A taxonomy of multi-user co-located interaction environments

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ABSTRACT
Designing interfaces for multi-user co-located interaction in the context of a leisure environment for the general public[1] involves many challenges. An important one deals with the visual identification and tracking of one's own actions on shared interfaces.

To better design interfaces that promote and facilitate interaction in those environments, it is important to understand the relations between different aspects of such interfaces and the degree of difficulty of participants to visually identify and follow their own actions.

In this article we propose a definition of co-located interaction and classify several reviewed and analyzed projects that fit that specific definition using five high-level characteristics: group size, activity type, I/O distribution, display simultaneity and user attribute.

Key Words
Co-located interaction; data visualization; visual identification.

ACM Classification Keywords
H.5.3 Information Interfaces and Presentation (e.g. HCI): Group and Organization Interfaces.

INTRODUCTION
With financing from the French National Agency for Research, a consortium has been formed bringing together several institutions and agencies to develop a platform, entitled *CoSiMa*, for the creation of co-located collective interaction projects. Taking part of the consortium, EnsadLab (the research laboratory of the « École Nationale Supérieure des Arts Décoratifs ») is commissioned to develop a module for the graphics rendering and data visualization in the platform.

A few *CoSiMa* projects and prototypes in which we took part have already been deployed to the general public such as the *SurExposition* [2] project during the Festival of Lights of 2014 in Lyon, and the *Collective Loops* prototype exhibited during the Ircam Open Days in 2015.

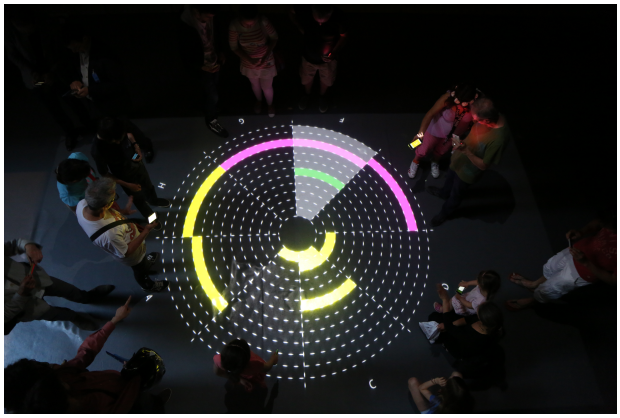

Figure 1. ***Collective Loops*** **at Ircam Open Days, 2015**
Photo © Filipe Pais

Previous experiments were carried out in 2009 and 2011 through the project *Discontrol Party* [3], in which a major cognitive obstacle for an individual interacting in a group was spotted: the identification of one's own actions on a shared interface and the understanding of their effects.

The author's thesis project, conducted as part of the *CoSiMa* project, aims to better understand the reasons behind those difficulties and tries to find graphical and technological solutions in order to facilitate and promote individual, multi-individual and collective interactions in a co-located context.

Drawing upon the developments and observations conducted on *CoSiMa* projects, this article first attempts to define key terms of such interfaces. It then describes different technological and contextual aspects of multi-user co-located interaction projects, and proposes a taxonomic classification of existing projects in regards to those aspects.

The main goal of this taxonomy is to identify and evaluate relevant design patterns that can be employed in co-located multi-user interaction interfaces in order to minimize the difficulties of the identification and tracking of each user's own actions. As a first step towards this taxonomy, we present a framework to classify multi-user co-

[1] Individuals who are not expected to have prior knowledge of the presented interactive system

[2] `http://www.surexposition.net/`

[3] `http://diip.ensadlab.fr/en/projects/article/discontrol-party`

located interaction interfaces and identify the factors that impact the visual identification of user actions. Such a framework would allow practitioners to better design and develop interfaces suited for multi-user interaction in a co-located context.

CO-LOCATED INTERACTION: A DEFINITION

Co-located interaction is a gradually emerging topic in the CSCW and HCI communities [1, 10, 17, 12].

While the term « co-located interaction » (sometimes spelled « collocated interaction ») has been employed in many publications such as [11, 19, 8], it has not, to our knowledge, yet been formally defined. In most publications, the term is usually coined to refer to a, generally small, number of users interacting on a common interface while sharing the same physical space.

In order to better frame the scope of our research, it seemed important to bring more precision to this definition. 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. The following definition tries to deal with this aspect:

> *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.*

Based on this definition, participants in projects such as *Discontrol Party* [3] and *Exposing Contact Patterns* [4], in which they can walk freely between several separated physical spaces while continuing to interact with the system, are considered to be in co-located interaction only with other participants of the same delimited space.

