Investigating Collaboration in Art and Technology

Yun Zhang

Introduction
How do creative minds get together and create something new which may not be achieved by a single mind? Creativity often needs collaboration, because people generally have limits on certain type of skills to implement their creative ideas. In the context of the digital art world this type of collaboration might be between artists and artists or artists and technologists. In the world of filmmaking, the collaboration might be between directors and sound artists, photographers and animation specialists and so forth. When these types of collaboration take place, it is always interesting to ask what are the characteristics of the collaborative process, how are innovative ideas developed, how are they applied to the outcomes, and last, but not least, how do people come together with a shared goal and work together to create something extraordinary despite the fact that they often have different ways of thinking and communicating.

As a professional researcher, I am seeking answers to these questions from a practitioner’s point of view. My approach to the research was to carry out an observational and ‘non-participative’ study of how creative ideas were developed and implemented during a three months collaborative process when I was ‘embedded’, so to speak, in the project team. That team consisted of an artist who led the project and two computer experts both of whom were specialists but in different types of digital technology. I begin with a brief description of the art-technology project called GEO Narrative Landscapes. The research involved analysing the interaction between the artist and technologists from which I developed a schema based on different types of communication modes. The findings included common types of conversation within each communication mode, how the modes related to each other and how they were distributed in terms of frequency and duration across the meetings. Finally, I discuss the contribution of this research to our understanding of collaboration between artists and technologist.

Context
The art-technology project studied in this research is called GEO Narrative Landscapes. GEO is an interactive artwork that is intended to attract audiences to the Brickpit Ringwalk, an elevated circular walkway at the Sydney Olympic Park (Figure 1). The artistic goal was to convey impressions of the site in words, photography and video images in
order to create a layered virtual environment in which audiences could move around and explore.

Figure 1: Still image of Brickpit Ringwalk

GEO is an ‘immersive’ environment where the user can explore a remote location seen through the eyes of other people. The user interacts with the system by moving around in front of a wall-sized rear projection screen and a six-by-six grid of pressure sensors detects where the users are standing. Displayed on the screen is video and text material relating to the location. The artwork is designed for installation in a museum. The user can explore the remote space at several levels of interaction, and explore different people’s views of particular aspects of the site (Zhang et al, 2007). Three views of the GEO screen interface in a test environment are shown in Figure 2. This work was exhibited from April to May 2007 at Beta-space in Sydney’s Powerhouse Museum. Beta-space is an exhibition space where the general public can engage with art outcomes of leading research in art and technology (Costello et al, 2005).

Figure 2: View of three layers in the GEO interface

The GEO project was carried out in a multi-disciplinary research team comprising of an artist, two technologists and one observer. All participants were co-located in the same city. The artist was the designer of the digital artefact and also the leader of the team. The two technologists were in charge of different parts of the technical functions of the project: one was mainly working with the software application MAX/MSP (Cycling74), the other was mainly working with the programming language Java.1 The basic collaboration mode for this project was via group meetings. The duration of the group meetings was from
between approximately thirty minutes to one hour based on on-site-demand and the frequency of the meetings was once a week.

**Research Methods**
The main data collection approach adopted in this research was non-participant observation and semi-structured interviews (Yin, 2002) (Denzin and Lincoln, 1998). Non-participant observation is a method where researchers ‘stand to one side’ and view the experience or the environment (Slack and Rowley, 2001). In this project, the observer used video facilities to record the meetings between participants and took field notes each meeting. At the end of the observation period, a semi-structured interview was conducted with each participant separately. In addition, the project-related emails between participants were also included as part of the data collection in order to arrive at as detailed a picture of the collaboration as possible.

For the data analysis, the protocol analysis method was used, which has been broadly applied in cognitive science (Suwa et al, 1998) and collaboration research (Cross et al, 1996), where verbal reports of thought sequences are elicited as a valid source of data on thinking (Ericsson and Crutcher, 1991). During the protocol analysis, a coding process is involved, where categories of fundamental knowledge (such as concepts, attributes, values, tasks and relationships) are applied to label the data (Richards, 2005; Suwa et al, 1998). These labelled data indicate that they are examples of these categories. A group of these categories is called a ‘coding scheme’, which reflects the researchers’ focus on particular aspects relevant to their research questions (Suwa et al, 1998). The coding scheme for data analysis applied in this study is based on a selected group of categories drawn from the COSTART coding scheme, developed in previous research. More detail about this analysis scheme may be found in (Zhang and Candy, 2006). A brief description of each code may be found in Table 1 below. The data analysed consist of eighteen video-recorded meetings between participants over a five months period with supplementary information from field notes and email exchanges. The main data analysis was carried out applying the code sets (see Table 1) to the data.

