A relational approach to understanding interactions in interactive art

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Chapter 1

Introduction

This thesis presents a study on modelling interactions in interactive art. In this chapter, we begin by introducing the background of interactive art and the significance of modelling interactions within this field. The main aims and research questions addressed in the thesis are then outlined. This is followed by a summary of the approaches and methods employed to investigate these questions. Finally, the chapter concludes by presenting the overall structure of the thesis and its main contributions.

1.1 What is Interactive Art?

Interactive art is often characterised by active audience participation and the creation of dynamic art systems employing digital technologies. Unlike static artworks such as paintings, interactive art involves a two-way influence between the artwork and its audience, prompting both parties to respond to and shape each other's actions. However, the concept of audience participation is not exclusive to the realm of digital interactive art. Under the umbrella of participatory art, Fluxus artists in the 1960s pioneered performances or "happenings" that actively involved spectators as participants and collaborators (Holdar, 2017). Around the same time, Brazilian artist Lygia Clark developed "relational objects" designed to heighten the audience's awareness of their own bodies through actions with these objects proposed by the artist (Bourriaud, 2002). In both cases, the role of the audience shifted from passive spectatorship to a more engaged, creative one.

The integration of computers into art practices further revolutionised the development of interactive art, exemplified by the 1968 exhibition *Cybernetic Serendipity* at the Institute of Contemporary Arts in London (Usselmann, 2003). This exhibition showcased cybernetic art

based on the principle of feedback and control, employing electronic or computer technologies to respond dynamically to external stimuli such as environmental changes or audience actions. These explorations of computer-based interactivity gave rise to a new form of interactive art, opening up opportunities to create dynamic systems capable of engaging with audiences in new ways that were not possible before.

Recognising the transformative impact of computers on artistic practice, Cornock and Edmonds propose a taxonomy of art systems involving computer technologies in a 1973 paper, examining the relationships between artworks, participants, and the environment(Cornock & Edmonds, 1973). It is worth noting that Cornock and Edmonds use the term "system" to describe both the total system, including the artwork and the influencing elements (e.g., participant, environment, time), and the artwork as a system. This taxonomy classifies the total system and includes:

- The static system: The artwork remains unchanging, similar to traditional art objects.
- The dynamic-passive system: The artwork changes over time or responds to environmental factors without participant intervention.
- The dynamic-interactive system: Extends the dynamic-passive system by incorporating participant input, creating a feedback loop between artwork and audience.
- The dynamic-interactive system (varying): A special case in which the artist modifies the system or process in ways not covered by its original definition.

Cornock and Edmonds also introduce the concept of "the matrix" to describe the overarching system within which both the art system and participants operate. Within this matrix, participants play an integral role, at least partially determining the artwork's outcome. Consequently, the traditional role of the artist is challenged: although the artist conceives and initiates the work, they cannot fully control every aspect of its outcome, and furthermore, they often must collaborate with other artists or technical specialists to realise a complex, dynamic art system. As a result, there is no fixed outcome and the artwork becomes non-deterministic.

At the core of interactive art lies the relationship between the artwork and the audience. When analysing computer-driven participatory art, Bell distinguishes interactive art systems from other types of participatory art by emphasising the mutual exchange between humans and machines—or artwork—in a manner similar to a conversation between two human beings (Bell, 1991). This conversational analogy is further advanced by Schraffenberger and van der Heide, who propose a dialogue model for audience–artwork interaction, highlighting that both artwork and audience can not only respond to each other but also have the freedom to act

independently—much like two human interlocutors (Schraffenberger & van der Heide, 2012, 2015).

However, such interactive dialogues are not restricted to exchanges between a single audience member and one artwork. As we will elucidate in Chapter 4 and Chapter 5, many interactive artworks involve multiple participants, and in some cases, these may even be nonhuman life forms. In these scenarios, the interaction takes place not only between the artwork and the audience but also among the participants themselves, resulting in complex relational dynamics (Ahmed, 2018). Furthermore, as Kwastek observes in her analysis of digital interactive art, these artworks are frequently presented in public settings with an intentionally positioned performative area, which allows other spectators—or potential participants—to observe the interaction (Kwastek, 2013).

