A relational approach to understanding interactions in interactive art

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Chapter 4

Describing and Comparing Co-located Interaction

4.1 Introduction

In Chapter 2 and 3, we introduce the relational model and its accompanying web-based tool, the Relational Modelling Tool (RMT), designed to describe and visualise interactions in interactive art[1]. However, until now, we have not demonstrated the practical application of RMT. This chapter addresses this gap by illustrating how RMT can be employed to describe and analyse various forms of co-located interaction. co-located interaction refers to scenarios in which two or more audience members engage simultaneously with an interactive artwork within a shared physical space. In such contexts, the presence of and interactions among audience members are not merely incidental, but are integral to the artwork itself.

While much of the existing research focuses on audience-artwork interaction, co-located interaction introduces an additional layer of complexity by incorporating interactions among audience members. We consider this an instructive case for demonstrating the capabilities of RMT in capturing the multifaceted dynamics among multiple interacting elements. By applying RMT to a curated selection of interactive artworks designed for co-located interaction, we aim to evaluate its effectiveness in describing and comparing diverse forms of co-located interaction. Additionally, we seek to derive insights into the defining characteristics of such interactions based on the analysis yielded by RMT.

The content of this chapter largely builds on our earlier publication presented at the 12th

[1] The latest version of RMT is accessible via: https://modeltool.liacs.nl

EAI ArtsIT conference(Xu et al., 2024). However, at the time of that publication, RMT had not yet been developed, and the analysis was conducted solely using the relational model. Here, we revisit the selected artworks, re-analysing them with RMT to demonstrate the enhancements in description and analysis afforded by its functionalities.

The chapter is structured as follows: First, we provide a detailed explanation of the seven classification dimensions we developed to categorise a diverse range of co-located interactions, which further inform our selection of representative artworks, which we then describe; Next, we introduce eight selected artworks, providing individual descriptions followed by descriptions of their co-located interactions using RMT; In the subsequent section, we present a comprehensive discussion of the insights gained about co-located interaction, drawing on the similarities and differences identified across the artworks; Finally, we evaluate the effectiveness of RMT in supporting this analytical process, reflecting on its strengths and potential areas for improvement.

4.2 Classifying Co-located Interaction

To demonstrate the capability of RMT in capturing and describing diverse forms of co-located interaction, we develop a set of classification dimensions to select different artworks that are representative of different forms of co-located interaction. The classification dimensions aim to systematically delineate co-located interactions sharing common attributes and show the breadth of the landscape of co-located interaction in interactive art, which can in turn help us position the selected artworks within this landscape.

4.2.1 Previous classification

Mubarak proposed a taxonomy to classify co-located interaction in art installations based on factors influencing the audience experience (Mubarak, 2018). The first dimension *scale* describes the number of participating audience members and is classified as small (less than 10), medium (11 to 100), large (more than 100). The *interaction modality* refers to the method by which the audience interact with the artwork, which can be: through direct physical manipulation (direct); through individual remote input devices (facilitated); captured by non-invasive sensing technologies (ambient). The *input and output distribution* indicates the distribution of input and output devices of the art system and is classed as centralised, partially distributed and fully distributed. The ability of the audience to recognise the effect of their actions in the artwork is described as *feedback attributability* ranging from low to medium to high. The *activity type* describes the audience activity solicited by the artwork, which can be: collaborative

when the audience has to work together; competitive when the audience has to challenge each other; solitary when each audience acts independently. Finally, the last dimension proposed by Mubarak, *participation symmetry*, is first defined by Bell as the "distribution of actions and contributions between participants" (Bell, 1991), which can be either symmetrical when the audience participate equally, or asymmetrical when the audience plays different roles.

4.2.2 Defining classification dimensions

While Mubarak defines factors that influence the audience experience of co-located interaction, here we are interested in how such interactions manifest. Taking Mubarak's taxonomy as a reference, we propose our classification dimensions that focus on delineating the various forms of organisation and participation. To start, the levels of *scale* are delineated by arbitrary numbers and can hardly be considered a defining factor of an artwork. Instead, we propose *participation style* to describe the arrangement of the audience. And it can be classed as duo, which is for two audience members; group, which takes place among one or more groups of audience with limited numbers (larger than 2); crowd, which takes place among one or more crowds of audiences without any practically imposed limits on audience numbers. Additionally, the audience may have varying levels of commitment, either participating consistently throughout the interaction or having the freedom to join and leave as they wish. To distinguish between these two types, we propose *audience constellation* with fixed or fluid scale levels, respectively.

Both *interaction modality* and *input and output distribution* pertain to aspects of the input and output set-up of the art system. For *interaction modality*, we find it difficult to draw meaningful distinctions among its different types. For instance, the audience can directly manipulate a virtual object via camera-tracking technologies, which blurs the distinction between direct and ambient modalities. For *input and output distribution*, we think that the technical configuration of the art system cannot sufficiently describe the access the audience has to it. A set of distributed devices can still be accessed by the audience equally and publicly. Instead, we propose the dimension *input and output access* and distinguish private (accessible to one audience member only), partially public (accessible to more than one but not all audience members), and public (accessible to all audience members). An art system can have multiple private, partially public, public or mixed varieties of inputs and outputs.

The *feedback attributability* impacts the individual experience of participants, but is less of a defining factor differentiating different forms of interaction. Instead, we would like to adopt the dimensions of *activity type* and *participation symmetry*. Moreover, in many interactive artworks, the audience engages in open, hybrid and/or exploratory social activities that

can neither be defined as collaborative nor as competitive. Sometimes the audience can also invent and transition between different types of activities. Therefore, we class *activity type* as individual, which means the audience participate individually and independently; social, which means the activities require more than one audience member to perform together; and mixed, which means both types are supported. For *participation symmetry*, besides symmetrical and asymmetrical, we include varied to indicate when participants can transition between the two.

Lastly, as mentioned before, the art system can not only respond to the audience but also initiate the interaction. We propose *initiator* to indicate which element initiates the interaction, and it can be the audience, art system, other, and varied when the elements have equal chance to initiate the interaction. All the dimensions and their respective scale levels are presented in table 4.1.

Table 4.1: Classification dimensions and their scale levels for co-located interactive artworks.

Dimensions	Scale levels			
Participation style (PS)	Duo	Group	Crowd	
Audience constellation (AC)	Fixed	Fluid		
Input access (IA)	Private	Partially public	Public	Mixed
Output access (OA)	Private	Partially public	Public	Mixed
Participation symmetry (PSy)	Symmetrical	Asymmetrical	Varied	
Activity type (AT)	Individual	Social	Mixed	
Initiator (In)	Art system	Audience	Other	Varied

4.3 Artwork Selection

The classification dimensions define a 7-dimensional space with over 3,000 different combinations that represent potential forms of co-located interaction. However, these dimensions are not entirely independent of each other, for instance, the *input and output access* cannot be partially public if the *participation style* is duo. It is also reasonable to assume that not all combinations have been realised. Nonetheless, it is impractical to cover all existing varieties of co-located interaction within the scope of this chapter.

To tackle this dilemma, we suggest prioritising some dimensions and scale levels to narrow down the selection while still preserving the potential to show the diversity of co-located interaction. Considering that not all combinations of the dimensions can be realised in each *participation style* and that the group and crowd share quite some similarities, we do not consider each scale levels independently but aim to cover all the variations in the final selection.

In addition, the different types of *input and output access* indicate how much freedom each audience has in the interaction and what kind of information is available to them. They affect the organisation of the audience, however, they are less significant than *participation symmetry* when it comes to considering the effects of the audience's action on the art system and the interaction. Therefore, we decide to not consider the varieties of *input and output access* when selecting the final artworks.

Furthermore, for *participation symmetry*, we propose to take the scale level varied as an alternative to either symmetrical or asymmetrical. Given the definition of co-located interaction, the audience are likely to engage in social or mixed instead of individual activities. As co-located interaction mainly concerns the involvement of the audience and the art system, we focus on the audience or the art system as the *initiator*. These considerations significantly reduce the space from which artworks can be selected, making the selection process more practical.

We searched for artworks in online archives such as the Ars Electronica Archives ("Ars Electronica Archives", 2023) and the Archives of Digital Art ("Archives of Digital Art", 2023), and from personal knowledge of existing artworks. We selected eight artworks that satisfy the selection criteria and occupy a meaningful position in the classification. These chosen artworks encompass a range of interactive experiences, including performances, games, and interactive installations, and were created between 1997 and 2016. All artworks and their corresponding classification scale levels are summarised in table 4.2.