The results are now described.

<table>
<thead>
<tr>
<th>Communication behaviour</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agreement</td>
<td>Agree or disagree with others.</td>
</tr>
<tr>
<td>Enquiry</td>
<td>Ask questions, which commonly start with ‘when’, ‘where’, ‘how’ and ‘what’.</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Analyse an object according to a criterion. It can be either positive or negative.</td>
</tr>
<tr>
<td>Hypothesis</td>
<td>Express a personal representation of a subject.</td>
</tr>
</tbody>
</table>
Inform | Provide information with respect to the nature of an object or criterion; illustrate a fact; explain some knowledge new to others; inform a state.
---|---
Justification | Argue or explain the rationale of a certain choice.
Solution-generation | Suggestions for problem solving and specific applicable plans.
Recall | Retrieve knowledge about previous experience.
Fragment | Sentences which are hard to understand or do not make much sense.

<table>
<thead>
<tr>
<th>Communication mode</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer-screen-assisted</td>
<td>Conversation conducted when participants talk with each other while constantly referring to some components of a computer screen, which could be a desktop screen or laptop screen.</td>
</tr>
<tr>
<td>Drawing-assisted</td>
<td>Conversation conducted when participants made some drawing on the paper while communicating with each other.</td>
</tr>
<tr>
<td>Object-assisted</td>
<td>Conversation conducted when participants talk with each other while constantly referring to an object. In the GEO project, participants spent majority of the time on only one object, a proposal, which is a schematic story board developed by the artist. During this mode, the proposal could be a printed version or a document in PDF format on computer screens.</td>
</tr>
<tr>
<td>Interactive-system-assisted</td>
<td>Conversation conducted when participants interacted with the artefact or constantly referring to the digital artefact showing in the interactive space, such as walking around the interactive floor pad area while communicating with each other.</td>
</tr>
<tr>
<td>Face-to-face</td>
<td>Conversation conducted when participants talk with each other without using any medium, such as computers, physical objects etc.</td>
</tr>
<tr>
<td>Others</td>
<td>Other non-related communication, such as participants made phone calls; or participants work individually and quietly.</td>
</tr>
</tbody>
</table>

Table 1: Communication Behaviour and Communication Modes

Table 1 provides a summary of the communication behaviour and communication modes. The details and results are now described.

Results

In this section, first, the common features of the relationship between participants’ topics of conversation and the particular communication mode used. Second, a statistical analysis is presented that compares sequence, frequency, and duration of each coded segment across meetings.

Face-to-face

This type of communication happens where participants communicate with each other without referring to any medium. Four topic areas were identified within the face-to-face communication mode: first, the artist and the technologists were exploring project goals and plans. Second, the artist and the technologists were exchanging knowledge and expertise. Third, other project issues, such as deadlines, funding and fourth, digressions, such as personal greetings, news, were discussed. The conversations in relation to goal/plan participants conducted are, for example, what participants wanted to achieve in the next couple of weeks and what kind of general effects the artist wanted the artwork to have.
**Computer-screen-assisted communication mode**
In the ‘computer-screen-assisted’ mode, participants communicate with each other while referring to and manipulating objects in front of a computer. Two circumstances were identified where the computer-screen-assisted communication mainly occurred. First, the technologists were showing the artist what they had achieved or explaining technical aspects of the artefact and second, the technologists and the artist were addressing a technical problem or the technologists were working together to resolve technical problems. During these circumstances, the programming software Max/MSP was usually displayed on the computer screens and the technologists were usually trying to explain to the artist how to achieve a specific effect of the artefact in Max/MSP, such as how Max/MSP controlled the movements of the floor pad.

**Object-assisted communication mode**
The ‘object-assisted’ mode means that participants communicated with each other while referring to a physical object. It was observed that the physical objects participants referred to were mostly proposals, whereas the design information of the artefact was illustrated in detail. These details included the layout descriptions of the interface, what audiences see on the screen and the time frames for audiences to activate certain effects. Furthermore, the presence of the proposal during the group discussion was a printed document or a digitalized file displayed in a computer screen. Two circumstances were identified where the participants conducted this communication mode: the artist tried to explain what kinds of effects he wanted to achieve, or the technologists tried to connect what they had done to the design information illustrated in the proposals.

