A relational approach to understanding interactions in interactive art

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Chapter 2

A Relational Model of Interaction

2.1 Introduction

In Chapter 1, we outline the importance of a structured interaction model in facilitating our capacity to understand, compare, evaluate, and create interactive artworks. Additionally, we highlight the necessity for developing a comprehensive interaction model capable of adequately capturing the relational exchanges between the art system and its participant(s), especially in complex scenarios involving multiple participants. Building on this foundation, this chapter begins with a critical review of existing interaction models and analytical tools for describing interactions in interactive art. We evaluate the strengths and limitations of these approaches, distilling key insights and considerations that inform the development of our relational model of interaction. This model forms the cornerstone of our research and the theoretical underpinning of this thesis.

Following this analysis, we introduce the relational model, defining its core concepts—element, action, and communication—along with the various descriptors used to specify each concept. We argue that the relational model offers a consistent and versatile tool for dissecting and analysing diverse forms of interactive dialogue. While this chapter focuses on providing a comprehensive introduction to the relational model and situating it within the broader landscape of modelling approaches in interactive art, its practical applications in modelling various forms of interaction—and beyond—are demonstrated in Chapters 4, 5, 6.

This chapter builds extensively on our previous work presented at the 28th International Symposium on Electronic Art (Xu, Lamers, & van der Heide, 2023). Initially, the relational model was conceived to describe co-located interaction, which is the central topic of Chapter 4, as detailed in our publication. However, as the model evolved, it became evident that its

core concepts, descriptors, and analytical method could be readily adapted to address a wider range of interactive and participatory processes. This adaptability is exemplified in later chapters, which demonstrate its applications in modelling diverse interactions and beyond. Consequently, in this chapter, we recontextualise the relational model as a general interaction model, positioning it alongside and in comparison with comparable models and tools.

2.2 Existing Interaction Models in Interactive Art

A comprehensive review of existing taxonomies and models for classifying interactive art is provided by (Schraffenberger & van der Heide, 2015). In this section, we examine a selection of interaction models and tools with a focus on describing and dissecting the interactive dialogues in interactive art. These include both conceptual frameworks and practical tools or languages designed to analyse interaction dynamics.

As this examination focuses specifically on modelling interactions in interactive art, we do not include modelling approaches from other domains, such as the Unified Modeling Language (UML) commonly used in software engineering. While we identify significant overlaps between our approach and UML sequence diagrams, a detailed comparison and discussion of these relationships can be consulted in Chapter 7.

2.2.1 The feedback loop model and variations

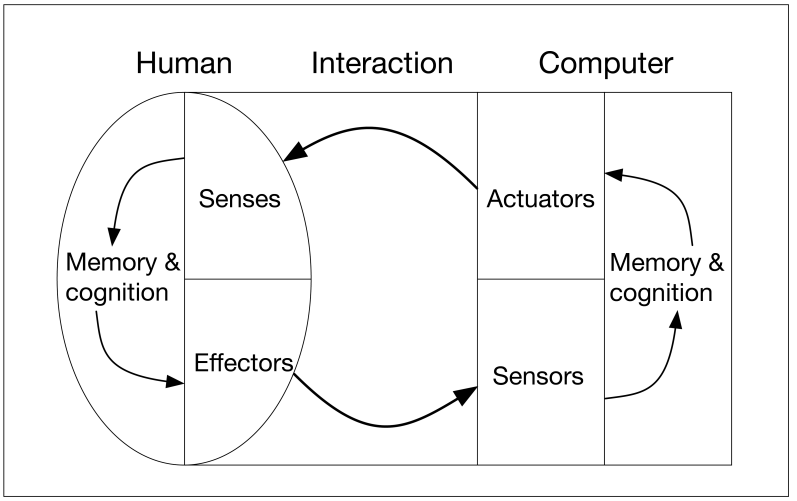

Figure 2.1: Diagram illustrating the feedback loop model. Reproduced from (Bongers, 2000)

