especially when working on large scale installations that can handle several hundred participants with multiple individual and shared devices, as in *Discontrol Party*, by giving them a comprehensive view of the different phenomena that can occur in their installations, and allowing them to make more informed design choices. However, considerable work still remains to be done before a truly viable and comprehensive graphical modeling

language is forged. Participatory design activities involving artists, designers and developers could greatly help move towards that goal.

5.3 Summary & perspectives

This chapter presented and reviewed two distinct approaches to a graphical modeling language for co-located interactions in art installations. The first proposal addresses the arrangement of the various individual and shared interfaces as well as the data flow between them, whereas the second one addresses the entire apparatus, from material and spatial resources to the wide range of activities performed by participants through their interactions with the system and their peers.

Both approaches exhibit advantages and disadvantages when compared to each other. The high-level of abstraction of the symbols used in the first one makes it very easy to apprehend, but this in turn highly limits its expressive power. Based on a well established mathematical and graphical modeling language, the expressiveness of the second approach is, on the contrary, quite high, but that makes it more complex, requiring more time to seize and adopt.

It thus appears that for *CoPN* to become a suitable tool, higher levels of abstraction might be required. In the same manner as *Mobilizing.js*, which aims to allow users to work in different levels of abstraction depending on their development skills, *CoPN* could take further advantage of the hierarchical concepts of CPN to allow users to start with a model at a level of abstraction almost as high as the first modeling approach.

Notwithstanding the shortcomings of the current state of the modeling language, once the difficulties mentioned earlier are overcome, such a language could not only be used for modeling and simulation, but could also serve as a support to software requirements specification and programming. It could also be used as a base for a real-time visualization tool, allowing artists to monitor their installation and modify its parameters in real-time in order to promote a particular collective organization.

Furthermore, although I have focused on modeling co-located interactions for art installations, most of the concepts apply to other contexts such as work environ-

ments with locally distributed interfaces, and interactions with large public displays. Thus, with minor adjustments, the modeling language could also serve the CSCW community amongst others.

6

Conclusion & perspectives

This dissertation and the works described within explore issues and challenges faced both by artists when conceiving art installations that enable co-located interactions, and by participants when interacting with the works.

I first clarified a few important terms and gave an overview of the state of the art in various domains. Then, based on a review of a wide range of art installations that satisfy a set of criteria, I proposed a taxonomy that focuses on aspects that affect the emergence of a collective, shared experience and its nature. I then presented several design cases, with particular attention to a study performed on the prototype project *Collective Loops*, and discussed some of the major lessons learned from them, before shifting focus on two graphical approaches to modeling co-located interactions. While this singular approach primarily concerns interactive arts, it may be relevant to a wide range of research communities, including, and foremost, that of HCI, as well as CSCW, New Interfaces for Musical Expression (NIME), interaction design, and even culture, museography in particular.

To conclude, a summary of this dissertation's key contributions will be presented, followed by research areas in which I believe future work remains to be done to further our understanding of co-located interactions around art installations and beyond.

6.1 Contributions

Building on previous, more general, classifications, the proposed taxonomy in [chapter 3](#) tackles a very specific type of computer-supported interactive art, and combines a set of dimensions that, I deem, are of most importance when considering the nature of the individual and collective experience that is aimed for.

The set of identified dimensions aims at offering a tool for the classification and comparison of works that allow multiple participants to interact simultaneously in a co-located setting. It can also help artists in their decision making process when designing such systems.

In an attempt to support a wide range of works, I have chosen not to address the specific technologies used, but to consider the interaction modalities enabled by the various technologies. With the same aim, I have also elected to consider the distribution of input and output separately instead of treating them jointly with terms such as SDG and MDG, commonly used to classify groupware.

The taxonomy does not purport to cover all characteristics of the works, nor does it attempt to do so. It, however, contributes to the research by offering a novel perspective at a genre of interactive art that still remains to be fully explored.

On top of the contributions made through software developments for the *CoSiMa* platform and the *Mobilizing.js* library, the design cases and the lessons learned from them, discussed in [chapter 4](#), also contribute to our understanding of different phenomena that occur in art installations that enable co-located interactions. While some of those phenomena are fairly common in HCI, others are more specific to the context of co-located collective interactions in walk-up-and-use systems.

For instance, while the user studies performed on the central case around *Collective Loops* were not conclusive, they allowed us to pinpoint two major cognitive issues in such installations. The first one concerns the learning and adoption phases of the individual interface by participants with the absence of predetermined goals and little or no mediation. And the second one concerns the attentional weights of interfaces and their impact on the emergence of a shared and collective experience.

This dissertation brings an equally significant contribution to modeling co-located interactions. The two, very distinct, graphical approaches proposed in [chapter 5](#) can be used to describe, classify and compare installations. The first approach has already proven to be an adequate tool to sketch out the relationships between the individual and shared interfaces. I also believe, despite the need for enhancements, that the second approach could be a very effective tool in designing and conceiving systems that enable and promote co-located interaction.

While those contributions are interconnected and complimentary and were, to a great extent, established in parallel throughout the thesis project, each of them can be considered separately as a tool or guideline when designing collective co-located interactions for art installations.

6.2 Future work

The limited research undergone in the area of computer-supported co-located interaction, and more particularly in the interactive art domain, leaves many perspectives for future work. In addition to those pointed out in previous chapters, I discuss some of the perspectives below.

6.2.1 Balancing the individual and shared user interfaces

As discussed in previous chapters, I argue that a genuine collective and collaborative experience — especially in unguided collaboration, when no predefined goal is announced and little to no human moderation is provided — can only emerge from a bottom-up process. Thus, striking the right balance in the attentional weights of the various individual and shared interfaces can bolster the emergence of a collective and collaborative experience.

Based on the conducted experiments described in [section 4.2](#), we can draw up the hypothesis that the individual actions, produced through the interaction with individual devices, could be thought of as an initiator, accelerator and catalyst of the collective interaction. For instance, once the interaction initialized and the learning phase accomplished, mobile phones, initially used as input and output

devices, could gradually see their output capacities reduced, increasing that of their input — reinforcing then their role as an input interface — and consequently releasing the users’ attention to the benefit of the shared apparatus. However, more research needs to be done to verify such a hypothesis.

Further research could also investigate how *perceived affordance*¹ (Norman 2002) and *feedforward*² (Djajadiningrat et al. 2002) principles can help in the initial learning phase, allowing newcomers to become rapidly acquainted with the possibilities offered by an installation, and, therefore, devoting more time to the construction of a collective experience.

6.2.2 Personal, on-demand, feedback

Another area of possible exploration resides in the enhancement of attributability through personalized, on-demand feedback. Indeed, while feedback attributability was deemed high for a large number of works, only one of those (*Overexposure*) supports over 500 participants, and the high attributability of its feedback is largely due to the fact that only one message is displayed at a time.

With the current and upcoming possibilities offered by mobile phones and wearable devices and their high ubiquity, it has become possible to create installations that can be experienced by several hundreds, and even thousands, of co-located people simultaneously.

If we are to design for such a large scale whilst combining both individual and shared user interfaces, feedback attributability can become a major hassle. Similar to Apple’s new “shake mouse pointer to locate” feature added to their operating system *macOS* as part of *El Capitan* (version 10.11) — which allows the user to locate the mouse’s cursor by briefly enlarging it when the device is shook — one possible solution could consist in allowing participants to trigger on-demand feedback, allowing them to, temporarily, locate their own representation in the shared interfaces.

¹A means by which a user interface communicates the possibility, or not, of an action

²An interface design principle described by Djajadiningrat et al. (2002) as being the “communication of the purpose of an action”, thus giving users the ability to understand the effects of an action before it is triggered

6.3 Concluding remarks

As pointed out in this dissertation, designing co-located interactions for walk-up-and-use systems in public settings is a highly complex endeavor, in which many factors need to be dealt with, and particularly when personal devices are combined with shared ones.