**Interactive-system-assisted communication mode**
The ‘interactive-system-assisted’ communication mode happens where participants communicate with each other while interacting with the artefact. Two major circumstances were identified during the occurrence of this mode: first, the technologists were interacting with the artefact to demonstrate how the interaction behaves based on different kinds of floor pad movements. Second, the artist was interacting with the artefact while asking questions, giving feedback about the current version of the artefact and making suggestions for changes.

**Drawing-assisted communication mode**
The ‘drawing-assisted’ communication mode happens when participants communicate with each other while drawing with a pen on a notebook or on a white board. In the drawing assisted mode, only one behavioural circumstance was observed, which is when participants were trying to articulate an idea or potential solution.
Patterns of communication behaviour

The following table presents the distribution of the artist and two technologists’ communication behaviour. It shows that: first, the top three types of communication behaviour participants spent most time on are the same, which are inform (A: 47.01%; Ta: 49.03%; Tb: 57.87%), solution-generation (A: 21.9%; Ta: 19.14%; Tb: 14.45%) and enquiry (A: 13.09%; Ta: 15.55%; Tb: 12.44%); second, some communication behaviour distributions between the artist and the technologist Ta are relatively similar, such as inform (A: 47:01%; Ta: 49:03%), and solution-generation (A: 21.9%; Ta: 19.14%). In comparison, the artist’s and the technologist Tb’s communication behaviour distributions are relatively different. For example, inform (A: 47.01%; Tb: 57.87%) and solution-generation (A: 21.9%; Tb: 14.45%). Third, in terms of evaluation behaviour, the artist had the highest percentage between the two technologists (A: 6.19%; Ta: 3%; Tb: 4.11%).

<table>
<thead>
<tr>
<th></th>
<th>Solution-generation</th>
<th>Recall</th>
<th>Justification</th>
<th>Inform</th>
<th>Hypothesis</th>
<th>Evaluation</th>
<th>Enquiry</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artist</td>
<td>31.9%</td>
<td>26.1%</td>
<td>4.1%</td>
<td>4.0%</td>
<td>0.1%</td>
<td>6.1%</td>
<td>11.0%</td>
<td>2%</td>
</tr>
<tr>
<td>Technologist A</td>
<td>19.1%</td>
<td>22.1%</td>
<td>5.4%</td>
<td>19.0%</td>
<td>2.4%</td>
<td>3%</td>
<td>15.5%</td>
<td>3.3%</td>
</tr>
<tr>
<td>Technologist B</td>
<td>14.4%</td>
<td>0</td>
<td>3.2%</td>
<td>57.8%</td>
<td>2.3%</td>
<td>4.1%</td>
<td>12.4%</td>
<td>5.3%</td>
</tr>
</tbody>
</table>

Table 2: Distribution of participants’ communication behaviour

The first result illustrates the types of communication behaviour that participants mainly exhibited: inform, solution-generation and enquiry. This indicates that artists and technologists communicated with each other in three main ways: first to inform others with their own knowledge, second, to produce solutions to solve the problems, and third to ask questions and clarify opinions. The second result, related to the similarities and differences between participants’ three major types of behaviour, indicates that the artist and the technologist Ta served a relatively similar role during the majority of the collaboration in terms of informing knowledge, asking questions and generating solution. The third result, related to the evaluation behaviour, shows that the artist made evaluation related decisions more often than the technologists. This indicates that the artist as leader controlled the evaluation process within the collaboration, such as potential solutions generated in the collaboration or outcome of the collaboration.

Patterns of communication modes

The analysis results of five communication modes was presented in three different forms: sequences of five communication modes in individual meetings, frequencies of each of the five communication modes in every individual meeting and across eighteen meetings and
the time participants spent on each communication mode in every meeting and across eighteen meetings.

**Sequences**
Using INTERACT, the mode of communication with precise starting and finishing time in each meeting was captured. These segments were presented and visualized in a time-line based graphic: interaction graph (Mangold, 2005). This type of data representation has been found to be very useful for comparing the trajectory of participants' communication modes over a period of time. From the comparison of the individual meeting’s interaction process across eighteen meetings, three interesting patterns were found in terms of the sequences of five communication modes within each meeting. First, in fourteen out of eighteen meetings, where the face-to-face mode occurred, the face-to-face mode happened both at the beginning of the meeting and at the end of the meeting; second, in ten out of fourteen meetings, where both the computer-assisted and the interactive-system-assisted modes happened, the computer-screen-assisted mode and the interactive-system-assisted mode were sequenced one after another; third, in seven out of eight meetings, where the drawing-assisted mode and the interactive-system-assisted mode were both conducted, the drawing-assisted communication mode took place immediately after the interactive-assisted communication mode.