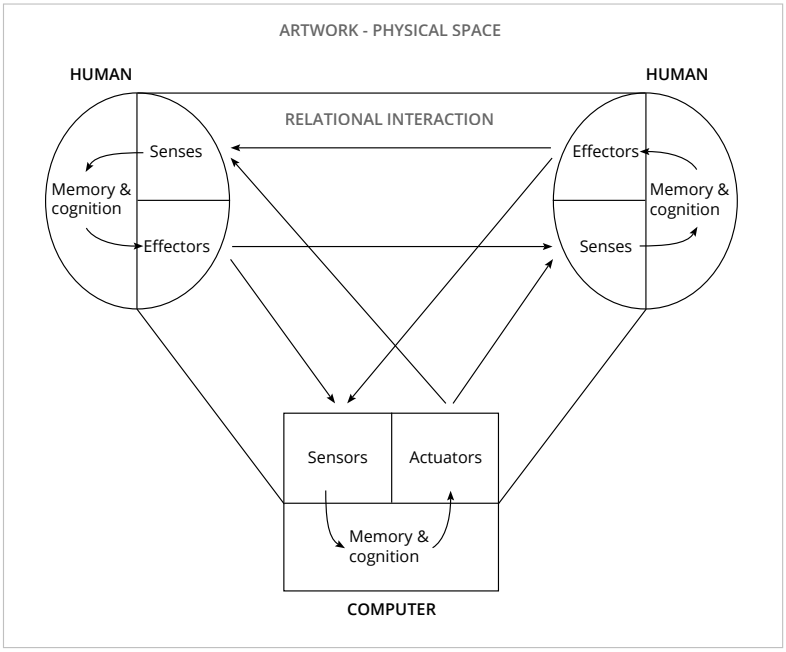

Figure 2.2: Diagram illustrating the model of relational interactive art. Reproduced from (Cabrita & Bernardes, 2016)

Drawing on the principles of cybernetics, Bongers introduces a feedback loop model to describe the physical interactions between individuals and electronic systems in multimedia art (Bongers, 2000) (see Figure 2.1). At the core of this model are the concepts of feedback and control: the system provides feedback to assist the user in articulating control, or delivers feedforward messages to actively guide the user. Bongers has demonstrated that the feedback loop model can be applied to understand the interaction between a performer or an audience member and a digital art system, such as an electronic instrument. Additionally, Bongers also extend the feedback loop model to describe a triadic scenario where the interaction takes place between a performer and an audience member through the art system. However, focusing on the human-machine interaction, the model does not account for the interaction between the performer and the audience member directly if they were to be present in the same physical location, leaving a gap in its applicability to more complex, multi-user contexts.

Building on the feedback loop model, Cabrita and Bernardes propose an interaction model specifically tailored for analysing interactive artworks aiming to foster and strength social connections between audience members, which are coined as "relational interactive art" (Cabrita & Bernardes, 2016). As illustrated in Figure 2.2, this model incorporates another human par-

ticipant who interacts both with the human and the computer in similar feedback loops. Cabrita and Bernardes further specify that the human-human interaction and human-machine interaction are of equal significance and consistently present throughout the interaction. Additionally, the authors emphasise the interdependence of audience members' actions, with the computer interpreting these actions as collaborative behaviours that "guide its response and shape the next instance of human action." However, while the model offers a promising theoretical foundation, Cabrita and Bernardes do not provide practical examples or applications to demonstrate its utility in real-world scenarios.