Active participation in design and development activities around future events will contribute to further enhance my understanding of the faced challenges and elaborate new ways to overcome them. In fact, a new *Discontrol Party* event is planned in early 2018 as part of the event *Nous ne sommes pas le nombre que nous croyons être* and the *Faits d'hiver*¹ dance festival at the Cité Internationale des Arts in Paris, France, which already promises to provide rich and manifold interactions.

¹<http://www.faitsdhiver.com/>

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Appendices

A

Interview with Usman Haque

Below is an excerpt of an interview conducted by video conference on September 26, 2017 with Usman Haque, a London-based architect and artist and founder of *Umbrellium*¹.

————— *preamble discussion* —————

Usman Haque: It's worth pointing out a couple of things before we get started to set some context.

First of all, I do not typically call myself an artist. The discipline I'm contributing to is architecture. And my approach and interest, and the disciplines I'm trying to contribute to, are those of spatial interaction design, perception, environment, and all that makes up architecture. So the question of aesthetics and art almost never enters into my design process.

I also would like to point out that *Mini Burble* is a project that builds on almost 15 years of development, from *Sky Ear* through *Open Burble*, *Mega Burble*, and then *Mini Burble*. I would argue that *Open Burble*, which was from 2006, has the most interesting participatory element to it. And so, if I were to actually research into modes of participation, that would be the one that I would really want to go into, especially because the question of modeling was really complex and was very difficult, I would dare say impossible.

¹<http://umbrellium.co.uk/>

Whereas *Mini Burble* is, in a sense, more manageable. It is a very direct one to one kind of relationship, and so, perhaps, that makes it easier to research, but in my view is a little bit less rich.

Oussama Mubarak: Is the complexity of *Open Burble* related to the fact that the structure is built by the participants themselves?

UH: Well, yes, because they designed it and assembled it. The way that they assembled it explicitly changes the way that the patterns respond to those who then control it, which might actually be different people. That means that in *Open Burble* it is the members of the public that are affecting (although not fully, and I would argue that this is a limitation to it) the transfer function of input to output. They are not just changing the input and therefor changing the output, they are changing the way the input is translated, the very translation layer. By configuring the structure in a different way they are effectively making a different ‘cellular automaton’ that, therefor, has different patterns and different outputs. Participants may not be fully conscious of that design process, and there are a few limitations to that, but what I refer to as the ‘transfer function’ is actually being modulated by the participation, and that is the key thing for me in *Open Burble*; that it was not me that fixed that. In *Mini Burble*, [the transfer function] is fixed, and so the tablets have one way of translating input into an output, twitter has a slightly different way.

OM: We are specially concerned in our research about the relationship between the individual and shared interfaces, and how participants manage the attentional switches from one to the other. We are thus particularly interested in *Mini Burble* as the interaction with the structure occurs through the tablets or twitter.

Well, one of the things that was surprising in *Open Burble*, was that the people which are designing the structure are going through one kind of operation, which takes actually several hours, and then they assemble it. But they have no actual understanding of how the design decisions they make are going to have any larger effects. The second is, the people who are actually holding onto the structure, and then flying it and triggering the different patterns, can’t actually see what they are doing. In order to see what they are doing, they have to go back about a 100 meters. And so, it’s not quite that attentional shift that you’re talking about, but it has that aspect of a necessary multiplicity of view points.

OM: How exactly are the color patterns created in both installations?

UH: That's where we get into the question of modeling and why it was so difficult. In *Mini Burble* it was straight forward, because the entire control mechanism is centralized. Effectively, there's a computer that receives signals and then can send to an address balloon what ever pixel color it needs to be. When I created *Open Burble*, for various reasons — partially because of budget constraints, partially because I was actually interested in this idea that I wouldn't know where things would be because they'd be designed on site, and partially for pragmatic reasons, namely weight, because we're building a floating structure — all of the balloons were autonomous; there was no central control system. They really were cellular automata, in the sense that none of them had an ID, all they knew was the state of their nearest neighbor, which was communicated in infrared pulses.

This is why it gets really complex in terms of modeling. You can try and model a cellular automata, but we were constrained by the fact that the chipset inside each of the balloons was only 4k — that was all that was available at the time — so we didn't have a lot of complex communication going on, but all that we could do was, basically, count the number of pulses we've received in the last, let's say 100 milliseconds — but we don't know where they're coming from or who they're coming from — and then do things with that.

What we ended up doing was building, I think, about 10 different modes, where in one case, we would look at the rate of change of pulses per millisecond, in another it would be how many pulses we've received in the last second, and in another it might be mapping those things in a color wheel and then going around the hues, in another it would be strength of color, so very few pulses would be blue, lots of them would be red, and in each one of those we would also then vary what does the individual balloon do; when it hits red, does it suddenly fire off lots of pulses of its own? Or does it just transfer; for each pulse it receives it send out another pulse? Or does it only send out a pulse when it's received five?

There are many, many, different ways to work. And because we couldn't adequately model how people would design the system, and we couldn't adequately model approximately 400 people doing slightly different things, we actually had no idea which ones of the modes would work best, or which ones would be successful, or

really even what they would look like.

What we created was this handlebar that had accelerometers in it, and, again, based on different modes, you could "pump it" to create lots of pulses, or "pump it" to vary the pulse intensity, or you could synchronize to somebody next to you to balance out the pulses, and there was a lot of different things that would go on. And so, to answer the question of how the colors were triggered, it really changed all the time, so that's why sometimes you might see in the videos that the color is actually rising quite a lot, and other times it almost appears random. In other times it almost looks like bits of it are catching fire, with explosions of colors. There was all sorts of different modes that we had, and because it wasn't centralized we also had to balance with all of this the power expense, for example, over the course of the evening, if they were on all the time, we had about three hours of battery life. We had roughly a four hour performance period, so we had to diminish the interactivity; if an individual balloon had been lit more earlier on, then we'd have to make it light less frequently later on. This is where the cellular automata model starts falling more into a kind of neuron model, where if it's been excited too much, then it needs more activity to trigger it.

It's for all those reasons that I'm saying that it is the project that I would have loved to spend a bit more time to dive into, just thinking about what any of this could mean or teach or what have you.

Mini Burble came to be when we got to the stage where we, basically, got tired of having to insert 2000 batteries into 1000 different balloons and having all of that angst and worry, and ended up centralizing the system, which meant that we could also make the system much brighter and start to incorporate all the things that *Mini Burble* has: build-in interactive twitter, tablets, the Internet, and even video (I think you can now send videos to it), etc.

OM: You indicated that participants of *Open Burble* sometimes needed to collaborate to achieve a certain output. In *Mini Burble*, how does the concurrent interactivity actually work? Does one's drawing erase the others'?

UH: We've tried it in slightly different ways, in different events. I'm trying to remember which one we decided was the most successful. I think that where we

converged on last, basically was that, you draw on the tablet, and your mark would immediately, or quasi immediately, appear on the surface. Anyone else who's path overlaps with yours will overwrite yours immediately as well. But you could actually see it on the tablet itself.

Actually, I think we have taken that away. I think we might have taken away your capacity to see it on the tablet, so that you don't look at the tablet so much and just use it more as a trackpad. I think we took that away so that people's attention would be focused on the thing itself.

And then twitter, basically, overrides everything. If you tweet a color to it, then it would basically wipe out the entire screen. It wipes the screen in a single frame. So if you tweet "green" to it, it will all go green, but immediately people can start drawing on it.