Table 4.2: Eight selected artworks and their classification scale levels.

Artwork	PS	AC	IA	OA	PSy	AT	In
Brainball (2003)	Duo	Fixed	Private	Public	Symmetrical	Social	Audience
Randomly Generated Social Interactions (2016)	Duo	Fixed	Private	Public	Symmetrical	Social	Art system
World Skin (1997)	Group	Fixed	Private	Public	Asymmetrical	Social	Audience
Zoom Pavilion (2015)	Crowd	Fluid	Public	Public	Asymmetrical	Mixed	Art system
Boundary Functions (1998)	Group	Fluid	Public	Public	Symmetrical	Social	Audience
Spatial Sounds (100 dB at 100 km/h) (2000)	Crowd	Fluid	Public	Public	Varied	Mixed	Art system
Lights Contacts (2009)	Crowd	Fluid	Partially public	Public	Asymmetrical	Social	Audience
Body Movies (2001)	Crowd	Fluid	Public	Public	Symmetrical	Mixed	Audience

4.4 Modelling Diverse Co-located Interaction

In this section, we introduce the artworks individually based on their positions in the classification dimensions and present the description of the co-located interaction within each artwork using RMT.

4.4.1 *Brainball* (2003) by Smart Studio

Figure 4.1: Smart Studio, *Brainball*, 2003. (©photo by paulbetterner)

Brainball is a game that utilises a brain-computer interface between two participants (Hjelm, 2003) (see Figure 4.1). The brain activity of each participant is measured using an EEG sensor, which controls the movement of a steel ball on a table. The more relaxed player, as detected by the sensors, scores a goal over the other player. Since ***Brainball*** requires the simultaneous participation of two players, it can be classified as a duo *participation style* within a fixed *audience constellation*. The *input access* is private as each player uses the sensor individually, while the *output access* is public as the ball movement and a screen displaying gathered brain-

wave data visible to all present. The *participation symmetry* is symmetrical, as both players contribute equally to the interaction. Given that the interaction takes the form of a competitive game, the *activity type* is social. The interaction is initiated by one player (*initiator*) pressing a button. ***Brainball*** exemplifies a form of co-located interaction with a fixed and symmetrical participation style in a social activity initiated by the audience.

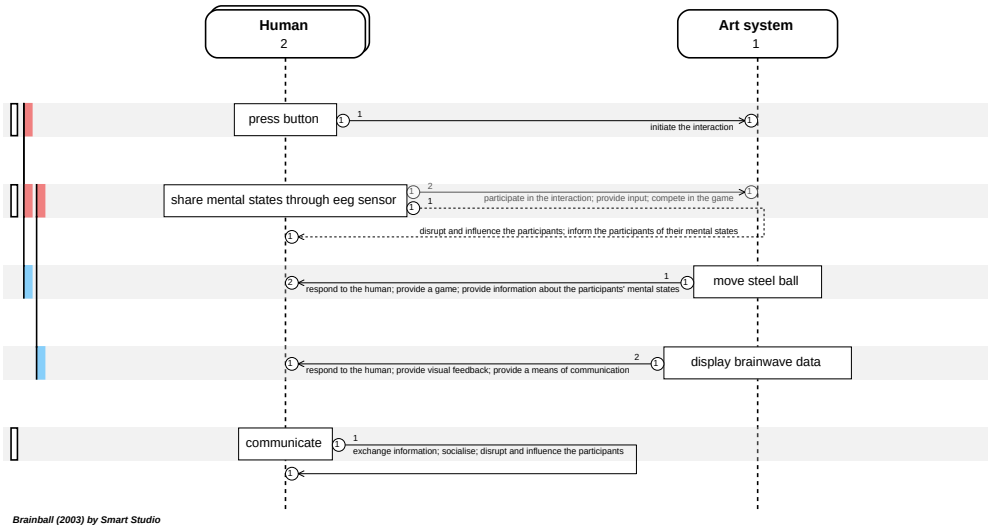

Figure 4.2: Visualisation of described interaction in ***Brainball*** using RMT.

The detailed description of ***Brainball*** can be accessed in this worksheet[2] and the visualisation is shown in Figure 4.2. Using RMT, we identify two element profiles: two participants and an art system. All actions of the elements are intended for participating in the interaction. The interaction begins with either player pressing a button to initiate a direct public communication with the art system. Following this, both players connect to the EEG sensor, sharing their mental states through a direct private communication with the art system. This step enables them to provide inputs to the art system, actively participate in the interaction, and compete in the game.

In response to these inputs, the art system moves the steel ball towards the player who is less relaxed, thereby creating a game dynamic and conveying information about their relative mental states. This action results in a form of direct public communication to both players. Simultaneously, the art system displays real-time brainwave data on a screen, offering visual feedback in a direct public communication to the players. This feedback further informs the

[2]https://modeltool.liacs.nl/?artwork=brainball

players about their mental activities, resulting in a mediated public communication between them, distracting them from relaxation and disrupting their performance.

Throughout the interaction, the players can engage in a direct public communication with each other, exchanging information, socialising, and attempting to disrupt or influence each other's performance.

4.4.2 *Randomly Generated Social Interactions* (2016) by Anastasis Germanidis

Randomly Generated Social Interactions is an interactive performance in which the audience is instructed by the art system to interact with one another (Germanidis, 2016). While the artwork accommodates a group of participants, the interaction is primarily designed for pairs, therefore we classify it as a duo *participation style* within a fixed *audience constellation*. The artwork provides both private *input and output access* to each audience member through the use of mobile phones and headphones. Despite being assigned different fictional identities, the *participation symmetry* remains symmetrical, as all participants have equal roles in the interaction. The *activity type* is social, as the performance requires the audience to engage with each other. Unlike ***Brainball***, where the audience initiates the interaction, here the art system acts as the *initiator* by delivering instructions to participants. In summary, ***Randomly Generated Social Interactions*** demonstrates a form of co-located interaction with a fixed and symmetrical participation style in a social activity initiated by the art system.

The detailed description of ***Randomly Generated Social Interactions*** can be accessed in this worksheet[3] and the visualisation is shown in Figure 4.3. Using RMT, we identify two element profiles: two or more participants and an art system. All actions of the elements are intended for participating in the interaction. First, the art system assigns fictional identities to each participant through a direct private communication. This step provides background information and prepares participants for the upcoming interaction. Next, it delivers instructions to each participant, again via a direct private communication, to initiate the interaction, direct their actions, and stimulate social interactions.

In response to both actions performed by the art system, the participants enact these instructions, engaging in a direct public communication with one another as they participate in the interaction and comply with the command of the art system. By responding to these instructions, the enacting participants also transmit the instructions from the art system to the receiving participants through a mediated public communication.

Additionally, the participants communicate directly and publicly to each other to exchange

[3] https://modeltool.liacs.nl/?artwork=randomly

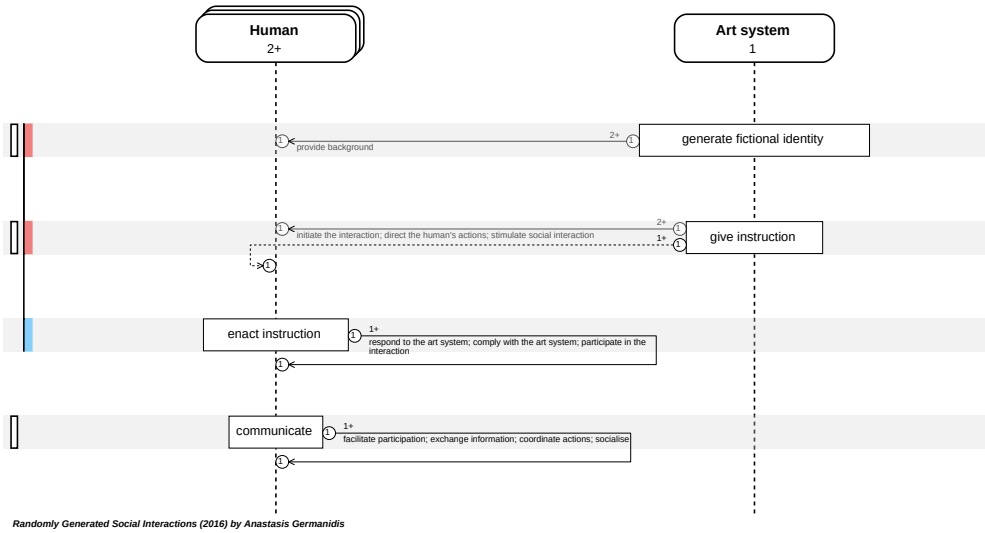

Figure 4.3: Visualisation of described interaction in ***Randomly Generated Social Interactions*** using RMT.

information, coordinate actions and socialise. This direct communication further supports their participation in the interaction.