The patterns identified above provide us with a view of how participants used these five types of modes within a timeline and inform the nature of the relationship between these communication modes in terms of time sequences. For instance, one of findings shows participants conducted the interactive-assisted mode and computer-screen-assisted mode sequentially, which indicates that these two modes have a strong inter-relationship. In the computer areas, they worked on some adjustments to the software application, such as changing certain parameters, to realize ideas that had been raised previously in interactive-assisted communication. Another finding in relation to the sequences shows that drawing-assisted mode happened quite often before or after the interactive-assisted mode. This suggests that participants used drawing on paper to explain ideas that were hard to explain with the interactive artefact mediation tool.

**Occurrences**

The following table shows the occurrence of each communication mode within eighteen individual meetings, where the last row shows the total number of actions in each mode and the meetings where the value of the occurrence is zero are shaded.
The results summarized in Table 3 are as follows: first, participants did not conduct every type of communication mode in each meeting; second, comparing the five communication modes, the communication mode participants conducted most often is the face-to-face mode (172 times); the communication mode participants conducted least often is the drawing-assisted mode (26 times), and in addition, the number of times the computer-screen-assisted mode (107 times) took place is very similar to the times of the interactive-system mode (115 times); third, the 5th column shows that the object-assisted mode happened much more often in the first half of the collaboration (from 1st meeting to 9th meeting: 54 times) than the second half of the collaboration (from 10th to 18th meeting: 10 times).

The results illustrated above show some interesting features of these communication modes. For instance, the second result shows that there are less than half the meetings where the drawing-assisted mode was conducted and the total occurrence is much smaller than the other modes. This implies that drawing as a traditional way of expressing ideas, did not play a very important mediation role in the art-technology collaboration.

Moreover, the third result indicates that the object-assisted mode occurrence decreased dramatically from the first half of the collaboration to the second half of the collaboration. The proposals, which the artist made to express his artistic ideas about the project, serve as an important mediation role in assisting building up shared understanding between the
artist and technologists. During the first half of the collaboration, as the shared understanding between participants was at an initial stage and a great deal of communication was required to make ideas embedded in the proposals applicable and understandable, the occurrence of the object-assisted communication was relatively high. When the collaboration went into the second half, participants decreased the time of the object-assisted mode, where the printed or the digitalized version of the proposal was used. This reflects the fact that participants had built up a better understanding of the artist’s goals and requirements than the first half time and participants did not need to refer to the proposals any more. Thus, this finding suggests that the role of the proposals as a mediation tool for communication can be used to measure the level of understanding between artists and technologists.

**Time distribution**
The following figure shows the total time participants spent on each mode in each meeting. The vertical axis shows the duration sum of all instances of each mode in each meeting and the horizontal axis represents the eighteen meetings which were recorded. F, C, I and O presents ‘face-to-face’, ‘computer-screen-assisted’, ‘interactive-system-assisted’ and ‘object-assisted’ modes. The drawing-assisted mode was omitted because it was a very low percentage of the time compared to the other modes. The further analysis was mainly carried on the other four modes.

![Time participants spent on each mode across eighteen meetings](image)

**Figure 3: Time participants spent on each mode across eighteen meetings**

The features identified from this figure are summarized as follows: first, the time participants spent on the face-to-face communication decreased gradually from the first meeting to the eighteenth meeting; second, the time participants spent on the interactive-system-assisted and computer-screen-assisted communication increased gradually from
first meeting to eighteenth meeting; third, the time participants spent on the object-assisted increased gradually until the 8th meeting and after the eighth meeting, the time decreased gradually.