2.2.2 The dialogue model of audience-artwork interaction

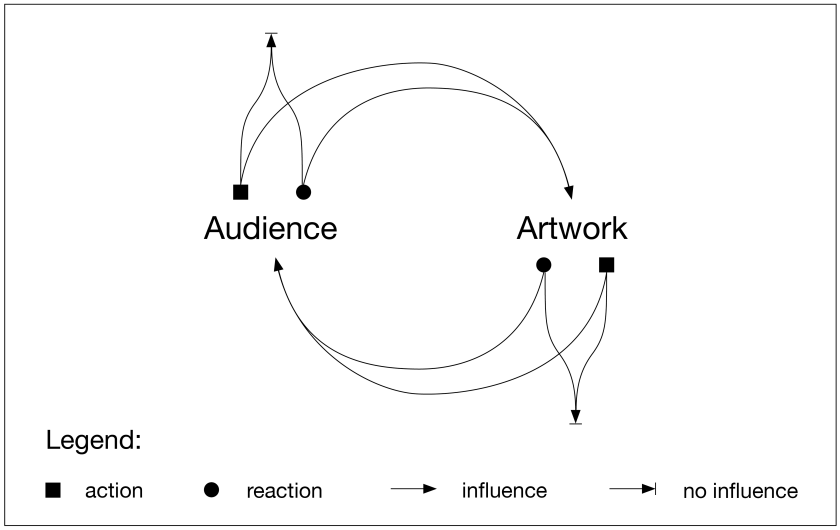

Figure 2.3: Diagram illustrating the dialogue model. Reproduced from (Schraffenberger & van der Heide, 2015)

In an extensive study of audience-artwork interaction within interactive arts, Schraffenberger and van der Heide review existing models and frameworks that aim to capture the diverse characteristics and types of interaction between the artwork and the audience (Schraffenberger & van der Heide, 2012, 2015). Although they acknowledge the usefulness of the feedback loop model, they highlight that its focus on control overlooks other significant dimensions of interaction in the context of interactive art.

In response, they introduce a dialogue model (see Figure 2.3) to describe audience-artwork interaction. Similar to a dialogue between two individuals—where both parties not only re-

spond to each other's propositions but also have the freedom to switch topics or interrupt—the dialogue model portrays audience–artwork interaction as a dynamic process in which both the audience and the artwork retain the autonomy to respond to each other in various ways and initiate independent actions. Consequently, neither acts randomly nor exercises complete control over the other.

2.2.3 A scoring system for describing interaction

Another significant contribution to modelling audience-artwork interaction is found in Bell's doctoral dissertation (Bell, 1991). In his thesis, Bell identifies key characteristics of participatory artworks that utilise computer technology and proposes a novel scoring system designed to track changes in the degree of participant control over time, analogous to a musical score. This system is structured around two axes: the horizontal axis documents the actions performed by the participant, while the vertical axis represents the sensory and motor modalities engaged in performing these actions and receiving reactions from the art system. By mapping interactions in this way, the system allows users to identify, at various stages of the interaction, which sensory aspects of the participant are controlled by themselves and which remain under the artist's direction (through the artwork). Additionally, the scoring system is designed to accommodate complex interaction scenarios; multiple *scores* can be layered or extended to represent branching pathways of options within the interaction.

2.2.4 A graphical language for modelling co-located interaction

Finally, we examine the modelling approaches proposed by Oussama Mubarak in his doctoral research (Mubarak, 2018). While Mubarak's research primarily focuses on modelling co-located interaction, we believe that his approaches are applicable to other forms of interaction and offer valuable insights for interaction modelling more broadly.

The first approach Mubarak introduces focuses on visualising the system layout of art installations. In this model, the key components are interfaces, which may be shared or individual, and are categorised as input, output, or both. The number of interfaces is documented, and their organisation is classified into one of three structures: 1) free, where interfaces can be accessed in any order; 2) queued, where interfaces are accessed sequentially; or 3) looped, where the installation cycles through all interfaces in a continuous sequence. The data flow between individual and shared interfaces is described as unidirectional, bidirectional, or symmetrical correspondence, the latter indicating that all interfaces share the same information. While this approach offers a concise representation of the technical configuration of artworks, it provides limited insights into the functional roles of individual interfaces within the inter-

action or their relationship to the audience. Additionally, it does not account for interactions between audience members, which are often a critical aspect of co-located experiences.

To address some of these limitations, Mubarak proposes a second approach based on Petri nets, a mathematical modelling language often used to describe information flow in systems with concurrent and asynchronous events. This approach results in a set of graphical elements representing different participant activities and components of the art installation, while indicating the transitions between these elements. Mubarak notes that it "can be used to model co-located human-human, human-machine, as well as human-machine-human interactions around art installations." Compared to the first approach, this method is more comprehensive and expressive, capturing a broader range of activities in co-located interactions. However, as this approach is still in its early stages of development, it often produces highly intricate and specialised descriptions that can be challenging to comprehend.