4.4.3 *World Skin* (1997) by Maurice Benayoun

World Skin an interactive artwork that takes the form of a photo safari within an immersive projection of a war zone landscape (Benayoun, 1997) (see Figure 4.4). One participant plays the role of a 'driver' and navigates in the virtual landscape, while others take on the role of a 'photographer', capturing photos of the landscape with sensor-fitted cameras. Like the previous two artworks, ***World Skin*** features a fixed *audience constellation* and a social *activity type*, as participants must collaborate to navigate the environment and take photos. However, unlike the other works, this piece requires more than two participants and the number of participants is limited by the available input devices, leading us to classify it as a group *participation style*. Each participant has private *input access* using their respective devices and public *output access* as the projection is visible to all present. The participants initiate the interaction and play different roles, resulting in an asymmetrical participation. Overall, this artwork exemplifies a form of co-located interaction with a fixed and asymmetrical participation style in a social activity initiated by the audience.

Figure 4.4: Maurice Benayoun, *World Skin*, 1997. (©photo by MoBen)

The detailed description of ***World Skin*** can be accessed in this worksheet[4] and the visualisation is shown in Figure 4.5. Using RMT, we identify three element profiles: one participant as the driver, one or more participants as the photographers and an art system. All actions of the elements are intended for participating in the interaction. To start, the driver initiates the interaction by moving the joystick in a direct private communication to the art system, which allows them to participate in the interaction and navigate the virtual landscape.

In response, the art system updates the landscape in a direct public communication to all participants. This response provides visual feedback about the actions of the driver, as well as content for interaction and a means of communication among participants. Additionally, the driver can also communicate to the photographers via the responses of the art system to express their points of view and collaborate with them in a mediated public communication.

The photographers, in turn, take photos of the landscape to initiate and participate in the interaction in a direct public communication to the art system. In response, the art system

[4]https://modeltool.liacs.nl/?artwork=worldskin

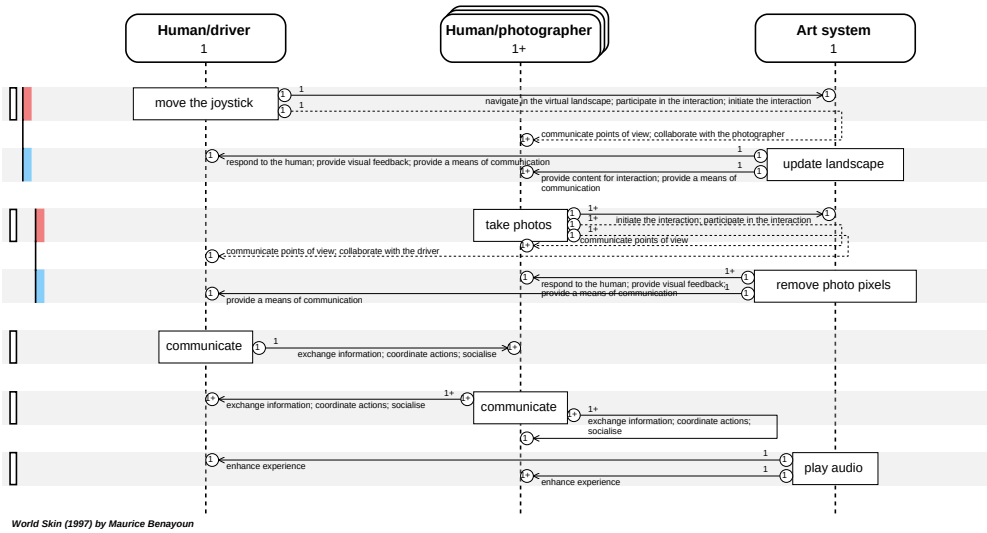

Figure 4.5: Visualisation of described interaction in ***World Skin*** using RMT.

removes the pixels of photographed portions of the landscape in a direct public communication to all participants, providing visual feedback about the actions of the photographers and a means of communication among all participants. The photographers can also communicate both within themselves and to the driver via the responses of the art system in a mediated communication, allowing them to express points of view and collaborate with the driver and each other. As multiple photographers can take photos simultaneously, multiple instances of these communications can occur concurrently.

Throughout the interaction, the art system also plays audio in a direct public communication to all participants to enhance their experience. Meanwhile, all participants can communicate directly and publicly to each other to exchange information, coordinate actions and socialise.

4.4.4 *Zoom Pavilion* (2015) by Rafael Lozano-Hemmer and Krzysztof Wodiczko

Zoom Pavilion is an interactive installation that immerses the audience in a live projection of their own images, captured through surveillance technologies (Lozano-Hemmer, 2015) (see Figure 4.6). Utilising recognition algorithms, the installation detects the faces and bodies of participants, establishing various relational dynamics within the exhibition space. Unlike the previous mentioned artworks, ***Zoom Pavilion*** accommodates a growing number of audience

Figure 4.6: Rafael Lozano-Hemmer and Krzysztof Wodiczko, *Zoom Pavilion*, 2015. (©Antimodular Research)

and there is no clear demarcation between observers and participants. We consider its *participation style* as crowd and *audience constellation* fluid, although the number of participants is ultimately constrained by the physical capacity of the exhibition space. Both of its *input and output access* are public, allowing all participants to share and perceive the experience equally. However, as the system selectively zooms in on certain individuals and draws connections between their bodies, it creates an asymmetrical participation dynamic. The *activity type* is mixed, enabling both individual and collective participation. The art system initiates the interaction by actively selecting and connecting participants. This artwork exemplifies a form of co-located interaction with a fluid and asymmetrical participation style in mixed types of activities initiated by the art system.

The detailed description of ***Zoom Pavilion*** can be accessed in this worksheet[5] and the visualisation is shown in Figure 4.7. Using RMT, we identify two element profiles: one or more participants and an art system. At the outset, one or more audience members enter the exhibition space, not necessarily intending to participate in the interaction. Nevertheless, their presence and actions are detected by the art system, initiating a direct public communication

[5] https://modeltool.liacs.nl/?artwork=zoom

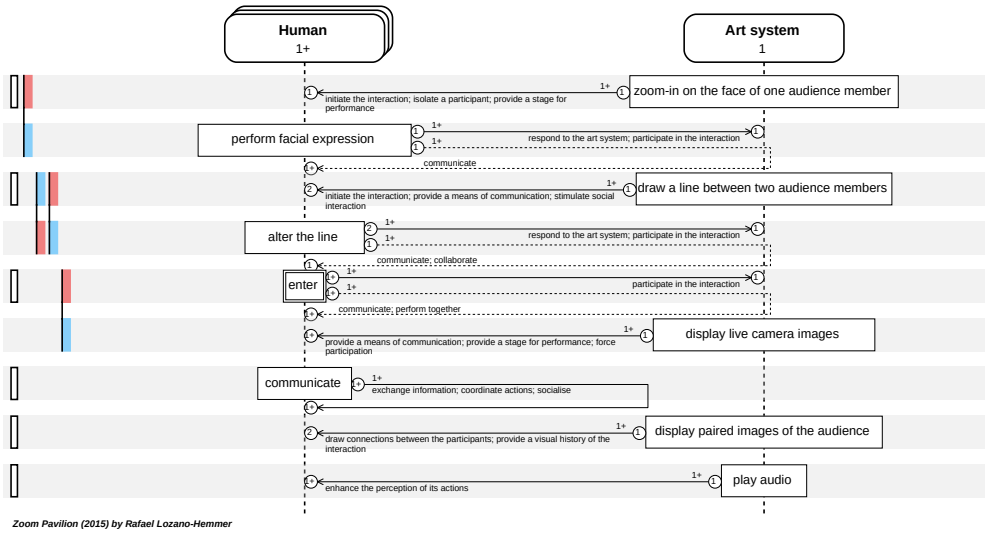

Figure 4.7: Visualisation of described interaction in ***Zoom Pavilion*** using RMT.

from the audience to the art system. In response, the art system displays live camera images of the audience, creating a direct public communication to all present. This feedback compels the audience to engage with the artwork and provides a medium for communication among them. Once participants become aware of the responses of the art system, they may choose to actively participate, further interacting with both the art system and each other through its feedback.