These results indicate that the communication time participants spent with the mediation of computers and the interactive artefact gradually increased from first meeting to the eighteenth meeting, the communication time participants spent without any mediation tools gradually decreased from first meeting to the eighteenth meeting, and the communication time participants spent with the mediation of proposals increased during the first eight meetings and decreased in the rest of the ten meetings. These results can be better understood when they are placed in the context of the whole collaboration. At the beginning of the collaboration, when the understanding between artists and technologists was not fully established, it was observed that participants were mainly working on knowledge exchanges, generation of solutions and goals and refinements of ideas. During this period, the face-to-face communication and the object-assisted communication predominated. However, as the collaboration went on, the shared understanding between artists and technologists was gradually established and participants moved towards spending a great deal of time on computers and interactive system as mediation tools to communicate with each other. During this period, the ideas or goals participants worked on were relatively concrete, such as the quality of the image, the sensitivity of the interactive system etc. This suggests that the use of mediation tools reflects the stages participants work on: when the face-to-face mode and the object-assisted mode are spent a great deal of time on, it is more likely that participants are working in the early stage of the collaboration and there is not much shared understanding which has yet to be built up. In comparison, increasing the time spent on the computer-screen-assisted mode and the interactive-system-assisted mode seems to indicate that a good level of shared understanding has been established.

**Findings and Discussion**

The findings from this study relate to a case of interdisciplinary collaboration in a single creative project. The findings have been related to previous work and other research in design. Their implications need to be considered in that light.

**Relationship Between Communication Modes and Stages of Collaboration**

In terms of the relationship between communication modes and the stages of collaboration, it was found that the information about the mediation tools in use can indicate particular stages in the collaborative process and a certain level of shared
understanding between artists and technologists. The results presented previously show that at the early stage of the collaboration, when a lengthy period of time was spent on face-to-face mode and proposal-assisted mode, participants were mainly involved in knowledge exchanges, solution generation and refinement of goals. At this time, the ideas they formulated were relatively abstract and unstable, and the understanding between the artist and the technologists was not very well established. In particular, the artist's concept proposal, in which visions for the creative work were expressed, served as an important tool for mediating between the artist and the technologists. The proposal became less important as shared understanding of the goals were established. As the collaboration went on, participants moved towards spending a great deal of time using computers and the interactive artefact as mediation tools to communicate with each other. During this period, the ideas or goals participants worked on were relatively concrete, such as the quality of the image and the sensitivity of the interactive system, which implies that more shared understanding between artists and technologists had been gradually established. In addition, it was found that during the computer-assisted mode and the interactive-assisted mode, many questions were raised and the level of uncertainty was reduced significantly.

It can be seen that the usage of a communication mode can identify the level of understanding between participants and furthermore, which stage of the collaboration had been reached. The basis of this finding suggests that artists collaborating with technologists and other contributors to the creative process could construct their proposals with this requirement in mind. It can also be claimed that computers and interactive systems, used as mediating tools, are substantially effective in improving the development of shared understanding between artists and technologists. However, this does not mean that the face-to-face mode and the proposal-assisted mode were not effective for contributing to the shared understanding so essential to the collaboration process. From this research, it was found that the face-to-face mode and the proposal assisted mode effectively improved the shared understanding between participants at the early stage. Beyond that, computers and interactive-artefacts seemed to be more effective during the collaboration for reshaping artist's perception and cognition in terms of transferring ideas from the arts to computer technology.

**Contributions to Creative Collaboration**

At the end of the collaboration, an evaluation study was carried out drawing upon the team members and people external to the project in order to provide opportunity to evaluate the process and outcome of the collaboration. The team evaluation was realized
by conducting an individual interview with each participant, where the questions related to motivation, the process of the collaboration and evaluation of the outcome were asked. From the in-depth interview of each participant, the findings indicated that the technologists considered that the project was successful both in terms of the collaboration itself and its outcomes. Equally, the artist acknowledged the technologists’ contribution positively and expressed the fact the collaboration in total was productive and successful. In terms of the outcome of the collaboration, the artist was more hesitant and, whilst agreeing that the project was successful within the time frame, nevertheless expressed a desire for more time and budget.

A second evaluation study was carried out by focus-group interview with a group of experts in the interactive art field, immediately after experiencing the interactive artefact in the studio. During the focus-group interview, the feedback was positive and the interviewees agreed that this artefact was ready to go into the public exhibition place for audience evaluation. Some feedback from the focus-group interview was applied to the artefact system afterwards. One suggestion was to minimizing the time frame of the passive mode in order to let the audience engage the artefact rapidly; another suggestion was to add some instruction to each layer of the artefact to provide better guidelines for the audience to interact with the system fully.