2.3 Considerations

The abovementioned interaction models in interactive art exhibit both strengths and limitations. The feedback loop model, for instance, is widely adopted by interactive artists and has been influential in conceptualising and understanding interactions within interactive art and other domains of Human-Computer Interaction(Bongers, 2000; Schraffenberger & van der Heide, 2015). Furthermore, as demonstrated by Cabrita and Bernardes, the feedback loop model can be extended and adapted to analyse more complex forms of interaction. However, as previously noted, the focus of the model on user control and system feedback is limited in capturing the nuanced dynamics specific to diverse artistic practices.

In contrast, the dialogue model proposed by Schraffenberger and van der Heide addresses some of the limitations inherent in the feedback loop model by proposing a more diverse and open framework to understand the dynamics between the artwork and the audience. Unlike the feedback loop model, which positions audience as the primary agent and art system as a (passive) tool, the dialogue model acknowledges the mutual responsiveness between audience and artwork. It considers both as potential agents capable of initiating independent actions and influencing one another. Nevertheless, both the feedback loop and dialogue models remain predominantly conceptual models, offering limited practical guidance for dissecting and analysing the specific interactive dynamics within individual artworks.

On the other hand, Bell's scoring system and Mubarak's graphical language present more practical approaches for modelling specific forms of interaction. However, these methods also have their constraints. Bell's scoring system focuses primarily on human-machine interactions within interactive art, which is insufficient for capturing the complexity of interactions

involving multiple participants, such as co-located interaction. Moreover, while Bell's model conceptualises the interaction between audience and artwork in terms of the level of control each exerts over the other—a perspective akin to the feedback loop model—it expands on this by acknowledging that the artwork can also exert control over the audience. This introduces a more nuanced bidirectional understanding of mutual influences within an interaction.

Meanwhile, Mubarak's graphical language employs a predefined set of graphical symbols to represent audience activities and the transitions between them over the course of an interaction. This approach is adaptable and scalable, enabling the description of more complex interactive scenarios and allowing for computational analysis of interactions. However, as Mubarak himself acknowledges, the system's abstract notations and lack of a user-friendly interface hinder its usabilities and functionalities, particularly for users unfamiliar with the framework. Furthermore, it does not provide any coherent, systematic guideline to facilitate the adoption of the language and in-depth analysis. Additionally, we argue that Mubarak's focus on activity transitions fails to sufficiently account for how the audience's actions influence the artwork and each other, as well as how the artwork's actions impact the audience.

Taken together, existing modelling approaches tend to be either too generic or too specific, lacking a balanced and comprehensive consideration of the behaviours of both the art system and its participants. A useful interaction model should be *descriptive*, providing sufficient structural information to describe the individual system or situation being modelled; *comparative*, containing metrics for comparing different systems or situations; and *generative*, guiding the creation of new systems or situations (Beaudouin-Lafon, 2000).

Furthermore, although interaction is inherently a relational process, existing models do not sufficiently describe the relationships between the audience and the artwork, or between audience members. As Ahmed notes in discussing forms of interaction in the context of interactive art installations, there is a distinction between interaction and communication: "in communication, the receiver may or may not respond, whereas in interaction, there is a requirement of a response for it to be an 'inter' action" (Ahmed, 2018). This aligns with our understanding of interactivity as a form of mutual responsiveness. In scenarios where multiple audience members are involved, this does not necessarily mean that each interacting partner should be mutually responsive to each other. However, the overall dynamics among them should enable certain forms of mutual responsiveness. If the interaction between an artwork and an audience can be seen as a dialogue of actions and reactions, we can begin to understand complex forms of interaction by examining the actions (and reactions) of all interacting elements. By tracing the directions of these actions, we can identify the different forms of communication at play and specify a network of influences between the audience members and the artwork, forming the foundation for understanding the overall interactive dynamics.

Moreover, the same action performed by an interacting element can yield different outcomes in different interactive artworks. For instance, an audience member waving their arm may change the colour of a visual display in one artwork, while in another, the same gesture may cause the artwork to move away. Therefore, it is crucial to also consider how an action affects other elements and its functions within the specific context of an interaction. We argue that specifying the roles of the various actions performed by the elements is essential for identifying their roles in the interaction and understanding the overall interactive dynamics. This not only aids in distinguishing and comparing different artworks but also reveals patterns that can inspire the creation of novel forms of interaction.