RELATED WORK

Several InfoVis and HCI papers have proposed taxonomies for interactive data visualization.

Grimstead et al. suggested, for example, a taxonomy by classifying collaborative visualization systems [6] using five dimensions: number of simultaneous users, user access control, communication architecture, type of transmitted data and user synchronization. Shneiderman proposed a taxonomy by task type for information visualization [21], and Yi et al. reviewed and categorized information visualization interaction techniques [25].

Yet, as far as we know, none have focused specifically on co-located interactive environments or the visual representation of interaction data in such systems.

[4] `http://www.sociopatterns.org/2008/06/exposing-contact-patterns/`

In the next sections, we review existing co-located interaction projects and classify them using five high-level dimensions that seem to have a direct impact on the visual representation of user actions.

CHARACTERISTICS OF CO-LOCATED INTERACTION

Following the analysis of several projects that fit our definition of co-located interaction, we identified some factors as having a potentially important impact on visual identification in a shared interface:

Group size

The number of supported simultaneous users is an important aspect of co-located interactive projects. Adequate technological and design choices need to be done in order to handle a targeted group size.

It is, for example, difficult to imagine supporting the interaction of a group of more than six members on a 30" (76.2 cm) diagonal interactive table.

Some research has been conducted on the effects of group size on the performance of collaborative tasks on large tabletop displays. Ryall et al. have, for example, observed that the group size influences the strategies employed by users when accomplishing the same set of collaborative goals on interactive tables [20].

Activity type

The type of activity intended by the project could be classified into the following three categories: **individualistic**, **collaborative** and **competitive**.

The *Cambiera* [10] project was, for example, created to specifically support collaborative work for document analysis. The co-located multi-player indie game *Hidden In Plain Sight* [5] was, on the other hand, designed to encourage competitive efforts. Whereas the tabletop interface developed by Klinkhammer et al. [14] was created for an individualistic usage since each user interacts with the table independently from other users.

Some projects support multiple activity types, but each activity type is usually assigned to a specific mode of the project as in BallBouncer [22], which has four game modes: Beach Balls, Bubble Pop, Basketball and Time Bomb each supporting one of the activity categories described above. In our analysis, we will consider each mode to be a separate project.

I/O distribution

Various DUI (Distributed User Interfaces) models have been described and analyzed in regards to how they can be used to support co-located interaction and collaboration [12].

The following models are commonly used:

- **SDG** (Single-Display Groupware): this model enables co-located users to interact « via a shared computer with a single shared display and simultaneous use of multiple input devices » [23]. Although having only one input device, multi-touch tables are usually considered to belong to the SDG category.

[5] `https://www.youtube.com/watch?v=72XXzdVP26g`

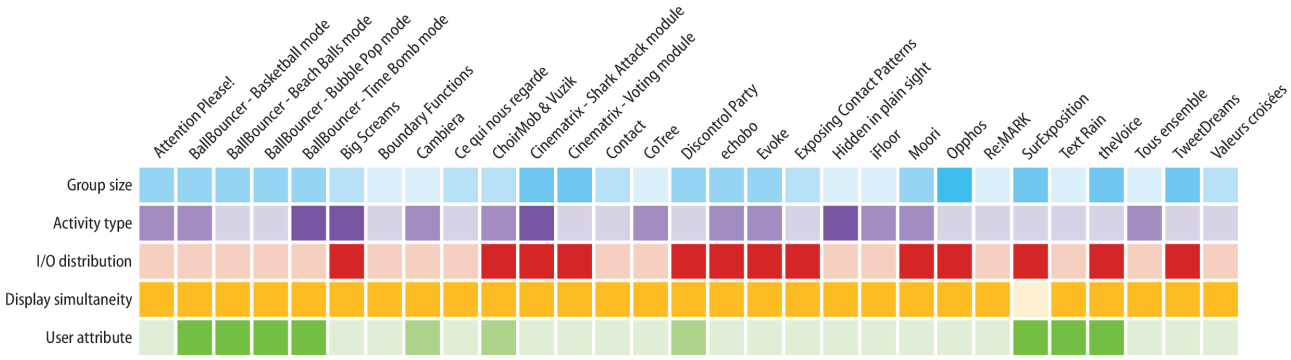

Figure 2. A matrix chart classifying 25 projects, and their derivatives, across 5 dimensions

- **MDG** (Multi-Display Groupware): multiple connected individual/personal and collective/shared devices can form a single environment to support the interaction of multiple users [24].