It can be seen from the findings above that this collaboration was considered to be successful and the artefact outcome was also considered to be promising by all parties to the collaboration. Whilst this study tells us something about the relationship between the role of the collaborators and their contribution to the creative work, we also need to consider how different the collaborative process made to the development of the creative work as apposed to it being carried out by the artist alone. It is not difficult to understand that the artist made a great deal of contribution towards the creative perspective of the project but a further question here is how much did the technologists contribute to the creative process? Evidence suggests that the technologists contributed mainly through giving up to date advice about the kinds of technology available to meet the requirements of the artist’s vision. Without a high level of expertise, the project would have taken much longer and, realistically, might never have been achieved. In addition, because they understood the constraints of the technology, they were also able to provide constructive advice about how to achieve a result within a realistic time frame. With the five collaboration modes identified in this chapter, it was found that technologists’ contribution to creative ideas extended across all the different modes, but when it came to
‘computer or interactive tool mediated’ mode, they led the conversation more often than the other types of mediation.

Furthermore, an additional and significant factor was that the two technologists, having different expertise and experience in art-technology collaboration, had quite different ways of contributing to the project. Technologist A was a designer himself and had worked extensively with artists beforehand and Technologist B was a highly skilled computer programmer by training and experience. From the evidence of the data, it can clearly been observed that technologist A affected the conceptual formation of the work more than technologist B whilst technologist B mainly provided assistance and implementation when the conceptual model was finalized.

The roles in this type of collaborative and interdisciplinary creative process have been modelled by Candy and Edmonds (2002). Their model consists of three main activities: creative conceptualisation (the ideas and motivations of the work), construction (implementation or making) and evaluation (of the outcomes whether product or process). In the GEO case, by applying this model, it was observed that the interaction between the artist and technologist A is a partnership model with artist control where both of them participated fully in all of the key creative stages, with artist takes complete responsibility for the evaluation of the outcome. The interaction between the artist and the technologist B can be identified as an example of the assistant model, where the technologist did not contribute noticeably to the creative conceptualisation and evaluation, but was highly effective in the actual construction of the artefact.

The findings drawn from this study provide insights into how the collaborative creative process was facilitated by external mediation tools, such as computers, interactive artefacts and project proposals. For instance, the mediation of project proposals performed a significant role in supporting the collaborative process in the early stages whilst the mediation of interactive artefacts and computers in parallel influenced the middle and later stages. This research adds to our understanding of collaborative creativity that can be applied, for example, by facilitating the communication modes that are most significant at different stages of a project. Additionally, the work addressed here makes a contribution to improving the supportive process in art-technology collaboration. Let us consider an analogue involving the history of bibliographic database library searching that illustrates this point. In the 1970s and 1980s, bibliographic database library searches required training in specialised database languages. Today, owing in part to studies of database searches and the improving the supportive process, the searching has
been simplified to the point where users, with only a couple of hours of training, are capable of doing the database searching themselves. The intermediary support is no longer a necessary link in the process of cooperation. In the context of art-technology collaboration, this research contributes to a point of time in the future when the creative worker is free to focus on their own work and the technologist is free to focus on the learning and applying of new techniques.

Conclusions
The central issue developed in this chapter is the exploration of methodologies by which artists, a particular subgroup of creative professionals, may be systematically studied in their collaboration with technological support experts or specialists. An approach was presented to analysing the communication patterns of interdisciplinary work using the categories: the face-to-face mode, the proposal-assisted mode, the computer-assisted mode, the interactive-artefact assisted mode and the drawing assisted mode. This approach and the analysis techniques may generalize to the study of collaboration between other working professionals, such as designers, architectures, engineers and so on. By bringing together the findings of a qualitative analysis and quantitative analysis of these modes, a systematic account of an art-technology collaboration project was achieved.

Finally, this research presented here may open new possibilities for studying art-technology collaboration. As it was found out that the mediation of computers may help both artists and technologists produce solutions, it might be worth conducting further studies where participants use different software programs to implement a similar artistic idea within the same timeframe. We might be able to discover which existing software programs are more effective in facilitating the collaboration process between artists and technologists. In addition, other questions that have arisen from the work can be explored in future work: for example, as it was found that proposals can help artists to articulate artistic concepts and help technologists to clarify the artistic requirements, does it mean such proposals need to be made as detailed as possible or will a proposal with too much detailed information limit the creative process between artists and technologists? Moreover, as it was found that the mediation tools varied at different stages of a project, so in the future, it could be valuable to develop a series of specialised strategies and methods to select the mediation tool most significant at each stage.

Java is a programming language and computing platform first released by Sun Microsystems in 1995. It is the underlying technology that powers state-of-the-art programs including utilities, games, and business applications.