One of the things we've been influenced by is *Reddit Place*¹, an experiment by reddit². Every year they do a mass participation exercise. This one really caught our attention. Basically, they created a canvas, I think it's about 1000 pixels by 1000 pixels or so, and everybody can write one pixel, but then they can't write again for another 15 minutes, based on their IP address. And so, millions of people collaborated in creating images that just changed, they were basically coordinating to try and create patterns on this surface. It's a really fascinating experience. That's something that, I think, we would aspire to, but was never quite achieved with *Mini Burble*. Because what was taking place there, was actually people learning how to use the system in order to then coordinate to do pretty impressive stuff, considering the constraints of the initiative.

————— *main interview questions* —————

OM: You design and create massive interactive structures for public spaces such as *Burble London* and *Mini Burble Paris*. What type(s) of aesthetic experience(s) do you aim for?

¹<http://www.newsweek.com/reddit-place-internet-experiment-579049>

²<https://www.reddit.com/>

UH: I really don't have an aesthetic experience in mind. The kind of psychological experience that I'm trying to create is one where people feel that it's their project to a certain extent. It's that sense of ownership that I'm looking to turn over to people. It wasn't in *Mini Burble*, but this was something that happened in *Open Burble*. Somebody who was there actually ended up blogging about the project and had some photographs of it and said "that's my baby up there", "look what I did", and kind of talked about it as her project.

For me, that was the key success. That's the kind of thing that I'm trying to solicit; that sense of responsibility for the structure, almost, or responsibility for the outcome. Again, *Open Burble* played with that very much, because of the size of it, and the fact that members of the public themselves were holding on to it. They had that responsibility not to let go of it. They could have all let go of it, but then everyone would have lost it. So it's less about aesthetic experience, it's more of a relationship that I'm looking to create between people and the thing that's going on in front of them.

And I think, by the way, this is where really what I'm looking for is how to erase the distinction between the designer of the system and the people who start to take it on. Because ultimately, the proof of the project would be if people really didn't think about me, or a designer, or that this was somebody's initiative, but that it's really their's. Now, that's an ambition that I can't say necessarily that any project would fully achieve that, but I think we get close to it. That's the key thing in every project I do. It's not the aesthetic experience.

I suppose that the aesthetic experience matters only so far as it becomes a good excuse, almost, if you see what I mean. That it's the thing that gives people a reason to come out in the streets and be part of something much larger than them. And that's where the real interest in the spectacular really comes from. When people have that sensation that they're doing something larger than themselves, that they're having an effect, almost like a superpower that emanates just because they're working together, that's where the aesthetics kind of comes about.

OM: In *Burble London* the colors of the structure are controlled by participants through the shaking of handle bars which are part of the structure, whereas in *Mini Burble*, participants can draw on the structure remotely via a custom interface on

tablets. Did this shift from direct to indirect interaction change the way participants perceived the impact of their actions on the structure?

UH: In a sense, it was actually a shift from indirect to direct, rather than from direct to indirect, if you see what I mean. In part because of the things I was explaining before, but also particularly because when they are interacting with the handle bar, they're not actually able to see beyond the colors right in front of them. They're not able to see what they're doing across the entire surface. And so, that ambition that I talked about earlier; about wanting to do something much larger than yourself, I think people largely felt — and even I did when I was doing it myself — like “OK, I'm probably having an effect, way up there, but I don't know. I saw other people doing it when I was 100 meters away, but I don't know for sure that I am.” And so in *Mini Burble*, when people are working with the tablet, rather than it being an indirect, it becomes much more direct. Because you can literally see; you draw some kind of shape or pattern or line, and it's reflected in front of you immediately at the scale of the building that is right next to you. So I think that was the shift in perception.

OM: And the fact that many participants can draw simultaneously together, does that not affect their ability to perceive the effects of their actions?

UH: With the tablets, I think we typically only have 10 tablets out. So it's not that messy. And so largely you can kind of see what it is that you are doing, or the effect that you have.

But here, I might actually mention another project, which is called *Primal Source*, where we were grappling with specifically this problem; where we were basically creating a cloud on a beach, in that case there were several hundred if not thousands who were using their voices to trigger patterns on this cloud. In that case it was very important for me to try and figure out how, with a limited number of microphones as inputs, to really feel as though it was not just random noise but that they were actually doing something. And so, what I ended up doing, was basically: I coded it to respond as quickly as possible to the rhythm of someone's voice. So the frequency of their voice in that cacophony of many people making sounds actually didn't matter, but the rhythm did. And by making that happen as quickly as possible, when you made a particular rhythm, your eye was immediately drawn to

the shape that corresponded to that rhythm. So that was a very particular set of perceptual/aesthetic strategy to make people feel that they understood where their contribution was coming from. And it so happened that if, for example, you make a sound of a particular rhythm, and somebody else starts making a sound as well that is being picked up by the same microphone though a different person, what I would do — with a bit of frequency distinguishing — is: I would add the rhythm from that voice onto the first one but also create a new pattern with the new voice. That would mean that if I got it wrong, and it was actually the same person, they would actually see their contribution. If I got it right, that didn't really distract from the fact that they had created this pattern. They didn't seem to notice that there was a difference. Whereas that second person, their eye would be drawn to that thing that just responded immediately.

You're basically trying to catch their attention in that half second. If they notice that, then they can see straight away that it was happening. We didn't really do careful analysis of the crowd to see this, but again and again and again, I did hear people in the crowd saying: "look, look, that was me", "no that was me", "that one over there was me." And people explaining to each other: "Yeah this is how you do it", "You see that one over there". And so, it's a bit of technical strategy coupled with a bit of what I understood of the psychology of people; which is that the time domain is really important, the immediacy of response, coupled with the understanding that it's actually about the rhythm. It's not about the shape or color or what have you, it's getting that rhythm right, between sound and sight that really did that.

We haven't had to be confronted with that in *Mini Burple* so much, because it's relatively easy to see.

OM: This is, in my opinion, one of the hardest things to manage in such installations: giving the ability to participants to understand which action produced a certain feedback, especially when several hundreds of people are participating simultaneously.

UH: I think that's actually one of the fundamental design challenges of the 21st century, in general. How do we know that our interactions in the city, or against climate change, or in the democratic institutions, has an impact? How do we know that our input counts?

One really funny thing about *Primal Source* was that, what I've described makes total sense for everyone in the first few rows — who are making the sounds and can see it happening — but the people who are about 10 rows back did not have that perceptual connection. All they understood was that there's a bunch of people making a ridiculous amount of noise, and there are some random patterns on the screen. I remember there was actually this blog comment, or a comment on the video, where somebody said: "Why is everyone making so much noise? Don't they understand that art should be experienced in quiet contemplation?" So the question of knowing one's contribution, it's also different for other people to know, not just their own contribution, but what others within the scene are doing.

OM: In which of those two installations (*Burble London* and *Mini Burble*), do you feel that the active and passive public better understood the relation between the actions of the participants and their impact on the colored patterns of the structure, and why?

UH: To add to the previous answer, I can't say necessarily that one was better than the other, but I think that it's a complex question. Because, in a sense, the knowledge around *Mini Burble* and the understanding that "Oh, if you go over there you can use the tablet, and you have this effect". So in one sense, I think the people understood the relationship of what was going on on the tablet and the structure itself. In most cases there's a podium setup for people, or a little tent. So that relationship becomes quite clear.

But on the other hand, in *Burble London*, or *Open Burble*, which is the general project name for that version, you see people physically really, you know, hundreds of people just shaking and holding on to this thing. So that relationship is so direct. You may not see directly what the effect of their movement has on the color, but the understanding is kind of much clearer that people are controlling this thing, because they're using their entire body, synchronizing their movements together. Compared to the tablet version where people are quite static and moving their fingers a little bit. In other words, the third party looking at it probably intellectually understands better that there's a connection, but in actual fact doesn't see what's going on.