In summary, we argue that an effective model for adequately describing interactions in interactive art should provide a robust template and vocabulary capable of capturing the different relational dynamics occurring within an interaction. Such a model must account for the diverse relationships among the audience, the artwork, and, if present, other participants, enabling a clear understanding of how each element' s actions affect and relate to one another. Furthermore, we contend that this model should treat both the artwork and participants as equally agentic, a perspective that not only opens up new creative possibilities but also challenges conventional assumptions regarding the roles of humans and technological systems in interactive contexts. Finally, the model should be adaptable to accommodate various forms of interaction and scalable, allowing users to customise the level of detail necessary for modelling specific interactive scenarios.

2.4 Key Concepts of the Relational Model

In this section, we present our relational model for describing interactions in interactive art, building upon the theoretical considerations outlined in the previous section. A visual representation of this relational model is provided in Figure 2.4. The model starts by identifying the individual actors participating in the interaction, each of which is described as an *element*. To describe an interaction, the model examines the *actions* performed by the interacting elements, such as a movement, an update of a display, or pressing of a button. Following an *action*, a form of *communication* is created and directed at (an)other element(s). For each action, the model examines what *role(s)* it plays in the context of the interaction and how it influences other elements. In the following subsections, we further elaborate on each key concept and introduce the various descriptors for specifying them.

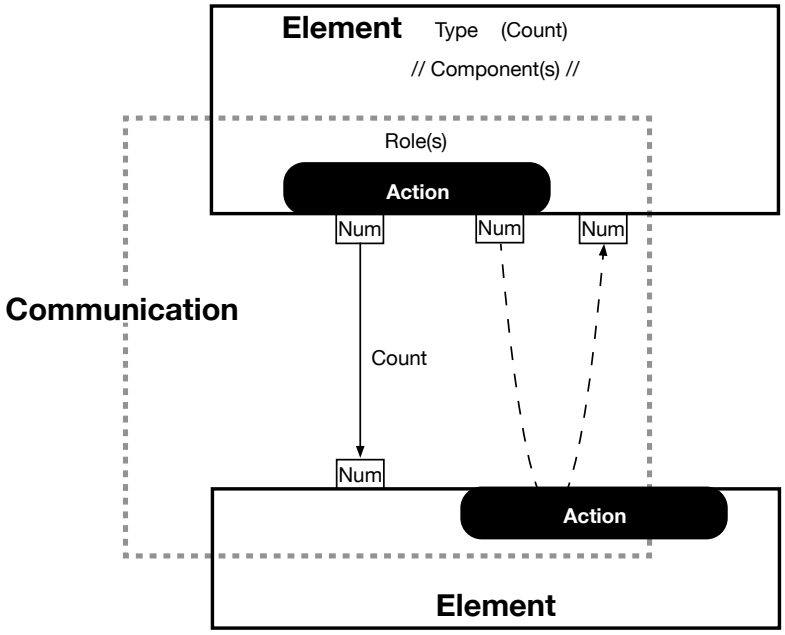

Figure 2.4: Diagram illustrating the relational model.

2.4.1 Element

Type: The categorical description helps to differentiate the elements. Within the context of interactive art, two primary types of elements are commonly identified: the audience and the art system. Cabrita and Bernardes, in their model of relational interactive art, conceptualise the interactive system of an artwork merely as a "computer" (Cabrita & Bernardes, 2016). However, we find this term misleading, as an interactive artwork often involves more than just a computer; other components of the artwork can be equally, if not more, significant in shaping the interaction. Furthermore, we argue that an interactive artwork encompasses both the technical art system—which does not necessarily rely on computers—and the requisite audience behaviour to complete the interaction. Therefore, we propose the term *art system* to describe an autonomous functional unit within an interactive artwork. An art system may comprise input units, output units, and processing units, similar to the computer element in Cabrita and Bernardes' model, or it may be made of physical materials that react to the environment and are manipulated by the audience. An interactive artwork may include a single art system or several art systems, each exhibiting distinct behaviours and capable of establishing dynamic connections with the audience. In the latter scenario, each must be analysed individually to account for their unique contributions to the interaction.