The art system also independently initiates interaction by selecting and zooming in on the face of an individual audience member in a direct public communication. This action isolates the participant, placing them in a performative role. The selected individual may respond by making facial expressions in a direct communication to the art system, thereby also indirectly communicating with other audience members via the responses of the art system. Additionally, the art system dynamically connects two participants by drawing a line between them, establishing a form of direct public communication directed at those involved. This action not only initiates engagement of the audience but also stimulates social interactions between them. The selected participants can respond by moving in a direct communication to the art system, which alters the line, enabling them to collaborate and communicate via the responses of the art system.

Finally, the art system pairs and projects images of the audience members' faces onto a wall, creating a direct public communication visible to all present. This action actively establishes connections between audience members and provides a visual record of the interaction.

Throughout the interaction, the art system plays audio that accompanies its actions in a direct communication to all audience members, enhancing their perceptions of its activities. And the audience can also communicate directly and publicly with one another, exchanging information, coordinating actions, and socialising.

4.4.5 *Boundary Functions* (1998) by Scott Snibbe

Figure 4.8: Scott Snibbe, *Boundary Functions*, 1998. (©Scott Snibbe)

Boundary Functions is an interactive installation designed for multiple participants simultaneously (Snibbe, 1998) (see Figure 4.8). The installation remains inactive when only one participant is present. When two or more people enter the space, the floor divides into cellular regions, each corresponding to the area closest to a participant—a pattern known as a Voronoi diagram. The *participation style* is group, as the number of participants is constrained by the physical set-up of the installation. Similar to ***Zoom Pavilion***, participants can freely join and leave the interaction in a fluid *audience constellation*. Both *input and output access* are public, as they can be shared and perceived by all participants. The *participation symmetry* is sym-

metrical, as the art system treats each participant equally. Since the art system also reacts to the social behaviours of the participants, the *activity type* is social, with the audience acting as the *initiator* of the interaction. It exemplifies a form of co-located interaction with fluid and symmetrical participation style in a social activity initiated by the audience.

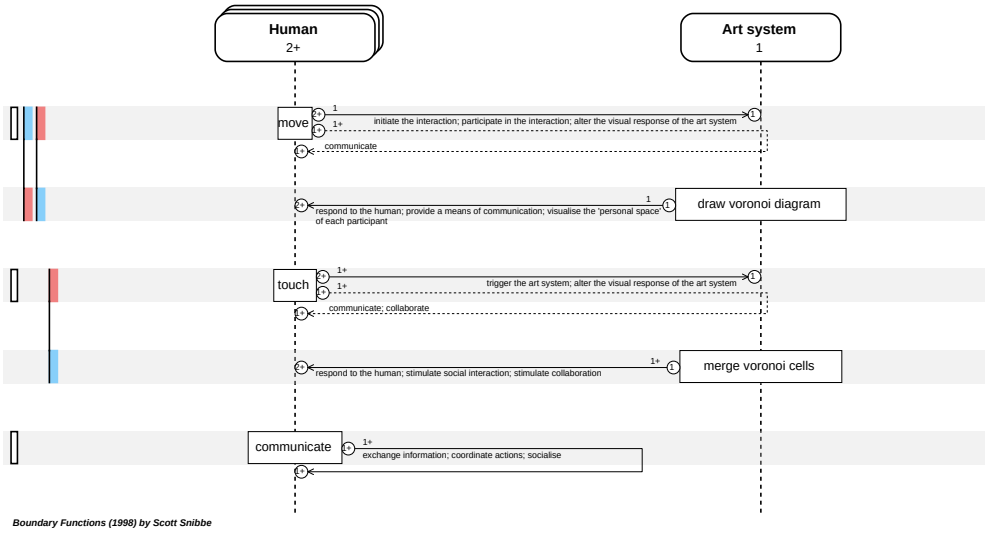

Figure 4.9: Visualisation of described interaction in ***Boundary Functions*** using RMT.

The detailed description of ***Boundary Functions*** can be accessed in this worksheet[6] and the visualisation is shown in Figure 4.9. Using RMT, we identify two element profiles: two or more participants and an art system. All actions of the elements are intended for participating in the interaction. The interaction begins when two or more participants enter and move within the installation space. Their movements are captured by the art system, establishing a direct public communication from the participants to the art system. This enables them to initiate and actively engage in the interaction.

In response, the art system generates a Voronoi diagram based on the positions of the participants in a direct public communication to all participants. This action visualises the 'personal space' of each participant, creates a visual connection among them, and provides a means of communication. Consequently, the participants can communicate with each other via the response of the art system by moving around to alter the Voronoi pattern.

Additionally, when two or more participants touch one another, the art system detects this action, resulting in a direct public communication from the participants to the art system. This

[6]https://modeltool.liacs.nl/?artwork=boundary

action allows the participants to trigger a distinct response from the art system. Specifically, the art system merges the Voronoi cells of the participants in contact in a direct public communication. This response further encourages social interactions and collaborations among the participants.

Throughout the interaction, participants can also communicate directly and publicly with one another, exchanging information, coordinating actions, and socialising.

4.4.6 *Spatial Sounds (100 dB at 100 km/h)* (2000) by Marnix de Nijs and Edwin van der Heide

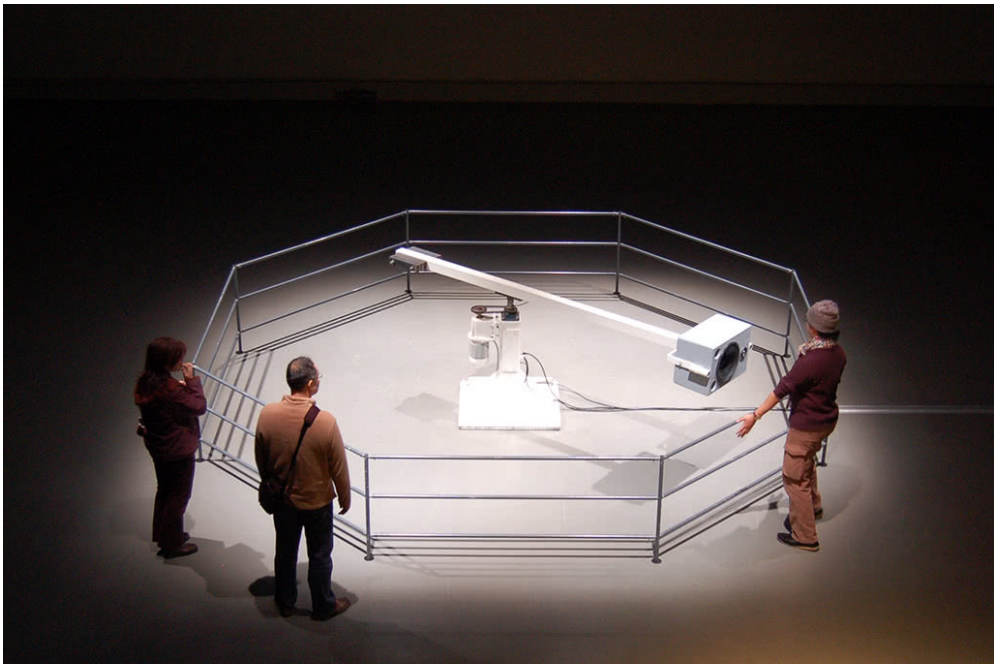

Figure 4.10: Marnix de Nijs and Edwin van der Heide, *Spatial Sounds (100 dB at 100 km/h)*, 2000. (©Edwin van der Heide)

Spatial Sounds (100 dB at 100 km/h) is an interactive installation that features a speaker mounted on a robotic arm, equipped with various sensors that detect both the actions of the audience and its own movements (van der Heide, 2011) (see Figure 4.10). The installation operates across four distinct interaction modes, which are determined by the behaviour of the audience and predefined parameters. The *participation style* is group, as the number of audience is limited by the sensing resolution of the art system. Similar to the previous two artworks,

the audience can join and leave the interaction freely in a fluid *audience constellation*. Unlike all previous artworks, the art system has different modes of behaviour and results in a varied *participation symmetry* and a mixed *activity type*. For instance, in mode 2 only one audience member is selected by the art system, while in mode 3 all audience members have equal chance to engage in a social activity solicited by the art system. The *input and output access* to the art system are public, and the art system initiates the interaction. This artwork exemplifies multiple forms of co-located interaction, characterised by a fluid and varied participation style across mixed activity types, all initiated by the art system. It also illustrates how different forms of co-located interaction can be combined to enrich the interactive experience. Below, we present the descriptions of each interaction mode separately.