I sometimes think of it like a noise music performance, or laptop music performance, where the performers at a laptop are not really moving. You don't actually

see the relationship between what they're doing and the music. You know that it's definitely there, just cause you know that this is how digital technologies work. But you don't see it, you don't have that understanding.

OM: How were the different modes of interaction in *Open Burble* created? Were they created by the people constructing the structure, or preconfigured?

UH: That was something that was hard coded ahead of time. Basically it was something like 10 modes, and it would switch every 6 minutes, and repeat every hour the ten sequences. The reason for having those 10 modes was actually because we had no idea which ones would work. And frankly, 6 minutes seemed to be about the right amount of time to have a mode that didn't work. If there was blank patterns for 6 minutes it seemed kind of manageable. That's why we chose that. And it also seemed like if you got a good mode, 6 minutes would give you just about enough time to learn it, enjoy it, and experience it. But because this was not a centralized system, everything had to be decided ahead of time, so that all of the balloons would basically go through those different modes.

OM: Did the different modes affect the way people understood the impact of their actions?

UH: Yes, that's definitely fair to say. Because there were some which I think effectively did result in total random patterns, or at least patterns that we could see no consistency to it. But, I had actually thought about this, and I did want there to be one moment where explicitly you could see what you've done. When the units were handed out at the beginning for people to start designing and assembling, those groups of units did have a particular color programmed in them. And one of those ten modes, more or less, would flash that color for 6 minutes. What that meant was that, if you've had worked on a portion of this molecule that ended up being in the top right, and the modules that you've had used had a violet color applied to it, then for about a minute or two per hour it would suddenly flash. The entire structure would show their specific pattern; the bit that they have assembled, because it would be all violet and nobody else's were. And so that was the moment where you could actually see that that was your contribution; that was the thing you had made or designed. So at that point it was not interacting with the people shaking around, it was merely presenting itself.

OM: Active participants of *Mini Burble* are simultaneously subject to multiple sources of attention: the large structure of balloons, the tablet interface, other active participants, and the surrounding crowd. Did participants often shift their focus from one source of attention to another, or were they more focused on one source in particular, and did that change throughout the interaction phase?

UH: I would say that they were mostly focused on the balloons, just because they're the big thing that's flapping around in the wind and usually there's quite a lot of wind and something is going on. Very rarely did people particularly focus on other stuff, so the tablets would only draw the attention of the ten people that actually had them in their hand really. And even then, as I mentioned to you, we didn't even draw on the surface.

Actually, let me just check that. Ling, you know, in *Mini Burble*, the latest version, we don't draw on the tablet the pattern that's on the burble anymore, right? We just have an outline that they can draw on, right?

Ling Tan : [...]

UH: Yeah. So the only feedback they're getting is on the structure itself.

LT: [...]

UH: That's right, yeah. So that's right, there's actually nothing on the tablet to draw their attention too much.

OM: And did you feel that people that use the tablets had to spend time looking at the tablet at the beginning to understand how it works, and if so, how much time did they spend before switching their attention to the structure ?

UH: Let me actually ask Ling, as she did a lot of the coding, and probably was the closest involved. Ling, we're just talking about *Mini Burble*. Oussama is asking about the people using the tablets and how much they understood about it. Oussama, do you want to ask your question again?

OM: We were speaking about *Mini Burble*, and the fact that there are the balloons, the tablets, and the crowd around the participants. I'm interested in knowing if people switched their attention from one to the other. When interacting with the

APPENDIX A. INTERVIEW WITH USMAN HAQUE

tablets, did they pay more attention to the structure, to the tablets, or to the people around them and if this changed throughout the experience.

LT: That's a good question. I'm not sure, giving that in Paris we were not necessarily interacting with the people using the tablets...

UH: Now that I think of it, there was actually a queue waiting for the tablets. So the phenomenon that was happening was that the people in the queue were observing the people with the tablets and, so they kind of knew what they were supposed to do, a little bit.

LT: For the one in Paris, there was a help poster, instructing them. But people understood what to do by looking at the person interacting before them. I noticed in tests that we performed with a few friends in London that the interface was quite intuitive. People immediately knew how to interact with it.

UH: At one point we were planning to show the pattern on the tablets, but we decided not to. I think maybe in the London test we had the patterns on the tablets...

LT: That was a conscious decision that we made.

UH: Yeah, we got rid of it to let people focus on the burble itself.

OM: Did active participants of *Mini Burble* coordinate their actions in any way, and how? Were they influenced by the passive participants around them?

UH: I saw people chasing and erasing each others' stuff.

LT: Yeah, there was something like that that happened.

UH: But it was not really constructive behavior. I think that's what was missing, and that's why I mentioned that reddit project, *Reddit Place*, for the ability for people to actually coordinate their actions outside of the system itself, if you see what I mean. In other words, the only way that they could interact with each other was through the tablet, unless they can shout it over to the person next to them. So they were not actually able to learn fast enough to be able to do that kind of coordination.

OM: If you were to evaluate the performance of *Mini Burble*, which metrics or criteria would you consider?

UH: As I have eluded to, the thing that I would want to evaluate — but for which I think that *Mini Burble* doesn't score very well on — is the extent to which people felt that the content that was being created was their realm; that they had done something meaningful and lasting. In *Open Burble*, I think that the contribution was far more robust, because it was longer lasting, it was much larger, it was more significant in terms of the actual effect.

I think that *Mini Burble* in a sense because it was a bit of a trivial action on a tablet, it kind of diminished the importance of the actions that people took with the structure itself. So if I was going to be very rigorous in evaluating it, I would want to look at: to what extent were participants able to modulate, not just the input and therefore the output, but also what I call the 'transfer function'; the function that actually converts an input to an output. The more that they can change that function, the more that, I think, they get invested in the thing, and the more deeply involved in the system design itself.

OM: Would you also consider for example, time in the interaction? Did you feel that people in *Mini Burble* spent less time because of the simplicity of the interaction, compared to *Open Burble*?

UH: No, I don't think they necessarily spent less time. For one thing, queuing took a long time for some people, and I would call that quite an investment in participating. But then when they were actually using the tablets, they would be there for a good chunk of time, and arguably perhaps longer than the people that had physically held down the *Open Burble*, who might have just done it for a couple of minutes and then got tired.

But I think that it was the embodiment of the action in *Open Burble* that became much more significant. The action of swiping on a tablet, I don't want to make any references to apps, but it has that kind of connotation of a relatively, you know... This is a bit of a tangent, but you know the book *To Save Everything, Click Here* by Morozov. He describes this phenomenon quite a lot, that: yes technology helps us to be able to interact with things, but actually, because it almost trivializes it, it can

make it so much less important.

OM: [short presentation to Colored Petri Nets and the CoPN modeling approach]

UH: It would be interesting to identify the fact that people in the queue are participants as well. And to realize that we actually hadn't factored them in. Not necessarily to diminish the queue, but to say: OK, what are they doing in the queue, let's design for that as well. I think that would be interesting.

OM: Yes, definitely.

UH: Pretty impressive. Can you make predictions based on that?

OM: We're hoping to, but we still need a lot of data and math models. We're currently more concentrating on the visual aspects of the language. We're working on a higher level of abstraction to allow artist to start a model and then work with a developer or other team members to add details to the model.

OM: [presentation of a simplified CPN model of *Mini Burble*]

UH: There's one very big thing missing from this model: the balloons' popping. I say that because that's something that really grabs people's attention. Although it's not a very common thing; we've actually got the structure much better designed. But when a balloon pops, I think we're now possibly losing only about 5 per evening, but when it pops, everyone just looks and there's a collective "Huh!", or a laugh or something. And I think that is a very significant moment of everyone focusing their attention at the same time.

OM: I didn't know they popped. That's very interesting.