The audience element refers to individual participants engaging with the artwork. In many interactive art contexts, some audience members actively interact with the artwork, while others remain passive observers. These roles are not fixed; participants may transition between these two modes. However, as our model focuses on the dynamics of interaction, it specifically includes those audience members who are directly participating in the artwork and whose actions influence the art system or other participants. Similar to the case of the art system, when distinct behaviours or roles are observed among audience members, each must be explicitly specified using the relational model.

Besides audience members, an interactive artwork may involve nonhuman organisms as participants. In such cases, these organisms can also be described as participating elements using the model. Furthermore, certain interactive artworks are influenced not only by the audience but also by environmental factors (Cornock & Edmonds, 1973). For instance, an art system may adapt its behaviour in response to fluctuations in ambient temperature or real-time internet traffic data. When such factors play a significant role, they can be categorised as environmental elements within the model.

Components: The devices, materials, and apparatus comprised of or used by an element during interaction. In the case of a computer-based art system, these typically include hardware components—sensors, computers, actuators, or displays—to sense the environment and execute actions, as well as software components such as tracking or control programs for processing data and generating commands. For audience, their participation often involves using their bodies to perceive, act, express, and communicate with both the art system and one another. Additionally, they may also utilise additional objects or personal devices. The components of an element define its material basis and help distinguish it from other elements.

Count: The number of elements of the same type that can simultaneously participate in the interaction. In some cases of interactive art, the interaction may involve a fixed number of elements, while in others, the elements may join and leave at any time. Moreover, some interactive artworks may specify a minimum number of audience participants. In this scenario, we can denote the minimal required number of elements with a '+' sign to indicate potential additions.

2.4.2 Action

An action refers to something that is done or performed by the element to participate in the interaction. It is a concrete step taken by an element or multiple elements that alters either themselves or their surrounding environment. Examples range from physical movements (e.g., walking, pressing a button) to updates in display modes (e.g., showing data on a screen or gen-

erating audio). Within the relational model, actions are the fundamental units through which elements connect with and influence one another, and thus every action described is directed towards other elements, or an 'outward' action. Activities that involve receiving information —such as sensing or observing—are not explicitly listed as actions. The direction of an action can manifest in two ways: first, the acting element intentionally performs an action directed at the receiving element; second, the receiving element actively captures aspects of the action performed by the acting element, even if the action is not initially intended for the interaction. The latter often occurs when an art system detects and responds to specific actions of the audience.

In a taxonomy of interactive artworks developed in the context of the Prix Ars Electronica, Kwastek identifies a series of key actions potentially performed by the audience as "observe, explore, activate, control, select, participate, navigate, leave traces, co-author, collaborate, exchange information and create" and the corresponding actions made by the art system are "monitor, serve as an instrument, document, enhance perception, offer a game, enable communication, visualize, sonify, transform, store, immerse, process, mediate and tell/narrate" (Kwastek, 2008). While these terms effectively capture the function of an action, they do not necessarily describe the concrete actions carried out by each element. When it comes to describe the interaction in a specific artwork, we first need to identify the individual, concrete actions performed by the elements.

Action role(s): For every action performed by an element, it is essential to define its role(s) within the interaction. These roles reflect the action's functions and its relationships to other actions performed by the same element or by different ones. An action can be *self-initiated* by an element or triggered by another element's actions as a *reaction*. As we discussed before, the terms identified by Kwastek provide a rich vocabulary for expressing these roles. However, in Kwastek's description, the actions of the audience tend to be more active, such as explore, activate, control, while the artwork tends to be at the service of the audience. By contrast, we do not impose any strict distinction between the roles of the audience and those of the artwork; both can assume the same roles. This more flexible perspective opens up opportunities to create new forms of interaction.