Interaction mode 1

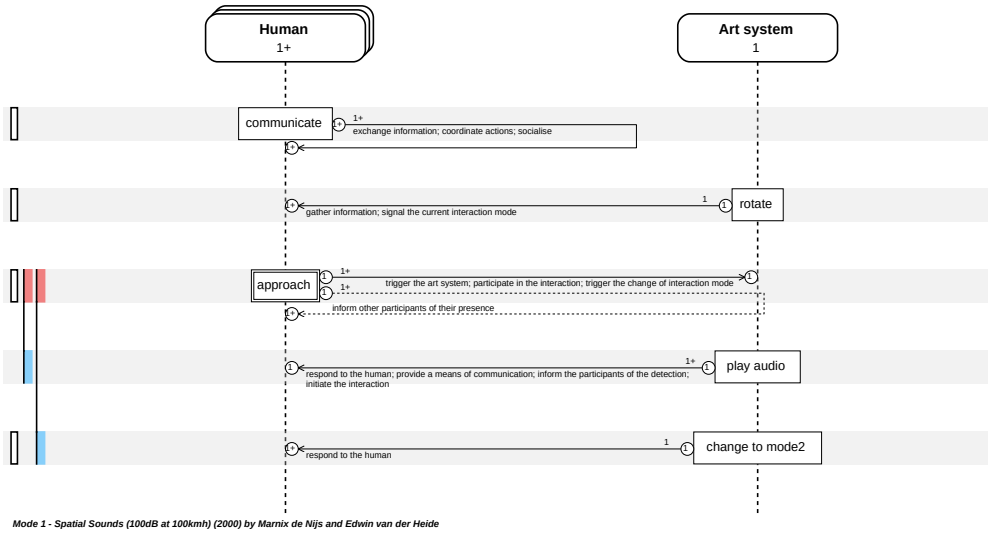

Figure 4.11: Visualisation of described interaction mode 1 in ***Spatial Sounds (100 dB at 100 km/h)*** using RMT.

The detailed description of the interaction mode 1 of ***Spatial Sounds (100 dB at 100 km/h)*** can be accessed in this worksheet[7] and the visualisation is shown in Figure 4.11. Using RMT, we identify two element profiles: one or more participants and an art system. In this mode, the robotic arm begins by rotating slowly, scanning the space while emitting a low humming sound. This action establishes a direct public communication to all audience members, allow-

[7] https://modeltool.liacs.nl/?artwork=spatialsounds1

ing the art system to gather information about their presence and signal the current interaction mode. During this phase, audience members may approach the system without necessarily intending to participate. However, once their presence is detected, a direct public communication is established from the audience to the art system, enabling them to engage in the interaction and potentially trigger a transition to a different interaction mode.

Upon detecting an audience member, the art system responds with an audio signal in a direct public communication to all present. This feedback informs the audience of the detection and initiates the interaction, while also serving as a means for communication among them. As multiple audience members can be detected simultaneously, several instances of this communication may occur concurrently. Consequently, participants can use these auditory cues to signal their presence to one another in a mediated public communication.

Throughout the interaction, the audience can also communicate directly and publicly with each other, exchanging information, coordinating actions, and socialising. After detecting an individual, the art system continues scanning for a predetermined period before transitioning to interaction mode 2. This shift is signalled through a direct public communication to all participants.

Interaction mode 2

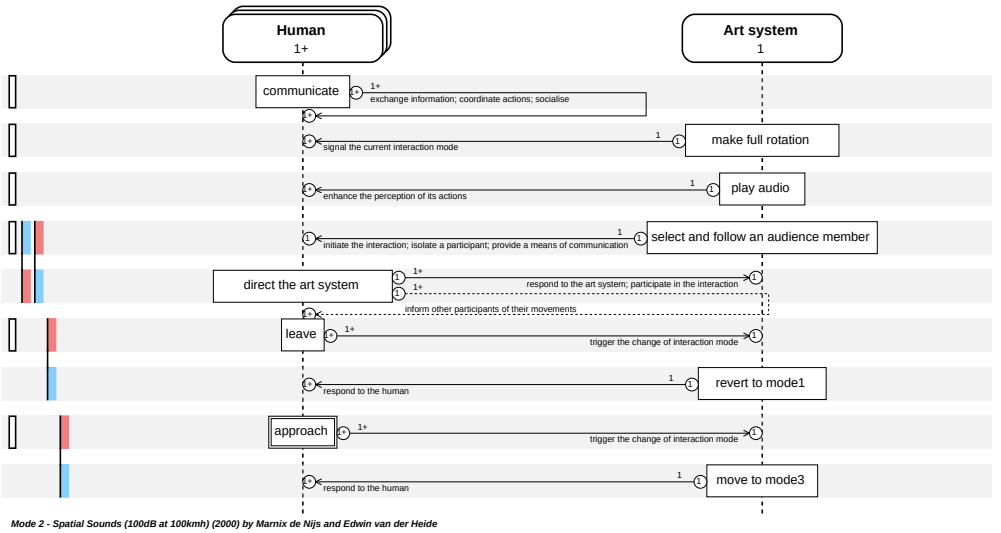

Figure 4.12: Visualisation of described interaction mode 2 in ***Spatial Sounds (100 dB at 100 km/h)*** using RMT.

The detailed description of the interaction mode 2 of ***Spatial Sounds (100 dB at 100 km/h)*** can be accessed in this worksheet[8] and the visualisation is shown in Figure 4.12. In this mode, we similarly identify two element profiles: one or more participants and an art system. At the onset, the art system performs a complete rotation to scan the surrounding space in a direct public communication to the audience, gathering inputs and signal the current interaction mode through direct. Following this, the art system selects and tracks a single participant in a direct public communication to initiate the interaction. By isolating the chosen individual from the broader audience, the art system also provides them with a means of communication. In response, the selected participant can move to influence the art system's position in a direct public communication to participate in the interaction. Furthermore, the participant can also convey their movements to the wider audience via the art system's responses.

Throughout the interaction, participants can also communicate with each other directly and publicly to exchange information, coordinate actions and socialise. Meanwhile, other audience members can still approach the art system, and their presence is detected by the system, establishing a direct public communication from the audience to the system. This detection triggers the art system to switch to interaction mode 3. It is important to note that although the art system attempts to follow a specific participant, it may lose track if the individual moves away or if another participant intervenes between them and the system. Additionally, when participants move away from the art system, this action is detected, prompting the art system to revert to interaction mode 1.

Interaction mode 3

The detailed description of the interaction mode 3 of ***Spatial Sounds (100 dB at 100 km/h)*** can be accessed in this worksheet[9] and the visualisation is shown in Figure 4.13. Here, we identify two element profiles: one or more participants and an art system. In this mode, the art system first rotates at a fixed speed to signal the current interaction mode and generates an audio based on the rotation speed to enhance the perception of its movement. These actions establish a direct public communication to all participants. Meanwhile, one or more participants can approach the art system without necessary intending to participate, establishing a direct public communication to the art system. Upon detecting a participant, the art system immediately changes its rotation direction and generates an audio response in direct public communication, thereby initiating the interaction and introducing a game-like experience for the participants. In turn, the participants can communicate with each other via these responses of the art system, allowing them to engage in a playful activity by passing the system around.

[8] https://modeltool.liacs.nl/?artwork=spatialsounds2
[9] https://modeltool.liacs.nl/?artwork=spatialsounds3

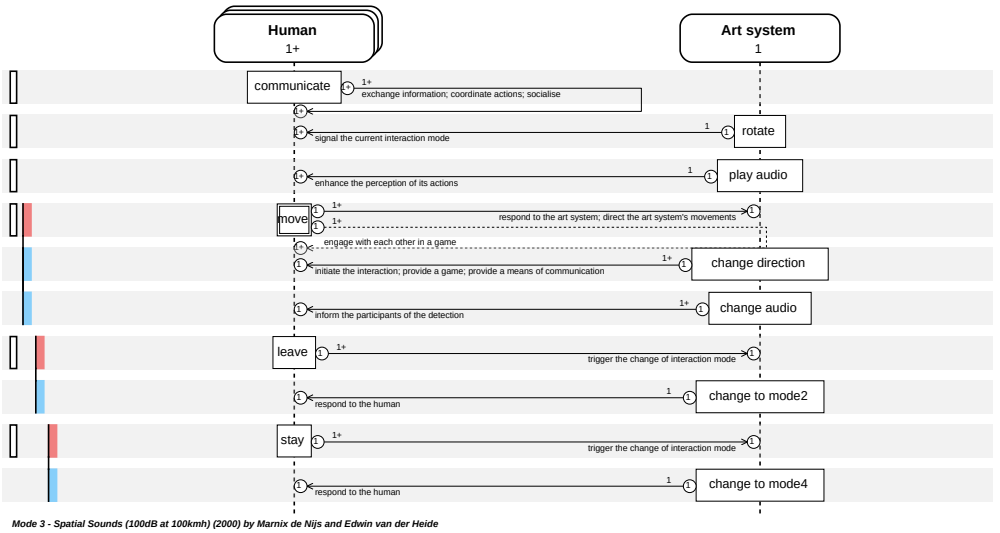

Figure 4.13: Visualisation of described interaction mode 3 in ***Spatial Sounds (100 dB at 100 km/h)*** using RMT.