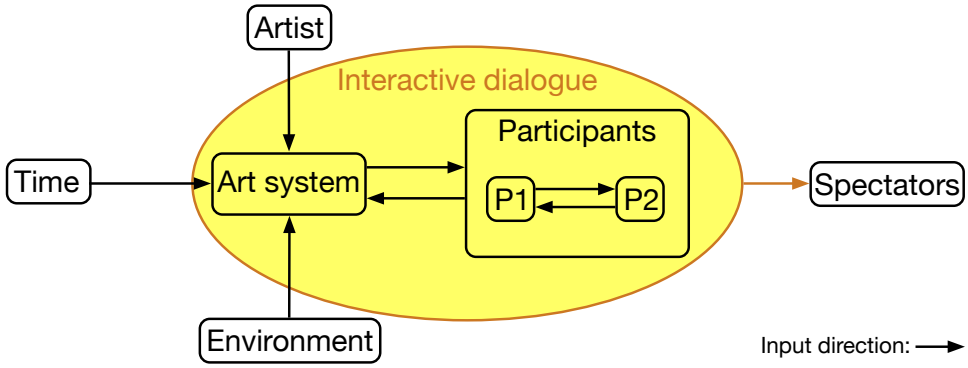

Figure 1.1: Diagram illustrating the primary factors influencing an interactive artwork, with the arrows indicate the main input flows, adapted and modified from Cornock and Edmond's classification diagram. The area highlighted in yellow background indicates where the interactive dialogue takes place.

Taking these perspectives into account, we can sketch out the key factors and various influences shaping an interactive artwork in Figure 1.1[1]. Furthermore, we consider the interactive dialogue an essential component of an interactive artwork. Therefore, we use the term "art system" to indicate the technical body of the artwork for greater clarity.

In this thesis, we are primarily interested in investigating how interactive dialogues manifest in interactive art and understanding the various interactive dynamics at play, particularly in artworks involving multiple participants, as illustrated in Figure 1.1. An in-depth study of these dialogues would not only yield insights into existing practices but also reveal new op-

[1]Here, we only consider the major input flows. It is reasonable to assume that the presence of spectators can also influence the performance of participants, and that the behaviours of participants may affect the decision-making process of the artist.

portunities for future research and artistic creation. To achieve this, we need a systematic and effective approach for dissecting and analysing interactions in interactive art.

1.2 Why Modelling Interaction?

In science, a model is commonly understood as a representation of a target—be it an object, phenomenon, process, concept, or system—designed to explore, explain, or predict that target's behaviour (Oh & Oh, 2011). Models serve as intermediaries between theory and the natural world, allowing researchers to develop theories based on empirical data while also guiding the practical application of established theories. Moreover, scientific models typically employ visual resources, analogies, and simulations to describe, explain, and predict real-world phenomena, facilitating the communication of complex scientific ideas. Importantly, a model does not aim to reproduce reality in its entirety; rather, it offers a simplified version of the target, emphasising selected aspects deemed significant for a specific purpose.

Specifically, a model provides a formal vocabulary and language to specify the target system's properties and behaviours. Edmonds, drawing an analogy to painters who describe colours in terms of hue, texture, and other qualities, advocates for a critical language to articulate, compare, and discuss interactive digital art (Edmonds, 2010). Such a language would enable us to systematically analyse and communicate the defining factors that shape an interactive dialogue. Consequently, in this thesis, we define a model of interaction as: a theoretical and conceptual tool that describes how interactions occur from a specific perspective, outlining key concepts, relationships, and principles governing interactive dynamics.

Meanwhile, modelling interaction refers to the practical process of applying an interaction model to represent, describe, or analyse real or hypothetical interactions. This process entails translating theoretical constructs of the model into concrete representations such as diagrams, formal descriptions, or simulations, either by hand or using specially designed tools. By doing so, researchers and practitioners can systematically examine, compare, refine, or implement complex and diverse interactions. Much like scientific models, developing and applying an interaction model enables a deeper understanding of interactive dialogues. Here, we further elaborate on the practical and theoretical benefits of modelling interactions in interactive art.

Firstly, modelling interactions can produce standardised visual descriptions that enhance communication among artists, collaborators, and audiences. For artists and designers, such representations are valuable for sharing concepts with technical team members during development or with curators and producers as part of proposals or setup plans. Externalising abstract ideas into visual or textual formats also provides tangible materials for reflection, adaptation, and experimentation, supporting ideation and conceptual development. For audi-

ences, the modelling practice offer a vocabulary to articulate their experiences, enabling artists to gather meaningful feedback.

Meanwhile, standardised descriptions also facilitate systematic comparisons between different artworks or the same artwork at various stages of development. These descriptions not only capture the essence of an artwork for archival purposes but also serve as valuable resources for future recreations, adaptations, or academic analyses. Moreover, systematic comparisons of large collections of artworks enable the identification of common patterns and unique characteristics across interactive artworks, contributing to the establishment of benchmarks and best practices that refine methodologies for creating and studying interactive art. These insights can also inspire the creation of new forms of interaction by questioning and challenging existing patterns.