UH: So the funny thing is, that we've actually designed that out. But there was a point, a few years back, where we were actually thinking of designing it in, by building a little coil into the electronics where heat would programmatically pop the balloons. As you were describing it, that question of focusing one's attention, that is a moment where everyone is aligned.

OM: That is indeed very interesting. I'm, in fact, also trying to model the effects of feedback from the system on the participants.

[presentation of the CoPN graphical notation]

UH: It's very interesting. I have to say that when you first showed the video, I was a bit skeptical, because I tend to be skeptical anyway of formal systems for design, especially in the context of architecture.

I don't know if you're familiar with space syntax. It's a discipline within architecture which looks at the formal distribution of environments and buildings, and tries to make predictions about the ways that people are going to enter the space. I'm a bit critical of it, simply because it thinks of architecture purely as a formal proposition and not as a socio-cultural or even as a political activity. So I think that, you're probably aware, that there's a potential to critic from the perspective of making formal something that maybe shouldn't be formalized. But I think that what's actually really appealing to me is the notion that they should be making a sketch. That it's not trying to tell me something, it's actually only telling me the things that I tell to it.

So I was really interested in the fact that you've picked out conversation as a specific thing here. Because I feel that the more conversational the system can be, the better. To be something that I, as a creator, have some kind of interaction with; it's not just an algorithm that's computing or predicting something. It's reflecting a set of relationships that I have explicitly designed and revealing, hopefully, a set of relationships that I haven't even thought of, or that I haven't designed for yet.

I'm kind of verbalizing my interest in it as I loom at it. Which is to say: it's very interesting indeed.

The use of the icons is less important to me, as someone who's reasonably comfortable looking at something numerically and computationally. But I can see why that would, at a glance, help people who are perhaps less comfortable with it.

OM: Following the presentation of the CoPN modeling language and the sample model for *Mini Burble*, would you consider other metrics or criteria when evaluating the performance of the installation?

UH: One thing that did spring to mind, actually two things, were to do with the relationship that people have to the event or the situation after they've left. I think

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this is an important part of it: the memory, the shared memory of the thing itself. For somebody like me, that's actually really fundamental. The fact that, for example, somebody came up to me 10 years after the Singapore thing and said "Look, here's my sketchbook of when I was part of it, and here's my scrap book," that was a really important part of the desire for that project; that it had this kind of lasting memory.

And the second, which is related, and which might be particular to *Mini Burble*, was the photographs. Partially because all of this, especially today, this kind of stuff is wrapped up into the question of social media and the representation of a piece of work to everybody else. You know, I mentioned the blogger talking about *Primal Source*, and wondering why everyone was screaming. The photograph that lives on, and becomes the collective memory of people who weren't there, but are, in a sense, a participant of sorts; a very remote experiencer of the project. And I think that one of the funny things about *Mini Burble* is, if you see it on social media, the number of people that take photos with the flash on, and therefore do not capture the colors, is very funny. To be able to capture the wider ripples of a project or to model that, and to be conscious of that, would be an interesting aspect of this.

It's afterward, but to a large extent also happening simultaneously. Our specific intent with the twitter thing — because I believe you don't have to tweet to a particular handle, you tweet a hashtag — was that lots of other people should be able to see that. Because if you tweet to a particular person, other people who are not following that person don't see it. But if they're tweeting to a hashtag, other people will see that, and they might even start to try it themselves. I don't think we went very deeply into designing this, but we were consciously thinking about the fact that people external to this actual location could potentially have an effect. And in fact, in one case I think there was a live webcam to the thing as well, so people could see when they're interacting remotely.

OM: So people actually send tweets remotely?

UH: Yes, definitely.

OM: If you were to create your own model of *Mini Burble* to be used as an analysis tool during the design process, what aspects of the installation would you model, and why?

UH: Well *Open Burble* is actually the one, as I mentioned, that I would really have loved to have better modeling tools for. Because it was a large scale and risky project. There were so many risks that we were taking up there. That's where I think modeling would necessarily have made our lives so much better.

With *Mini Burble*, I don't think I would have needed a whole lot more. Just because it was a more manageable thing. I don't think necessarily I would have needed to step outside of our own physical experience of building and testing that we go through. Because we start small and build up, and go out into the park and fly the thing and see how it works, and see what people do. So the modeling is actually less important.

OM: Did you anticipate the queues in *Mini Burble*?

UH: Yes, we had to design for that to be in a particular location so that it wouldn't obstruct traffic and things like that. So it's definitely things that we had anticipated for. What we didn't do — partially because we didn't think too coherently about it — was think too much about how do we design some kind of experience for the queues.

In another project, we did design explicitly for the queues. It's a project called *Assemblance*, where deep down a dark theater, underneath at the Barbican in London, we knew that the queues would be very long, and that people could potentially be waiting an hour to come in and experience it. And that it would be quite a complex interaction that they would be then faced with once they got inside. So we built a window into the installation that was big enough that you'd be next to it — probably for about 5 minutes — as you were going past, where you would see the installation and people doing things. But it then disappeared as you walked on the last 10 minutes before you'd get in. So we were consciously thinking about that effect of teaching people by giving them that kind of fragment. And we also created, in the queue, what I kind of call "Yoko Ono moments". I don't know if you know her work, which is a series of very short phrases and poems that are really stunning; a series that she did in the 60s. And so we had a few of those to kind of start people's mode of thinking as they were in this queue getting deeper and deeper, and then the window appeared, and then it went black again in the sequence of the queue. So, we had done that, but not in *Mini Burble*.

I suppose that, for the *Assemblance* project, it would have been very interesting to try and model people’s interactions with it. Because that was a project about people designing and building physical structures around them with an interface made of lasers that are creating shapes in 3D space. And, in that case, we had the idea that if people collaborated to build these light structures, the structures would be much more robust than if you built one on your own. So if somebody walks through something created by lots of people, it would still stay there, whereas if they walked through a light structure that only one person had created on their own, it would just disappear. So I think that would have been very interesting, especially in the light of the design of the queue experience, to have some kind of modeling for.

I think that one of the focuses we might have had there, would be perhaps to have a better understanding of what the likelihood of collaboration would actually be, and a way to figure out what is a better way to encourage people to collaborate and deliberately work together. That’s where that would have been helpful I think.

I think that in *Mini Burble* it was less of an intent; it was less intentional that people should explicitly collaborate on stuff. Whereas with *Assemblance*, that was right at the heart of it; that people deliberate and converse about: “Hey, come do this with me” and “We can do this” and “Oh! Look what I’ve just created by moving this way.” And we’ve also put into that, those things that we called ‘easter eggs’, which are things that would only happen if you did exactly the right thing at the right time. So you kept people, hopefully, saying: “Oh! Look, look!”

OM: I saw that, for *Open Burble*, you had created a virtual model of the structure. Did you use a modeling language? Did you create your own models? Do you create sketches?

UH: It’s a bit of everything. It’s definitely a bit of building the thing immediately; not waiting to think about what it should be, but building it to design that way. With *Open Burble*, I did have to build a sketch in *Processing* to try and look at the rate of the pulses and what possible patterns might actually come about, and how they might cascade. I was talking about how the pulses would get passed on — sometimes they’d be aggregated to do that — so I build a visualization of the burble itself in *Processing* to achieve that.

This also reminds me that, this question of modeling becomes really fundamental to some of the other projects that are web-based platforms like *Pachube* and *Thinkful*, where one of the key things you're trying to do is model, potentially, 50000 people coming to your website at the same time. There's a whole bunch of tools — that we actually sometimes have to create from scratch — to model a typical user, and then randomize 50000 times and then through it at the staging version of the website and see how it holds up and what breaks. So that notion of simulation and modeling does play a very strong role.