Display simultaneity

In this dimension we explore whether the interactive data of all users is represented on shared displays at the same time, or if only that of one user is shown at any given moment.

The interactive installation *SurExposition* [2] only exposes the interaction data of one user at a time on the shared display. Here the display simultaneity is treated as being **asynchronous**.

Most project, on the contrary, tend to display the data of all users at once. The display simultaneity of those projects is thus considered to be **simultaneous**.

User attribute

Here we examine the attribute, if any, used to distinguish users on a shared display.

The following general approaches have been spotted in the inspected projects: (1) **none**: no attribute is utilized to differentiate users, (2) **system attribute**: an attribute such as a color or a random id is automatically assigned by the system, and (3) **custom attribute**: the attribute is defined by the user. This includes existing user data such as a phone number or a photo, as well as custom user-generated attributes such as pseudonyms.

DESIGN PATTERNS

We reviewed the following 25 projects, and their derivatives, that fit the declared definition and classified them, to the best of our knowledge, in regards to the dimensions described in the previous section:

Attention Please! [6], *BallBouncer* [22], *Big Screams* [7], *Boundary Functions* [8], *Cambiera* [9], *Ce qui nous regarde* [9], *ChoirMob & Vuzik* [4], *Cinematrix* [2], *Contact* [10], *CoTree* [9], *Discontrol Party* [3], *echobo* [16], *Evoke* [11], *Exposing Contact Patterns* [4], *Hidden in plain sight* [5], *iFloor* [15], *Moori* [13], *Opphos* [18], *Re:MARK* [12], *SurExposition* [2], *Text Rain* [13], *theVoice* [14], *Tous ensemble* [15], *Valeurs croisées* [16], and *TweetDreams* [3]

Figure 2 ranks each project along the five dimensions in a matrix chart in which each dimension is associated to a different color. The color saturation amount of each cell indicates the ranking of the project in that dimension. The saturation increases according to the order of the corresponding value as it appears in the section above, with the exception of group size for which the saturation values correspond to a relative scale of five values, from extra-small to extra-large, depending on the number of participants supported.

Using this graph, we can first observe that only one project does not expose all users on the shared display at once: *SurExposition*, and that the MDG user interface distribution model is used almost equally as much as the SDG model in the analyzed projects.

Also, most projects only support up to 200 participants. Only a few are designed for large groups, and only one of them, *Opphos*, supports very large groups due to its mesh network architecture.

We can also notice that most projects do not include any user attribute that allows participants to distinguish their representation from others'. By looking closer into each of those projects, we can as well see that some of them do not even directly display any user interaction data on the shared devices.

CONCLUSION

In this work we introduced a definition for co-located interaction and proposed five dimensions by which we evaluated and ranked a set of projects in order to better comprehend how they handle the representation of users on shared output devices.

[6] `https://attentionplease.wordpress.com/`
[7] `http://www.bigscreams.com/`
[8] `http://www.snibbe.com/projects/interactive/boundaryfunctions/`
[9] `http://www.jasch.ch/cequinousregarde.html`
[10] `https://uva.co.uk/work/contact`
[11] `http://www.haque.co.uk/evoke.php`
[12] `http://www.flong.com/projects/remark/`
[13] `http://camilleutterback.com/projects/text-rain/`
[14] `http://todo.to.it/#projects/topix_iv`
[15] `http://dispotheque.org/en/tous-ensemble`
[16] `http://dispotheque.org/en/valeurs-croisees`

This classification revealed that projects rarely support very large group interactions, and that most of them do not allow users to easily distinguish their actions from others' by the means of attributes such as colors.

By building upon previous research in the domain such as that of Inkpen et al. in which they explored the effects of different display aspects on co-located collaboration [7], the thesis project seeks to bring new visualization techniques of interaction data for co-located collective environments as well as the development of modules for the *CoSiMa* platform to support and encourage large group interactions.

In addition to expanding the dimensions to include more specific graphical aspects for user representations, studies and observations done on *CoSiMa* projects should allow us to further explore and find solutions to the difficulties encountered by users in the identification and following of their own actions in co-located interaction environments.

A first user study was done on participants of the *Collective Loops* prototype project in June 2015 during the Ircam Open Days by means of user surveys and interviews.

More *CoSiMa* projects and prototypes will be deployed in the near future on which user studies will be undertaken to further apprehend the obstacles confronted by participants in the interaction, and the methods employed to circumvent them. A second *SurExposition* event is, for example, planned for December 2015 at the Palais de Tokyo in Paris.

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