Furthermore, structured interaction models also allow for the simulation and prediction of an interactive system' s behaviour. Through simulation, artists can explore how art systems respond to various inputs, including audience behaviours, before physical realisation. This predictive capability enables testing and refining interaction dynamics, identifying potential issues, and exploring alternative scenarios. Simulations also benefit curators and technicians by providing insights into the intricacies of an artwork, aiding in setup, maintenance, and troubleshooting.

Lastly, a systematic study of interactive art also contributes to other areas of Human-Computer Interaction (HCI). The unconventional thinking and creative efforts exhibited in the creation of interactive art can inspire new forms of interaction applicable to other domains of interaction design (Duarte & Baranauskas, 2018)(Duarte et al., 2019). Moreover, interactive artworks can be seen as experiments with emerging technologies, sometimes repurposing them beyond their conventional usage, which stimulates the development of novel interactive systems and technologies (Jeon et al., 2019). Beyond these practical benefits, interactive art frequently adopts a critical perspective on technological development, challenging established norms and inherent assumptions regarding the design of interactive technologies and our relationship with them.

1.3 Aims and Questions

There exist a wide variety of approaches attempting to describe, classify, and evaluate interactive artworks (Schraffenberger & van der Heide, 2012, 2015). However, most of these methods offer a limited, one-sided perspective, focusing either on the experience of the participants or the behaviours of the art system. As a result, they often fail to account for the relational exchange between the two and recognise interaction as a continuous, bidirectional

process, overlooking critical factors defining an interactive artwork. Recognising this gap, the central question driving this thesis is:

> **Q1:** How can we model interactions in interactive art in a way that effectively and structurally captures the relational exchanges between the art system and its participants?

A relational approach to describing interaction considers both the individual behaviours of the art system and the participants, as well as how they influence and condition each other through their actions and reactions. Since interaction is inherently a relational process, this perspective provides a deeper understanding of the dynamics and roles of the interacting elements. Therefore, the first objective of this thesis is to develop a relational model of interaction that offers a consistent analytical template and vocabulary for dissecting and describing interactions in interactive art.

Building on this theoretical model, we also aim to operationalise it by developing a modelling tool with an accessible interface and functionalities that facilitate the description process and visualise the described outcomes. In doing so, we seek not only to communicate the relational interaction model more effectively, but also to provide researchers and practitioners in interactive art with a practical tool that can benefit their workflows.

Using the relational model and the tool as the primary analytical lens, we will apply them to describe a diverse selection of interactive artworks. This process serves a dual purpose: first, to evaluate the modelling capabilities of both the model and the tool, and second, to discover patterns and insights into interactions in existing interactive artworks by systematically comparing the descriptions. This exploration leads to the second key research question:

> **Q2:** What insights into interactions in interactive art can be gained from a relational modelling approach?

Although the relational model is designed to be applicable to a wide range of interaction forms, this thesis focuses specifically on exploring variations in *co-located interaction* and *more-than-human interaction*. Co-located interaction occurs when multiple audience members interact simultaneously with an interactive artwork within a shared physical space, where the presence and interactions among audience members are not merely incidental but are integral to the artwork itself. This form of interaction extends beyond a dyadic audience-artwork relationship to encompass a more complex relational scenario, involving interactions both between the audience and the artwork and among the audience members. We argue that co-located interaction presents a compelling case study to evaluate the flexibility and adaptability of the relational modelling approach. Consequently, research question Q2 can be further refined into the following sub-question:

Q2a: What insights into co-located interaction can be gained from a relational modelling approach?

On the other hand, more-than-human interaction represents an emerging trend in interactive art, involving nonhuman organisms as participants to the interaction. This perspective challenges anthropocentric worldviews by recognising the agency and influence of nonhuman entities. As such, artworks within this domain must account for the significant role of nonhuman participants in shaping the interactive experience. Despite increasing interest in such practices, there remains a notable lack of critical studies examining the interactive and relational dynamics within more-than-human interactive art. Therefore, this thesis seeks to test the capabilities of the relational modelling approach in analysing such artworks and uncover insights and limitations inherent to them. This leads to the second sub-question of Q2:

Q2b: What insights into more-than-human interaction can be gained from a relational modelling approach?

In addition to modelling and visualising interactions, we argue that the relational model and its accompanying tool can also support the exploration of new forms of interaction that do not yet exist. By identifying patterns related to the roles of different types of elements in existing interactive artworks, this approach can inform the discovery and creation of novel interactive dialogues. Therefore, the next question we would like to address in this thesis is:

Q3: Can a relational modelling approach support the discovery and creation of new interactive dialogues?