2.4.3 Communication

When an element performs an action directed at another element(s), a form of communication is established. In the relational model, communications are regarded as the concrete mechanisms through which elements influence one another via their actions. To describe a form of communication, we specify the arrangement of the elements involved, and the information

flows among them. In doing so, we hope to depict a comprehensive picture of the network of influences among the elements. Specifically:

To: The element(s) at which the action is directed. These elements may be of the same type as the acting element or of a different type. The same action can also be directed at different elements, generating multiple forms of communication.

Means: The means by which the action reaches the receiving element. We identify two different types:

- Direct: The action is directly targeted at the receiving element, without the involvement of any intermediate elements.
- Via (intermediate element): The action is targeted at an intermediate element, which then transmits it, via its own action, to the receiving element. This is commonly referred to as a *mediated communication*.

Configuration: The numbers of elements at both ends of the communication. An action can be performed by one or multiple elements, and it can be directed at one or multiple recipients. We distinguish four configurations:

- One to One: From one element to one element only.
- One to Many: From one element to one or more elements.
- Many to One: from one or more elements to one element.
- Many to Many: From one or more elements to one or more elements.

Besides the number of elements, we also identify two settings in which the communication takes place:

- Private: Only the communicating elements can perceive the communication.
- Public: The communication can also be perceived by other elements and observers.

Count: The number of communication of the same form that can occur simultaneously. This does not necessarily require strict temporal synchrony; rather, it concerns more of the element's capacity to perform the action, hence the resulted communications, repeatedly. For example, an art system might detect one audience member at a time and emit an audio response. However, it aims to inform all audience members of its capacity to detect their presence. In this case, we consider there to be multiple instances of such communications occurring in parallel.

2.5 Discussion

In this chapter, we reviewed existing models and tools used to capture interactive dynamics in interactive art. Building on the strengths and limitations of these approaches, we propose the relational model as a tool for describing interaction, with a focus on capturing the relational exchanges among the elements. Unlike the feedback loop model and the dialogue model, the relational model provides a practical structure and vocabulary that can be applied to dissect and analyse specific interactions. This not only enables systematic comparisons across different artworks but also opens up the possibility of integrating computational methods into such analysis. Drawing on lessons from the scoring system proposed by Bell and the graphical modelling language proposed by Mubarak, the next step for the relational model involves developing a more intuitive and accessible interface to facilitate the modelling process, which is the central topic of Chapter 3.

The relational model does not impose predefined categories for the types of elements it can describe, and treats all elements—whether audience members, art systems, nonhuman organisms, or environmental factors—using the same analytical frame of reference. By adopting this inclusive and flexible approach, the model is highly adaptable, capable of describing a diverse range of interactive forms and enabling the analysis of interactions from the different perspectives of the various elements involved.

Central to the relational model is its focus on the dynamics of interaction, which it examines through the actions performed by each element and the resulting forms of communication between them. This approach provides a detailed understanding of how elements influence one another through their actions (and reactions), while also allowing us to clarify the roles each element plays within the interaction. Additionally, the open-ended structure of the relational model allows users to tailor the level of detail in their descriptions to meet the specific needs of their analysis, ensuring flexibility and precision.

Beyond analysis, the relational model can also serve as a template for conceptualising new forms of interaction. For instance, users can experiment by combining different forms of communication or redefining the roles of actions performed by elements to create new interactive dialogues. The model further encourages the exploration of unconventional forms of communication. For example, rather than interacting directly with the art system, audience members might influence it indirectly through the actions of another audience member, illustrating a form of audience-mediated communication. Additionally, the model invites speculation on how various forms of communication might interact—whether by disrupting, complementing, or otherwise influencing one another—opening up possibilities for crafting more complex interactive dynamics.

Despite these advantages, the relational model has certain limitations. While it describes element behaviours based on their actions, it does not explicitly account for reactions, which are reflected in the role(s) of actions. Therefore, it does not readily indicate the degree of responsiveness or autonomy exhibited by elements. Additionally, the model captures a snapshot of key interactive dynamics at a given moment, but does not fully account for the temporal evolution of interactions. For instance, the audience may be more exploratory at the onset, as they discover and master the interaction mechanism they may act and react differently. For analyses requiring these temporal or responsive aspects, the relational model can be complemented by other frameworks and taxonomies to provide a more comprehensive account of interaction dynamics.