Interestingly for us, what almost never takes place, is that we almost never model form or structure. We're less concerned about that. It's very much about systemic issues. That's the big uncertainty for us. And that's kind of why, again, the question of aesthetics, is almost like: “what ever comes out of this, that's the aesthetic”. Clearly I have some kind of sense of aesthetic because I make some choices, but I'm not that conscious of it.

OM: Would you consider using a graphical modeling language such as CoPN in the different stages involved in the design and development of your installations?

UH: As I mentioned, there are a couple of projects where something like what you showed would have actually been really quite interesting. Having said that, I think that what I would have wanted to do in that case is work with someone who is really proficient in doing that, that could help co-create or co-design some of that. I can't imagine, necessarily, me using that directly in my own design process. But rather using it as a shared canvas, where a bunch of us could look at something. In other words, it would make a lot of sense if it was a collaborative sketch. It makes less sense to me as something where I, as an individual, just designing or trying to simulate something.

OM: Did this interview change the way you viewed or considered your installations in any way?

UH: Just to be blunt, I've never been asked quite such deep questions about it. So yes, it kind of makes me feel like “Oh my gosh, somebody's interested! Somebody's interested in that stuff that obsesses me!” So, in that sense, yes.

I think also, it reminded me a little bit that, you can kind of tell that I'm less

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excited by the interaction model of *Mini Burble* than some of the other projects, so it reminded me that I really need to think about that again. Especially since it's one of the ones that's actually probably getting the most attention at the moment. So yeah, it's had that kind of effect.

Also, that notion of designing some of that stuff with intention. I say that because, to be perfectly frank, the idea of adding twitter to *Mini Burble* was not a very deliberate thing. It was just something we thought "Oh, not everyone can have a tablet, well, what if they just use their own phone? What's the easiest way for them to use their own phone ? Oh, it's twitter." You know, that kind of thing. And from that we started exploring how this could be done slightly better. But it did not come out of a direct decision to do something specific for twitter.

B Interview with Mouna Andraos

Below is an excerpt of a phone interview conducted on November 22, 2017 with Mouna Andraos, artist and co-founder of the Montreal interaction design studio *Daily tous les jours*¹.

Oussama Mubarak: You design and create interactive installations for public spaces such as *Bloc Jam*, *21 Balançoires*, *21 Obstacles* and *Mesa Musical Shadows*. What type(s) of aesthetic experience(s) do you aim for?

Mouna Andraos: A lot of our work is interested in trying to explore the idea of collective and shared experience. Asking the question of whether or not we can encourage people to engage with each other and with their environment somehow, and realize that they could have a role and an impact on the environment that's around them.

And so, one of our bigger ideas that some of our projects have tried to explore, is this idea that collectively, people could achieve more than individually. So we try to symbolize this through the project where we, in a way, reward different types of participation in different ways, and then encourage people to collaborate or interact with each other, on top of just with the actual interface in order to experience the project. And a lot of the work that we do is in public spaces, not always, but we're interested in a space where we get, kind of, very varied types of audiences that are not necessarily in a state of mind where they know that they are going to be invited to participate with a piece of technology or interact with something, etc. So we try

¹<http://www.dailytouslesjours.com/>

to integrate things in people's everyday lives or existing experiences. And, ultimately, if we can get a project to be an excuse for people to exchange with each others in a way that they would not have necessarily, then, for us, we've achieved what we're trying to do.

OM: Unlike in *21 Balançoires* — in which the motion of swings triggers musical notes locally — actions of participants in *21 Obstacles* control — both via the swings and mobile phones — remote visual elements displayed on a large shared interface projected on the facade of the President-Kennedy Pavilion. How does this difference between the direct interaction in *21 Balançoires* and the indirect one in *21 Obstacles* change the way participants perceive the impact of their actions on the installations?

MA: So, *21 Balançoires* has been quite a successful project, that kind of took us by surprise in many ways in the response of the public. I think it connected to the public in many different ways. *21 Obstacles* was maybe a little bit more of an exciting project for designers looking at games or [...] or architectural games. So, unlike *21 Balançoires* which has happened several years in a row, *21 Obstacles* was only a single year project. And so, in *21 Obstacles*, the experience of the participants of *21 Balançoires* remains the same, their main interest remains to swing and make music with their swinging, however, they indirectly — whether they are aware of it or not — control some elements on the giant screen behind them. So the giant projection behind them is really more targeted to the audience that is not on the swings, inviting them — who are maybe a few meters away, or who are waiting for swings, because there were some problems where there are too many lineups with people waiting for swings — to engage in a different way, and almost have this more omniscient view of what was going on in a way that someone on their seat, on a swing, might not get.

And so, they are really two distinct experiences, where the person on the cellphone is looking at the person on the swing, but really interacting from the cellphone to the big screen.

OM: I see. I did not know that people on the swings cannot see the actual large projection.

MA: It depends where they are, but it's not very comfortable.

OM: And so, there's also music in *21 Obstacles*?

MA: Yes, there's the same music as in *21 Balançoires*. And I think, for us, that is in parts why we used music: music enables you to multitask, think and enter multiple, kind of, access of relationship in a way that visuals won't. So let's say, hypothetically, people could be on the swings and look at the screen, I think that most probably changes the experience where you become much more focused on yourself and your individual representation on the swing, and that becomes the key focus. Whereas with the music elements, it's much easier to be in relationship with people around you, cause your mind can kind of processes the music while really engaging with people around you.

OM: In which of those two installations do you feel that the active and passive public better understood the relation between the actions of participants and their effects? In other words, did participants in both installations equally manage to identify which effects they were triggering through their actions, and did they adopt different strategies to do so?

MA: That's really a critical question when you're designing interaction; how do you give clear feedback so that people understand what they are doing. It's hard, and I assume it's because there's a learning curve and [...]. So in this case people on the swings were kind of focused on understanding still what they were doing with their seat, and people with their phone were basically... it was like a giant pinball machine that they were sending balls out, which would then move through the screen. So it's very simple to understand what the cellphone interaction was.

OM: So people on the swings were actually triggering two things: music and the movement of obstacles. Did people on the swings understand fairly fast that they were triggering music?

MA: Yes, I think generally people get that they trigger music. There's also kind of a collective intelligence that gets created on the spot when you propose a new interface. People communicate with each other, they see each other, they learn. So the fact that they trigger music, I'm pretty sure everyone understands.

How exactly they trigger music? At what moment in their movement is the music triggered? I think that's another level that maybe not all the users understand. And

then the kind of collaborative aspect of the music making, people get, because they know their music is mixed with other people's, but the fact that if they swing in synchronicity they generate even more music, that's something that they have to tell each other, read about, know...

OM: And did they also see and understand that they were also moving objects on the screen? Were they able to make the connection between their swing and the obstacle that they were controlling on the screen?

MA: I think that definitely not everyone did. I think also not everyone cares enough about what's going on to really try and understand. In a sense that the swings bring a lot of joy to people and they kind of focus on doing that. I think some people who were curious, of course saw the giant projection. Whether or not they tried to understand what the projection was might have been still a different level. So we probably had the whole range: from people that had no idea that the projection was connected, to those who understood that their motion was activating the objects.

We're also in the specific context of the *Quartier des spectacles*, and that area has seen significant amounts of video projection, and essentially on that specific wall behind the swings. So I think people also ... how can I say it... there's no sense of novelty that these two things were necessarily in relationship, because *Quartier des spectacles* has done other projections sometime that weren't related to the swings. It's also a screen that often has projections, so people don't necessarily look if they're not interested in that medium, or they're not curious.

OM: Did active participants in *21 Balançoires* and *21 Obstacles* coordinate their actions in any way, and how? Were they influenced or guided by peers or the passive participants around them?