Throughout the interaction, participants can also communicate with each other directly and publicly to exchange information, coordinate actions and socialise. If participants stay in front of the art system, they trigger it to switch to interaction mode 4. Conversely, if they move away, the art system reverts to interaction mode 2.

Interaction mode 4

The detailed description of the interaction mode 4 of ***Spatial Sounds (100 dB at 100 km/h)*** can be accessed in this worksheet[10] and the visualisation is shown in Figure 4.14. In this mode, two element profiles are identified: one or more participants and the art system. Initially, the art system speeds up its movement in direct public communication to all present to signal the current interaction mode and urge participants to move away. Once the participants do so, the art system slows down in a direct public communication as a response, indicating a change in its behaviour. Meanwhile, the art system also generates audio based on its rotational speed in direct public communication to all audience members to enhance their perceptions of its movement. The audience can then choose to move away as a response in a direct public communication to comply with the art system.

After a predetermined period, the art system automatically reverts to interaction mode 3.

[10] https://modeltool.liacs.nl/?artwork=spatialsounds4

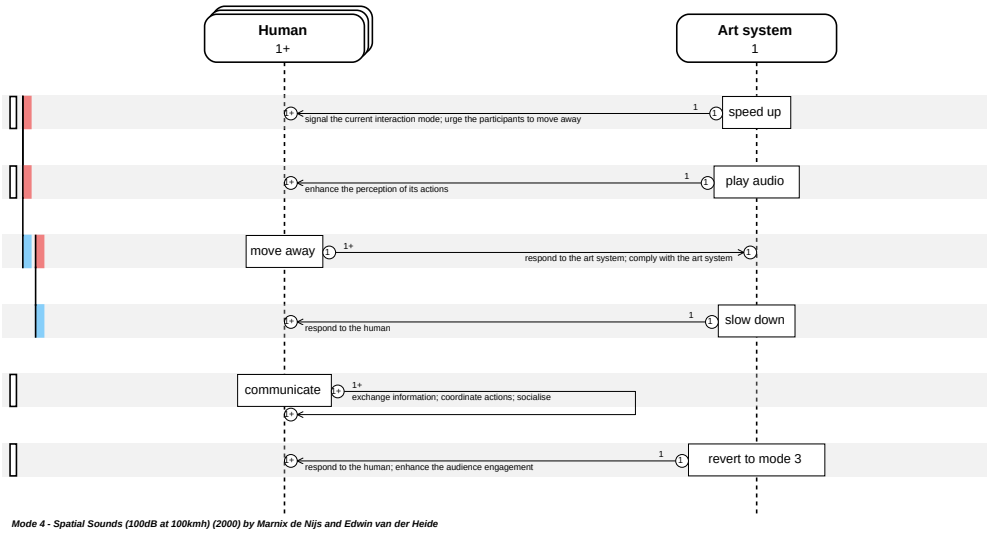

Figure 4.14: Visualisation of described interaction mode 4 in ***Spatial Sounds (100 dB at 100 km/h)*** using RMT.

Throughout the interaction, participants can also communicate with each other directly and publicly to exchange information, coordinate actions and socialise.

4.4.7 *Lights Contacts* (2009) by Scenocosme

Lights Contacts is an interactive installation that responds to physical contact between participants by generating varying sounds and lights in a public setting (Scenocosme, 2009) (see Figure 4.15). To activate the system, a participant must first place their hand on a sensor ball, effectively becoming an extension of the art system's sensing unit. When another participant touches the skin of the first participant, the art system detects changes in electrostatic charge, generating corresponding sounds and altering the lighting. The *participation style* here is crowd, as an unlimited number of participants can engage with the installation. Similar to the previous three artworks, the *audience constellation* is fluid, allowing participants to join and leave the interaction at any time. However, since the sensor ball is available to only a limited number of participants, the *input access* is partially public. In contrast, the *output access* is fully public, as the sounds and lights are displayed openly to all. Similar to ***World Skin***, the *participation symmetry* here is asymmetrical, as only some participants are required to touch the sensor ball. The *activity type* is social, with the audience relying on each other to initiate and sustain the interaction. ***Lights Contacts*** exemplifies a form of co-located interaction with

Figure 4.15: Scenocosme, *Lights Contacts*, 2009. (©Scenocosme)

fluid and asymmetrical participation style in a social activity initiated by the audience.

The detailed description of ***Lights Contacts*** can be accessed in this worksheet[11] and the visualisation is shown in Figure 4.16. Using RMT, we identify three element profiles: one participant as a sensor, one or more participants and an art system. All actions of the elements are intended for participating in the interaction. To start, one participant must touch the sensor ball of the art system in a direct private communication to activate it, thereby becoming part of its sensing unit. Subsequently, this participant must touch other participants in a direct public communication, or vice versa, to initiate the interaction, as well as influence the response of the art system. Additionally, when other participants come into contact with the participant who is in contact with the sensor ball, they too become part of the sensing unit due to the conductive properties of human bodies.

In response, the art system plays and alters the audio based on the proximity and touch intensity of the participants in a direct public communication to all participants. This action provides feedback about the actions of the participants, as well as a means of communication among them. Additionally, it also adjusts the light in accordance with the audio in a direct public communication to all participants to enhance their experiences. Via these responses of the art system, the audience can communicate with each other to collaborative play and performance.

[11] https://modeltool.liacs.nl/?artwork=lights

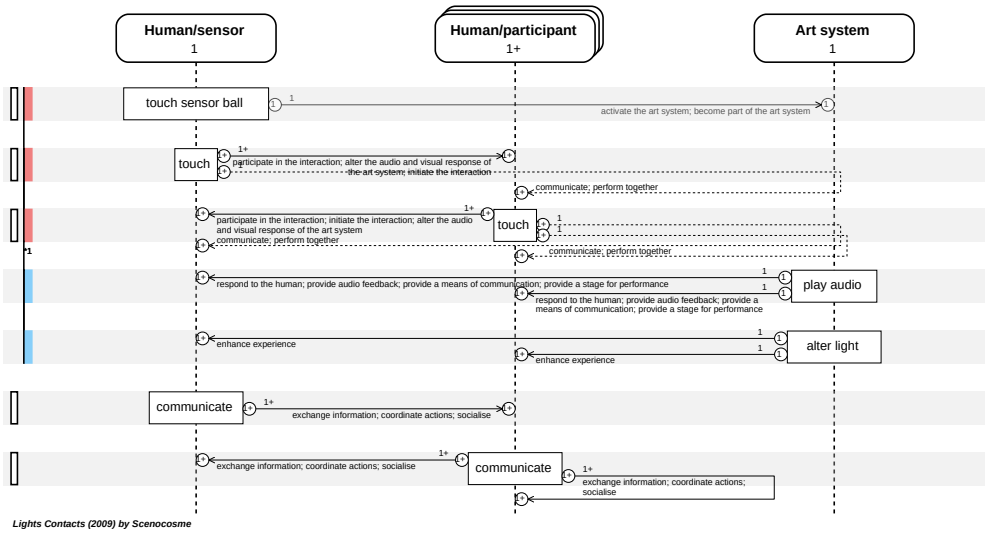

Figure 4.16: Visualisation of described interaction in ***Lights Contacts*** using RMT. *1: (If human/sensor touches sensor ball AND If human/sensor touches human/participant) OR (If human/sensor touches sensor ball AND If human/participant touches human/sensor)

Throughout the interaction, participants can also communicate with each other directly and publicly to exchange information, coordinate actions and socialise.