Through the development, application, and evaluation of the relational model and its accompanying tool, we can explore how this approach benefits the research and creation of interactive artworks, while uncovering opportunities and potential avenues for its future evolution. However, since no model can fully encapsulate the complexity of reality, we also critically examine the limitations of this approach, clearly defining its scope and intended applications scenarios. These reflections are encapsulated in the following two research questions:

Q4: What benefits and opportunities does a relational modelling approach provide for understanding and creating interactive art?

Q5: What are the limitations of a relational modelling approach for understanding and creating interactive art?

1.4 Approaches and Process

To address the aims and questions of this thesis, we adopt three complementary approaches. The first approach focuses on theoretical exploration. We begin by reviewing existing interaction models for interactive art, critically examining their strengths and limitations. This analysis allows us to situate our relational interaction model within the broader landscape of interaction models. Building on this foundation, we define the core concepts and descriptors necessary to capture the relational exchanges among elements within an interaction, informed by relevant theoretical discussions. The result of this process is the initial version of our relational model of interaction.

We would like to emphasis here that our theoretical exploration was intentionally constrained within specific interaction models and related tools, and that the concepts and definitions of the relational model were developed with relative independence. While we acknowledge the broader theoretical discourses on interactivity and relationality in philosophy and art theory, these are not the primary focus of this thesis. Nevertheless, we recognise that our work intersects with these discourses in meaningful ways and could both contribute to and benefit from them in future developments.

Our second approach combines practical experimentation with reflective inquiry, adopting a *Research-through-Design* methodology where the development and evaluation of designed artefacts serve as a primary means of generating and communicating new knowledge (Zimmerman & Forlizzi, 2014). Building on the theoretical foundation of the relational model, we design and develop the Relational Modelling Tool (RMT) to describe, visualise, and generate interactions. By translating theoretical constructs into a tangible format with a formal structure, we critically examine the relational model, identify missing components, and uncover potential refinements. This process not only strengthens the model but also reveals opportunities to introduce new features and functionalities that were previously unanticipated.

The third approach centres on the empirical study of the application of RMT, both through our own use and by engaging a wider user group. Throughout its development, we routinely test the modelling capability of RMT by applying it to describe diverse interactive artworks. Here, we do not aim to provide an exhaustive list of artworks–as this would also be practically impossible–but instead carefully select a set of works representative of different forms of co-located interaction (Chapter 4) and more-than-human interaction (Chapter 5), based on developed taxonomies and preliminary analyses. These practical applications generate concrete data for evaluating its effectiveness and provide valuable insights into the described interactive dialogues. Additionally, we organised a workshop with external participants, where RMT is used to model and generate new interactive dialogues. This allows us to gather feedback on

RMT's usability and functionality while collectively reflecting on its strengths, potentials, and limitations.

Finally, we would like to emphasise that our research process is inherently nonlinear and highly iterative. This is particularly evident in the development of RMT. As mentioned before, the outcomes from the empirical evaluations of RMT have been instrumental in shaping its successive updates, leading up to the present version. At the same time, these findings have informed the ongoing refinement of the underlying relational model and contributed to our broader reflections on the strengths and limitations of a relational modelling approach for interactive art. As we expand and enhance the features of RMT, we continue to deepen our understanding of its capabilities and potential. This is only possible as the research and development processes are tightly integrated, where the outcomes from one process continuously provide input and inspiration for the other.

1.5 Thesis Structure

In addition to this introductory chapter, the thesis comprises seven further chapters.

Chapter 2 reviews existing interaction models and tools for describing and analysing interaction in interactive art, discussing their strengths and limitations. Drawing on this analysis, we outline the key considerations for developing an interaction model that can capture a wide range of interactions. We then introduce our relational model of interaction, defining its key concepts and descriptors for dissecting and analysing interactive dialogues.

Chapter 3 focuses on the design and development of the Relational Modelling Tool (RMT) based on the relational model. Here, we elaborate on the key components of RMT for describing and visualising interactive dialogues, compare its functionalities with the original relational model, and discuss its potential benefits and future applications.

Chapters 4, 5, 6 demonstrate the modelling capabilities of RMT in describing and visualising diverse forms of interaction and beyond. Each chapter explores a distinctive form of interactive or participatory art, providing selected artwork examples and descriptions of the respective interactions or participatory processes using RMT. We then discuss the insights gained into the different forms of interaction, the effectiveness of RMT's modelling approach, and its limitations and potential improvements. Specifically:

- Chapter 4 analyses eight carefully selected interactive artworks exploring co-located interaction-when two or more audience members are physically present at the same location, participating simultaneously in the interactive experience.