MA: I don't think across the two interfaces. They are too different in space. It might have been very anecdotal that they would. I think generally speaking, the people on the phone probably usually talked to each other, potentially: "Look! I Did this", "I did that", "Look at this", "Try that". And the people on the swings are encouraged to talk to each other and coordinate their efforts to generate more harmony. But across the two mediums, not necessarily.

OM: If you were to evaluate the performance of *21 Obstacles*, which metrics or criteria would you consider?

MA: Performance evaluation is something we've been doing extensively. We did one that you might have found on our website for the 21 swings, or the musical swings when we did a traveling version. And the criteria we were mostly interested in were: what kind of feeling it gave to people, whether or not they interacted with each other, whether they interacted with a stranger, etc. And these are always the criteria we're curious about.

As you might see, we've done some screen based, image based projects like *21 Obstacles*. We did *Bloc Jam* a long time ago. But it's not our favorite medium, because it's a very different relationship that we have with the screens. And so in this extent of having a gigantic screen bring together, yeah, it would be the same criteria, I guess. Did it bring people together? Did it bring awareness to each other? Did it give people a sense that they can have a role to play in their environment? Did they give them an empowering sense of controlling something at the scale of architecture.

OM: [short presentation to Colored Petri Nets, the CoPN modeling approach, and a simplified CPN model of *21 Obstacles*]

Before we go on, do you have any questions regarding the CoPN modeling language or the simplified model of *21 Obstacles*?

MA: Yes, the first question is: were did the assumption come from that a model is needed for artists to create stuff? Did that come from your observation that this was needed? Did you implement it, and did you try to design something using this, and does it create better results than not without?

The second thing to keep in mind is, in our case we're working with very general public. It's really important for us, and not a context of an exhibition or a game that people actually say "I want to sign up", and then spend an hour playing, etc. And so, simplicity is actually key. And, most often than not, we have to design a single interface. The case of *21 Obstacles* is definitely an exception. And I don't think it's something we should be necessarily moving towards.

APPENDIX B. INTERVIEW WITH MOUNA ANDRAOS

In our experience also, the more complex the model, the less successful our work as designer is. Our work as designers is to simplify as much as we can the models, so that people can very quickly understand what is expected of them and, kind of, jump on board. So a very complex model usually means that we haven't really figured out what the essence of what we are offering is, or what the essence of a project is. We have these conversations with our team, and some of our lead programmers always complain that we manage to start with something simple, and by the end, code becomes quite complicated because we're trying to take into account too many exceptions, too many special cases, which are usually a bad sign.

OM: For your first question, the idea of a modeling language actually came about because we had issues in our installations, which combine several interfaces. We noticed that people had a difficult time getting from an individual interaction on their smartphones to a shared one by looking at others, speaking to others, looking at the shared interfaces, etc. Most of the time, when one joined the interaction, they would spend too much time on their phone and not enough sharing a collective experience. So we tried to understand how to manage what we call the 'attentional weight of interfaces', or how to slowly simplify the smartphone interface to become a mere input interface, so that participants can pay more attention to the surroundings, people around them and the shared outcome.

And, as you have said, those installations are intended for the general public, which doesn't necessarily know much about the installation or the people they are interacting with. And art installations don't usually announce a pre-defined goal to achieve, unlike in a working situation, in which you collaborate with your teammates toward a known goal. It might be a crazy idea to attempt modeling such systems, but this has already allowed us to understand or see things in our installations that we did not see or fully understand before.

As for what you said about the complex models, I do understand. As a developer, it can indeed be frustrating when a simple project becomes complex. Although the presented model might seem complex, it is actually relatively simple. In fact, a large part of the model might be almost identical from one installation to another. Also, a Colored Petri Nets model can be very simple to start with, adding details later as needed. It is up to the modeler to decide to which level of abstraction they need to

go to. That's, in fact, one of the aspects of this language that attracted me compared to other modeling languages.

Did that answer your questions?

MA: Yes. Sure. Your instinct to use it as an analytical tool can be right. Because I believe that one of the questions is: where is the human factor and the human intelligence, in a way, in the model? Because you would necessarily have to assume specific behaviors in order to program them in. So there might already be some flows in that process, but if you do it more afterwards as an analytical tool, inputting observations, then that might help really identify patterns and things that you might not have seen.

OM: Indeed, I do believe that the models would only be good, at the beginning, as an analysis tool, because I don't think we'll have enough data to actually be able to produce models before hand for simulation or prediction. We will thus have to start using it as an analysis tool, and then once enough data is available, we might be able to use it as a design and development tool.

MA: Interesting. Once I'm in front of my computer I will have a closer look at the video of the model that you sent.

OM: Great. Well, following the presentation of the CoPN modeling language and the sample model for *21 Obstacles*, would you consider other metrics or criteria when evaluating the performance of the installation?

MA: I'll have to have a closer look for sure to be able to understand accurately. But if I go back to your first question, relating to the type and quality of the human interaction, then it would be to find a way to qualify it and quantify the human-human interaction. To expand on more than the human-computer interaction. Because the human-human interaction can grow in complexity in an interesting way.

OM: If you were to create your own model of *21 Obstacles* to be used as an analysis tool during the design process, what aspects of the installation would you model, and why?

MA: Again, relationships between people. And in our case, we are particularly interested in relationships between strangers. I would even add: Where do they come

from? Why are they there? etc.

OM: Would you consider using a graphical modeling language such as CoPN in the different stages involved in the design and development of your installations?

MA: I think you brought a good point. It depends on the learning curve. If there's no learning curve, then we'd be willing to try it and see whether or not it helps with scenario building. But if it's quite complex, then I think it becomes an obstacle. It cannot be as complicated to program a model than to program the real thing.

We build a lot and a lot of prototypes. So we do all sorts of prototyping to test our interactions and our assumptions about what things are. So part of our practice is critical that we get out of the computer, out of our heads, out of the brainstorming table, and into something that people can actually try. From [...], I think it would be the same problem there; you remain in a theoretical sphere, which really [...] does not have that much value. We have to be in the real world, testing our assumptions with people.

OM: Do you, however, use modeling in your work as a tool, or not at all?

MA: We would call it, I guess, more mapping than modeling. In the sense that, yes, there are some information [...] with predictions, with things like diagrams to represent research [...] insights and help us see more clearly where we have to go. But modeling that's more programmatic in one way or another, we haven't done, unless it is to solve really one aspect of the case, but not something full.

OM: Did this interview change the way you viewed or considered your installations in any way?

MA: Sure. We've been thinking of whether or not we want to recreate *21 Obstacles* as part of *21 Swings*, I guess [...] we're thinking again about whether or not it would be interesting to have the people on the phones and those on the swings more aware of each other. That might be a question.

And also, the interview reminded me of the importance of keeping the [...] clear and simple.

C

Collective Loops - Questionnaire

The following French questionnaire was handed out to participants of the first version of *Collective Loops* as discussed in section 4.2.3.

Collective Loops Questionnaire

N° participant : _____

Vous avez participé à une expérimentation qui met en interaction des participants autour d'un dispositif interactif collectif. Merci de répondre à toutes les questions ci-dessous concernant votre vécu et ressenti suite à l'expérience:

1. **Quel est votre âge ?** _____
2. **Quel est votre sexe ?** homme femme
3. **Quel est votre situation actuelle ?** étudiant en activité professionnelle autre
4. **Utilisez-vous les nouvelles technologies (ordinateur, smartphones, etc) au quotidien ?**
 oui non
5. **Étiez-vous déjà familier avec des logiciels de composition musicale ?** oui non

Si oui, lesquels : _____

6. **Avez-vous utilisé votre propre smartphone ?** oui non
Si non, possédez-vous un smartphone ? oui non

7. **Décrivez votre ressenti pendant l'expérience :**

8. Quelles ont été les obstacles et difficultés rencontrés au cours de l'expérimentation ?

9. Quelles ont été les aisances et facilités rencontrées au cours de l'expérimentation ?

10. Comment êtes-vous parvenu à identifier votre curseur ? Avez-vous réussi à le suivre ? Avez-vous réussi à suivre le fil de vos actions et manipulations ?