4.4.8 *Body Movies* (2001) by Rafael Lozano-Hemmer

Body Movies is an interactive projection installation for public spaces (Lozano-Hemmer, 2001) (see Figure 4.17). The audience members can participate by casting their shadows on a large projection screen to reveal hidden portraits and perform with one another. Similar to ***Lights Contacts*** and ***Zoom Pavilion***, the *participation style* is crowd, as there is no practically imposed limit on the number of participants, and they have the freedom to join and leave the interaction in a fluid *audience constellation*. The *input and output access* are both public, as they are shared and perceived by all audience equally. The *participation symmetry* is symmetrical, because there is no separately designated roles for the participants. They can interact both individually and with each other to reveal portraits or perform together in a mixed *activity type*. The audience initiate the interaction by casting shadows on the projection surface. Overall, ***Body Movies*** exemplifies a form of co-located interaction with fluid and symmetrical participation style in mixed types of activities initiated by the audience.

Figure 4.17: Rafael Lozano-Hemmer, *Body Movies*, 2001. (©Antimodular Research)

The detailed description of ***Body Movies*** can be accessed in this worksheet[12] and the visualisation is shown in Figure 4.18. Using RMT, we identify two element profiles: one or more human participants and an art system. All actions of the elements are intended for participating in the interaction. To start, one or more human participants cast their shadows on the projection wall in a direct public communication to the art system. This action allows them to participate in the interaction and communicate with each other. In response, the art system projects these shadows onto the wall in a direct public communication to all participants. This display reveals hidden portraits, offers visual feedback on their movements, and creates a platform for communication and performance. Via the response of the art system, participants can also publicly communicate and perform with each other.

Next, one or more participants can activate a hotspot in a direct public communication to the art system to participate in the interaction. This action triggers the art system to play back an audio response in a direct public communication to inform the participants of their achievements and provide another means of communication. As multiple participants can interact simultaneously, multiple instances of all above communications can occur concurrently.

[12] https://modeltool.liacs.nl/?artwork=bodymovies

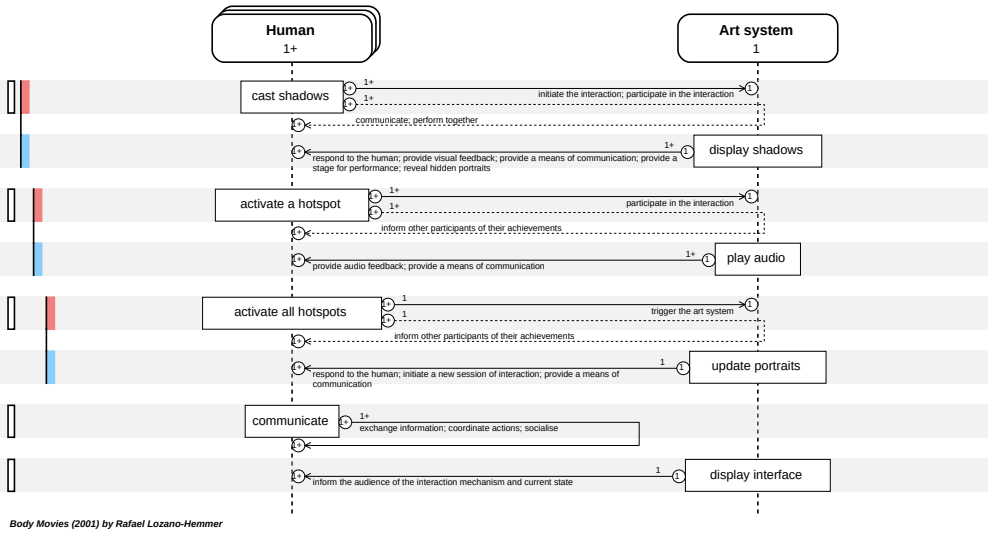

Figure 4.18: Visualisation of described interaction in ***Body Movies*** using RMT.

Moreover, one or more participants can also activate all hotspots in a direct public communication to the art system to trigger the update of the portraits. In response, the art system updates the portraits to inform the participants of this achievement and initiate a new session of interaction in a direct public communication. The participants can also inform each other of activating the hotspots via the responses of the art system.

Finally, the participants can communicate directly and publicly with each other to exchange information, coordinate actions and socialise. Throughout the interaction, the art system also displays its interface to inform the participants of the interaction mechanism and the current interaction state in direct public communication.

In our previous descriptions of ***Body Movies*** using only the relational model (Xu, Lamers, & van der Heide, 2023)(Xu et al., 2024), we specified only the action of casting a shadow performed by the human participants, as this is their primary method of participation and considered activating hotspots only as part of the roles of this action. However, when modelling the same interaction using RMT, it became evident that certain actions of the art system, namely "play audio" and "update portraits", occur only under specific conditions and are reactions to the audience' s actions. Therefore, we included the actions "activate a hotspot" and "activate all hotspots" so that the relationships between the actions of the human participants and the art system can be properly described.

4.5 Insights into Co-located Interaction

Based on the descriptions of the various forms of co-located interaction in the selected artworks, we identify five common themes from their similarities and differences and discuss them individually below.

4.5.1 Different types of reactions

In all selected artworks, there are actions performed by elements that serve as responses to other elements. We can say that the elements act and react to each other. This dynamic is particularly evident between art system and audience. Furthermore, upon closer analysis, we can identify several distinct types of reactions within these interactions.

To start, reactions performed by the art system can provide feedback about the effects of audience actions on the art system and the interaction. For example, in ***World Skin***, the art system updates the landscape display in response to audience navigating in the virtual landscape. Similarly, in ***Brainball***, ***Body Movies***, and ***Spatial Sounds (100 dB at 100 km/h)***, the art systems employ visual or auditory displays to inform the audience of the status of the interaction or its recognition of their presence. Additionally, the art system can provide supplementary sensory feedback on the actions of the audience, as seen in ***Zoom Pavilion***, ***Boundary Functions***, and ***Lights Contacts***, where information such as the distance between audience members and the intensity of their touch is translated into visual and/or auditory cues. Finally, the art system can also initiate or trigger interaction through its reaction. For instance, in both ***Zoom Pavilion*** and ***Spatial Sounds (100 dB at 100 km/h)***, the art system reacts to the presence of the audience with visual and/or audio responses to initiate the interaction.

Conversely, reactions performed by the audience primarily involve complying with or performing actions dictated by the art systems. For instance, in ***Randomly Generated Social Interactions*** and in interaction modes 2 and mode 4 of ***Spatial Sounds (100 dB at 100 km/h)***, the audience follows instructions or prompts from the art system to engage in specific actions. It is important to emphasise that these reactions are not isolated events but form part of a continuous exchange between actions and reactions. As a result, a reaction to one element can further trigger reactions or influence subsequent actions of the element.

4.5.2 Influences between actions

Besides this action-reaction relationship, actions performed by the elements can also influence each other in various ways. Firstly, an action can act as a prerequisite for subsequent actions, necessitating the element to execute the action prior to or concurrently with other actions. As

in ***Brainball***, an audience member is required to press a button to start the game. And in ***Lights Contacts***, one audience member must first touch and maintain contact with the sensor ball to activate the art system. Furthermore, an action can disrupt the execution of other actions. This is demonstrated in ***Brainball***, the display of real-time brainwave data and direct communication between the players can hinder their performance in the game. Lastly, an action can facilitate or enhance other actions, often taking place in parallel to each other. For instance, in ***World Skin*** the driver navigates the landscape to facilitate the photographers taking photos, and the art system plays audio to enhance their experience. The use of audio to enhance the perception of its other actions is also observed in ***Zoom Pavilion*** and ***Spatial Sounds (100 dB at 100 km/h)***, while in ***Lights Contacts*** it is the use of light that enhances the perception of the audio generated by the art system.

4.5.3 Roles of direct communication between audience

A distinct characteristic of co-located interaction is the ability of the audience to communicate directly with each other due to their co-location. This communication can occur through verbal exchanges as well as non-verbal means, such as gestures, facial expressions, and touch. Since it often takes place in parallel to other actions of the audience, direct communication can either facilitate or disrupt these processes. Such communication enables the audience to exchange information and coordinate their actions. By sharing their experiences and understanding of the interaction mechanisms, audience members can introduce new ideas, insights, and feedback on each other's performances. This dynamic is evident in all the artworks except ***Brainball***, where direct communication may actually interfere with the ability of the audience to remain composed, potentially impacting their success in the game.