- Chapter 5 explores the emergence of more-than-human interaction and the significance

of nonhuman participants in interactive art. It analyses five interspecies interactive artworks involving both human and nonhuman organisms.

- Chapter 6 extends RMT's application scope beyond interactive art by examining two participatory artworks that illustrate distinct audience engagement mechanisms, yet are not categorised as interactive art.

Chapter 7 presents the results from the workshop we organised to evaluate the capabilities of RMT in modelling, visualising, and generating interactive dialogues with a wider user group. To support the workshop, we also developed a generative component for RMT to support the discovery of new forms of interaction. We report on the workshop outcomes, including the interactions participants modelled and discussion insights on potential interface improvements, various application scenarios, and future development opportunities for RMT. Based on the feedback received, we iteratively refined RMT and reflected on lessons related to designing intuitive interfaces, involving users in the development process, understanding RMT's benefits and limitations, as well as clarifying its scope and positioning.

Chapter 8 concludes the thesis by summarising the research carried out in this thesis and our main findings. Specifically, we provide our overarching reflections based on the research questions, discuss remaining challenges and considerations in our approach, explore the broader implications of this study, and propose directions for future work.

Furthermore, it is important to note that each chapter within this thesis has been designed to also function as a standalone article. As a result, certain contents are reiterated to maintain coherence and comprehensibility for readers who may engage with individual chapters independently.

1.6 Contributions

Our key research insights are presented and disseminated through five peer-reviewed publications in international conference proceedings and a journal, which form the foundation of this thesis. These publications were developed in close collaboration with Edwin van der Heide, who acted as an unofficial supervisor throughout the PhD project. The publications detail the development, application and evaluation of the relational model and RMT for describing, visualising, and generating interactive dialogues in interactive art:

- Xu, D., van der Heide, E., Lamers, M.H. and Verbeek F.J. (in print). "Reflections on Using the Relational Modelling Tool for Describing, Visualising and Generating Interactive Dialogues". Submitted to *International Conference on ArtsIT, Interactivity and Game Creation 2025* and is accepted for publication.

- Xu, D., Lamers, M.H., van der Heide, E. (2025). "A Novel Web-Based Tool for Modelling, Visualising, and Generating Interactions in Interactive Art". In: Brooks, A.L. (eds) *ArtsIT, Interactivity and Game Creation*. ArtsIT 2025. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 650, pp. 3–19. Springer, Cham. Doi: 10.1007/978-3-031-97254-6_1.

- Xu, D., Lamers, M.H., van der Heide, E. and Verbeek F.J. (2025). "A Relational Look at Interactions between Humans and Nonhuman Organisms in Interactive Art". In: *Leonardo*, vol 58(2), pp. 220–228. Doi: 10.1162/leon_a_02660.

- Xu, D., Lamers, M.H., van der Heide, E. (2024). "Describing and Comparing Co-located Interaction in Interactive Art Using a Relational Model". In: Brooks, A.L. (eds) *ArtsIT, Interactivity and Game Creation*. ArtsIT 2023. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 565, pp. 198–217. Springer, Cham. Doi: 10.1007/978-3-031-55312-7_15.

- Xu, D., Lamers, M.H., van der Heide, E. (2023). "Towards a Relational Model of Co-located Interaction in Interactive Art". In: Mahé, E. (eds) *Proceedings of the 28th International Symposium on Electronic Art*, pp. 723–732. Doi: 10.69564/ISEA2023-92-full-Xu-et-al-Co-located-Interaction.

In addition, we have made RMT both publicly accessible and open-source [2]. In doing so, we ensure that artists and researchers can easily adopt, adapt, and build upon the software for their own projects. This open-source approach not only promotes reproducibility and transparency, but also encourages collaboration across disciplines and ongoing refinement of RMT in the study and development of interactive art.

Lastly, we contributed to the program of the 13th EAI ArtsIT conference at New York University Abu Dhabi Campus by organising and hosting a workshop titled "Modelling and Creating New Interactive Dialogues in Interactive Art"[3]. During the workshop, participants were introduced to RMT, guided through hands-on modelling exercises, and engaged in group discussions reflecting on their experiences and potential applications of RMT.

[2] The latest version of RMT can be accessed via: https://modeltool.liacs.nl. An instructional video about its application can be viewed here: https://youtu.be/HeniTtbI1SI. Its source code can be found in GitHub via: https://github.com/danxxxu/relational-model.

[3] Official event page for the workshop: https://artsit.eai-conferences.org/2024/workshop-session-modelling-and-creating-new-interactive-dialogues-in-interactive-art