11. Y a-t-il quoi que ce soit qui aurait pu faciliter l'identification de votre curseur ?

12. Avez-vous eu des difficultés à suivre votre curseur après l'avoir identifié ?

13. Sur une échelle de 1 à 5, dans quelle mesure étiez-vous conscient des gestes et actions des autres participants au cours de l'étude ?

1	2	3	4	5
je n'avais aucune idée de ce qu'ils faisaient				j'étais pleinement conscient de leurs activités

14. Avez-vous échangé avec les autres participants pour vous aider à identifier votre curseur ?

oui non

Si oui, par quel biais ? oral gestuel

D

Collective Loops v2

French Questionnaire

Below is the French version of the questionnaire handed out to participants of the second user study around *Collective Loops* as discussed in [section 4.2.5](#).

Collective Loops v2

Questionnaire

session : _____

heure : _____

Vous avez participé à une expérimentation qui met en interaction des participants autour d'un dispositif interactif collectif. Merci de répondre aux questions ci-dessous concernant votre vécu et ressenti suite à l'expérience :

1. **Quel est votre âge ?** _____

2. **Quel est votre sexe ?** homme femme

3. **Quel a été le symbole (chiffre) de votre emplacement au sol ?** _____

4. **Combien de temps avez-vous passé sur l'expérimentation du dispositif interactif ?**

< 2 minutes 2-5 minutes 5-15 minutes 15-30 minutes > 30 minutes

5. **À quel moment avez-vous compris le fonctionnement du dispositif interactif ?**

jamais après l'expérimentation pendant l'expérimentation au début l'expérimentation avant l'expérimentation

6. **Avez-vous réussi à suivre le fil de vos actions et manipulations ?**

pas réussi du tout plutôt pas réussi sans opinion plutôt réussi tout à fait réussi

7. **Étiez-vous conscient(e) des gestes et actions des autres participants ?**

pas du tout conscient plutôt pas conscient sans opinion plutôt conscient tout à fait conscient

8. **À quelle fréquence avez-vous fait attention aux choix des autres participants ?**

jamais rarement de temps en temps souvent toujours

9. **À quelle fréquence avez-vous échangé avec les autres participants ?**

jamais rarement de temps en temps souvent toujours

Par quel(s) biais ? oral gestuel

E

Collective Loops v2

English Questionnaire

Below is the English version of the questionnaire handed out to participants of the second user study around *Collective Loops* as discussed in [section 4.2.5](#).

Abstract: With works such as *Kinoautomat* by Radúz Činčera, *SAM - Sound Activated Mobile* by Edward Ihnatowicz, and *Glowflow* by Myron Krueger, artists have deployed, as early as the 1960s, art installations engaging novel situations of collective co-located interaction, i.e involving multiple or even many spectators interacting in the same place via and with a digital apparatus. The number of those works has continued to increase since the beginning of the 21st century, taking advantage of the new opportunities offered by advances in real-time computer vision technologies and the advent of ubiquitous computing marked by the multiplication and interoperability of mobile computing devices. While experiences in this area are more and more frequent, they have not yet been the subject of structured analysis and, even less, of proposals for dedicated tools and design methods. How can we, nowadays, conceive such interactive art installations whose intrinsic complexity involves questions of the technical, social, cognitive and aesthetic order?

This dissertation draws on previous work in the fields of human-computer interaction (HCI), computer-supported cooperative work (CSCW), and interactive arts research with the aim of increasing our knowledge of the challenges faced both by art practitioners and participants in such collective interactive installations, and, beyond, the designers of apparatus in a promising future. A set of tools and guidelines are proposed when designing collective co-located interactions for digital art installations. First a classification system is developed centered on the most decisive aspects that allow the emergence of a collective experience. Two distinct approaches are then explored to find the bases of a graphical modeling language for the design and analysis of such apparatus. Build on top of Petri nets, the second approach supports modeling the spatial and material resources of an installation, as well as the human-machine, human-human and human-machine-human interactions. The investigations conducted for this research have required laying particular emphasis on the conditions — whether spatial, material, or human — which affect the ability for participants to co-construct a common aesthetic experience in the absence of orchestration or a preannounced goal to be achieved. While this singular approach primarily concerns interactive arts, it may be relevant to a wide range of research communities, including, and foremost, that of HCI, as well as CSCW, New Interfaces for Musical Expression (NIME), interaction design, and even culture, museography in particular.

Keywords: co-located collective interaction, interactive art, collaboration, audience engagement, Petri nets.

Résumé : À l'instar d'œuvres telles que *Kinoautomat* de Radúz Činčera, *SAM - Sound Activated Mobile* d'Edward Ihnatowicz et *Glowflow* de Myron Krueger, des artistes ont développé, dès les années 1960, des installations artistiques engageant des situations d'interaction collective co-localisée inédites, c'est-à-dire impliquant plusieurs voire de nombreux spectateurs interagissant dans le même lieu via et avec un dispositif informatique. Le nombre de ces travaux ne cesse d'augmenter depuis le début du 21ème siècle, profitant des nouvelles opportunités offertes par les avancées dans les technologies de vision par ordinateur en temps réel et par l'avènement de l'informatique ubiquitaire marquée par la multiplication et l'interopérabilité des appareils informatiques mobiles. Si les expériences en la matière sont de plus en plus fréquentes, elles n'ont jusqu'à ce jour fait l'objet d'aucune analyse structurée et, encore moins, de propositions d'outils et de méthodes de conception dédiés. Comment, aujourd'hui, concevoir de tels dispositifs artistiques interactifs dont la complexité intrinsèque implique des questions aussi bien de l'ordre technique, social, cognitif qu'esthétique ?

Cette thèse met à contribution des travaux antérieurs dans les domaines de l'interaction homme-machine (IHM), du travail coopératif assisté par ordinateur (TCAO) et des arts interactifs dans le but d'accroître notre connaissance quant aux défis auxquels sont confrontés à la fois les artistes et les participants de telles installations et, au-delà, les concepteurs de ces dispositifs en devenir. Un ensemble d'outils et de lignes directrices sont proposés pour la conception de systèmes d'interaction collective co-localisée pour les installations d'art numérique. Est d'abord développé un système de classification centré sur les aspects les plus décisifs permettant l'émergence d'une expérience collective. Deux approches différentes sont ensuite explorées pour trouver les bases d'un langage de modélisation graphique pour l'analyse et la conception de tels dispositifs. S'appuyant sur les réseaux de Petri, la deuxième approche permet de modéliser aussi bien les ressources spatiales et matérielles d'une installation, que les interactions homme-machine, humain(s)-humain(s) et humain(s)-machine(s)-humain(s).

Les investigations menées pour cette recherche ont nécessité de mettre un accent particulier sur les conditions — qu'elles soient spatiales, matérielles ou humaines — qui affectent la capacité pour les participants de telles installations de co-construire une expérience esthétique commune en l'absence d'orchestration ou d'un objectif pré-annoncé à atteindre. Si cette approche singulière concerne en premier lieu les arts interactifs, elle peut revêtir également un caractère pertinent pour d'autres communautés de recherche, y compris et en premier lieu, celle de l'IHM, ainsi que celles du TCAO, des Nouvelles interfaces pour l'expression musicale (NIME), du design d'interaction ou encore de la culture, en particulier de la muséographie.

Mots clés : interaction collective co-localisée, art interactif, collaboration, participation du public, réseaux de Petri.