Moreover, direct communication among the audience can also become part of the interaction. Notably, in ***Randomly Generated Social Interactions***, the art system instructs the participants to communicate directly with one another, making this form of communication a central aspect of the interaction. Meanwhile, in ***Boundary Functions*** and ***Lights Contacts***, the physical contact of the audience with each other triggers responses from the art system, making direct communication a key mechanism driving the interaction.

4.5.4 Creating connections among audience

A recurring theme across all the selected artworks is the active role of the art system in establishing or facilitating connections among audience members during the interaction. Several distinct approaches are observed in how the art system achieves this.

Firstly, connections can be established arbitrarily. For instance, in ***Randomly Generated***

Social Interactions, the art system instructs the audience to engage and converse with one another. Similarly, in ***Zoom Pavilion***, the system randomly pairs the faces or bodies of two audience members, facilitating chance encounters.

Secondly, in some instances the art system necessitates interdependencies among actions of the audience, which means the actions of one audience member may affect or depend on the actions of others. Within this context, various methods are employed by the art system. To start, the art system can draw upon differences in the audience' s behaviours. For example, in ***Brainball***, the movement of the steel ball is determined by the relative states of relaxation between the two players. Alternatively, the art system can react to actions that require multiple audience members to perform together, as seen in ***Lights Contacts*** and ***Boundary Functions***, where the physical touch between participants is necessary to trigger the art system. Yet another manifestation is where the art system enables shared control over its responses among the audience. In ***Zoom Pavilion***, for instance, a line is drawn between two audience members that adjusts as they move closer or further apart. Similarly, in ***Boundary Functions***, the generated Voronoi diagram is determined by the positions of all audience members.

Another strategy employed by the art system to foster connections is to encourage collaborations among the audience members. This is evident in ***World Skin*** and ***Lights Contacts***, the audience members play different roles and have different functions, so they must work together to achieve a shared goal.

A final approach observed is seemingly counterintuitive: the art system creates connections between audience members by isolating an individual from the rest. In such instances, the art system deliberately focuses on a single audience member, placing them under the spotlight. This emphasis amplifies the actions of the chosen individual, triggering them to express and connect with others. This effect is evident in ***Zoom Pavilion***, where the system randomly selects and magnifies the face of an audience member. Similarly, in mode 2 of ***Spatial Sounds (100 dB at 100 km/h)***, the system randomly chooses an audience member to follow. This deliberate "isolation" also evokes an emotional connection among the audience, as the possibility of being chosen looms over all audience members.

4.5.5 Differing forms of mediated communication

In all selected artworks, at least one form of mediated communication is present, where one element communicates with another via a third element. The most common example of this is audience members communicating with each other via the art system. In artworks such as ***World Skin***, ***Body Movies***, and ***Zoom Pavilion***, the art system provides a platform for the audience to express themselves and perform. Additionally, the art system can translate information

about audience actions into sensory cues to be used by the audience to communicate with each other. This is evident in ***Zoom Pavilion***, ***Boundary Functions***, and ***Lights Contacts***, where the distance between the audience are translated into audio-visual cues.

Another form of mediated communication occurs when the audience communicates with the art system through another audience member. In ***Lights Contacts***, for instance, the audience member who is in contact with the sensor ball becomes part of the art system, allowing other audience members to interact with the system through them.

A third intriguing form of mediated communication is demonstrated in ***Randomly Generated Social Interactions***. Here, the art system generates content and instructs one audience member to act it out, thereby conveying the information to the other audience member. In this scenario, the art system communicates to the receiving audience member via the acting audience member, who effectively becomes a "tool" for expression.

4.6 Reflection on the Modelling Capability of RMT

As demonstrated in Section 4.4, RMT enables us to provide detailed descriptions of a wide variety of co-located interactions. To illustrate this, we carefully selected eight artworks that represent different forms of co-located interaction, primarily based on varying combinations of their *audience constellation*, *participation symmetry*, *activity type*, and *initiator*. RMT characterises co-located interaction by focusing on the actions of both the audience and the art system and the resulting different forms of communication. This approach allows us to specify the role each element plays in the interaction, as well as how they influence and relate to one another. The main concepts used in the model —the identification of elements, their actions and forms of communications to each other —were shown to be applicable to all artworks. Importantly, RMT offers a flexible analytical tool that can be adapted to examine and compare diverse forms of co-located interaction.

A notable strength of RMT's modelling capabilities lies in its emphasis on the relational exchange between actions. This is particularly evident in the case of ***Body Movies***. When using the relational model alone, the description of the behaviours of the audience were less detailed. However, as RMT requires a clear specification of triggering actions for the reactions in an interaction, the relationships between the actions of the audience and the art system are clearly articulated through their conditional links. As a result, RMT not only produces a more comprehensive description, but also aids in making decisions during the modelling process.

RMT does not presuppose inherent differences between the behaviours of the art system and the audience; instead, it seeks to describe both on equal terms. This perspective opens new possibilities for conceptualising interactive dialogues, such as leveraging the audience

as a medium for expression and communication. This idea is particularly relevant in light of advancements in artificial intelligence, which have led to the development of increasingly sophisticated technical systems capable of performing tasks traditionally associated with human agency. Nevertheless, we also notice the differences between the behaviours of art systems and audiences. The actions of art systems are often concrete and well-defined, as they are typically programmed and scripted, whereas audience actions tend to be more open-ended, diverse, and individually variable. Consequently, general terms are often employed to describe audience actions. However, we also see opportunities here to create art systems that are more "human" and can surprise or even make mistakes; such as in ***Spatial Sounds (100 dB at 100 km/h)***, where the art system may misidentify the audience, resulting in a more unpredictable and engaging interactive experience.

When considering the audience, the relational model focuses mainly on those who actively participate in the interaction, excluding those who are merely observing. In some artworks with fluid *audience constellation*, the distinction between participating and observing audiences is blurred, as in ***Zoom Pavilion***, ***Spatial Sounds (100 dB at 100 km/h)***, and ***Body Movies***. In contrast, other artworks clearly distinguish between these roles, regardless of whether the *audience constellation* is fluid or fixed, as demonstrated in ***Brainball***, ***Randomly Generated Social Interactions***, ***World Skin***, and ***Boundary Functions***. In the latter cases, the presence of observing audiences can also influence those who are actively participating, and it may be valuable to incorporate this influence into RMT and the relational model.

4.7 Discussion

In this chapter, we have demonstrated the effectiveness of describing and comparing different forms of co-located interaction in interactive art using RMT. The tool provides a systematic approach to examining co-located interaction, enabling us to analyse such interactions in concrete terms and uncover the various relationships and influences between the interacting elements. Additionally, it highlights opportunities for creating new forms of communication and interaction. Although we have focused on co-located interaction here, the same methodology can be applied to study other types of interaction and audience participation. We believe that RMT demonstrates potentials in advancing our understandings of interaction in interactive art.

Based on the outcomes derived from applying RMT, it becomes evident that co-located interaction expands the concept of an interactive dialogue into a network of intertwined actions and reactions among multiple elements. The interacting elements not only can act and react to one another in various ways, but their actions also influence each other in ways that are essential to the interactive dynamics and for establishing complex relationships among the elements.

This opens up possibilities for envisioning new forms of interaction by composing different types of action-reaction sequences and influences between actions. For example, rather than the art system providing feedback to the audience as demonstrated in the selected artworks, the reverse could occur. A promising direction for future research would be to conduct a comprehensive exploration of existing relationship typologies and examine their prevalence across the actions of different elements in interactive art.

One aspect of co-located interaction that was highlighted in our analysis of the selected artworks pertains to its inherently social nature. By definition, co-located interaction requires the simultaneous participation of multiple audience members in the same physical space, making their interplay central to the overall interactive experience. To facilitate this, art systems can employ various strategies to foster connections between audience members, drawing upon their ability to communicate directly in different ways, and devising novel forms of mediated communication. The examples from the selected artworks provide a foundation for further exploration in these directions. This insight underscores the capacity of interaction to leverage and incorporate existing social dynamics among participants, while also hinting at the potential effects these dynamics may have on the interaction itself.

Finally, in developing classification dimensions and artwork selection criteria, we aim to select a diverse range of artworks with minimal bias. However, due to the availability and accessibility of documentations, the selected artworks primarily originate from a Western cultural context and were created between 1997 and 2016. Moreover, due to practical concerns, we could not cover all varieties of co-located interaction, but focus on some aspects we deemed most significant. Considering the focus of our classification dimensions on parameters that define audience participation, it would be worthwhile to model and analyse more recent artworks and explore different classification methods, such as those focused on audience experience or varying cultural contexts.