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The studio as laboratory: Combining creative practice and digital technology research

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Abstract

Creativity research is a large and varied field in which the subject is characterized on many different levels. The arrival of digital media and computational tools has opened up new possibilities for creative practice. The cutting edge in the digital arts is a highly fertile ground for the investigation of creativity and the role of new technologies. The demands of such work often reveal the limitations of existing technologies and open the door to developing new approaches and techniques. This provides the creativity researcher with opportunities to understand the multi-dimensional characteristics of the creative process. At the same time, it places new demands upon the creators of the technological solutions and pushes forward our understanding of the future requirements of creative technologies. This paper is concerned with the nature of creativity and the design of creativity enhancing computer systems. The research has multi-disciplinary foundations in human–computer interaction and creative practice in Art, Design, Science and Engineering. As a result of a series of studies of creative people and the associated developments in technology, a strategy for practice-based research has evolved in which research and practice are interdependent activities that have mutual

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benefits as well as distinctive outcomes. This paper charts the development of that co-evolutionary process from the foundation studies to recent outcomes of a major project in art and technology collaboration. The notion of the Studio as a laboratory in the field is introduced and a new methodology for systematic practice-based research is presented. From the results of the investigations that took place, opportunities for the development of technology environments for creative collaboration are proposed.

Keywords: Creativity; Collaboration; Practice-based research; Software environments; Creative technologies

1. Introduction

Creativity research is a large and varied field in which the central subject is characterized on many different levels. The arrival of digital media and computational tools has opened up new possibilities for creative practice. For the rapidly expanding numbers of computer users, the role of computers in creativity is a relatively new and largely unexplored avenue. In computing communities, the subject was rediscovered in the area of computational creativity (e.g. Boden, 1990; Partridge and Rowe, 1994) and more recently in human–computer interaction (HCI) (Shneiderman, 2002; Candy and Hori, 2003).

The gulf between the creative practitioners and the creativity researchers remains a large one but, in the field of computer support for creativity, this is being addressed by enabling practitioners to take an active role in the system development process. In order to gain an understanding of creative practice, evidence is needed from fields where creative thinking and innovative outcomes are the core business. The cutting edge in the digital arts is a highly fertile ground for the investigation of creativity and the role of new technologies. Almost every day new forms are emerging where innovative combinations of vision, sound and text-based media are being created. The demands of such work often reveal the limitations of existing technologies and open the door to developing new approaches and techniques. This provides the creativity researcher with opportunities to understand the multi-dimensional characteristics of the creative process. At the same time, it places new demands upon the creators of the technological solutions and pushes forward our understanding of what is needed for digital technologies to be truly creativity enhancing.

This paper is concerned with a long-standing exploration of the nature of creativity and the design of creativity enhancing computer systems. The prospects for developing such systems and the research needs that were implied were introduced, for example, in a book that arose from a 1991 meeting on Artificial Intelligence and Creativity (Edmonds, 1994). The two principal questions we have been addressing are: how can we understand the nature of human creativity in its many forms and how can digital technologies be made to fit the needs of creative people? Taking the evidence from our research investigations and those of others, our intention has been to build a solid foundation for the design and construction of better digital tools for creative purposes. The research methodology is based on the gathering of 'observable' phenomena and the data is analysed using protocol analysis techniques (Ericsson and Simon, 1993). The research has multi-disciplinary foundations in HCI, Art, Design and Engineering as well as and studies of creativity.

Arising from a series of studies of creative people and associated developments in computer technology, a strategy for practice-based research has evolved in which research and practice are interdependent activities that have mutual benefits as well as discrete outcomes. The notion of the Studio as a laboratory in the field is introduced and a new methodology for systematic practice-based research is described. An overview of results of the studio studies is then presented and opportunities for the development of technology environments for creative collaboration are proposed.

2. Creativity

The word "creativity" conjures up many different interpretations. Related concepts such as novelty, innovation and originality are but component elements of a larger and more complex picture. Other attributes such as having usefulness or being significant socially and culturally are also considered to be essential parts of that picture. Overall, there is a strong measure of agreement amongst creativity researchers that creativity arises where there is a happy combination of factors such as personality traits, social influences, environmental constraints and cultural values but that there is no single recipe for making it happen.

There are three key ways in which creativity has been studied and characterized: by people, by product and by process. For the term creativity to have any distinctive meaning beyond other human capabilities such as learning, ideally the three elements need to be considered as part of a total picture. Current research into the nature of human creativity takes many different forms, including controlled experiments and biographical case studies. There continues to be a steady stream of research that reveals interesting and divergent perspectives. For an understanding of those approaches, the review edited by Sternberg is a valuable source (Sternberg, 1999). In relation to designing computer support environments for creativity, Nickerson makes a number of recommendations for the enhancement of creative work based upon a survey of research findings that are valuable pointers to understanding what can help or hinder the creative user (Nickerson, 1999, pp. 407–418).

2.1. Creativity with computers

For those whose concern is to understand the opportunities and limitations of computer technology for creativity, a key question that the research from the creativity research community does not answer is whether or not the use of computer tools makes a difference to the process or its outcomes or both. If, as it seems, from anecdotal evidence and everyday experience, it is likely there is an impact of one kind or another, the question is what kind of tools and resources are most effective, or indeed, least effective? In a related area, that of computer support to early design, the barriers that computers pose to conceptual thinking has been the subject of research and considerable work to develop tools that address those limitations has been carried out (e.g. Gross, 1996; Do and Gross, 2001).

The rapid growth of digital technologies in creative work can be seen as an example of providing a form of enhancement to creativity. However, we are not yet at the point of being able to validate that proposition with any degree of certainty. That creative people are seeking to develop new forms and develop new techniques is not at all surprising given the intrinsically exploratory nature of the pursuit. The experience of many has been that there is much progress needed before computer systems provide the kind of natural, intuitive interaction that allows the user to focus on the creative process itself.

In the early 1990s, the proposition that computers were creativity enhancing vehicles was a difficult one to sustain. Now, on the other hand, the use of computers in creative processes is well recognized. The true value of computers in enhancing creativity, however, is still often unclear. The work described in the following sections represents key points in the studies that identified requirements for computer systems that supported creativity.

2.2. Studies of creativity

Empirical research into the nature of human creativity takes many different forms, including ethnographic studies, case studies, protocol data studies and controlled experiments. One approach has been to examine creative work in terms of the totality of the person's activities. Case studies in design, science and engineering were undertaken in order to identify the characteristics of the creativity and the implications for designing general-purpose creativity support systems. Investigations into cases of creative work were undertaken: laboratory studies of scientific knowledge based work (Candy et al., 1993) and retrospective, historical accounts (Candy and Edmonds, 1994, 1996). From this, a number of models of creativity were derived (e.g. Candy and Edmonds, 1995; Candy, 1997) and those models were tested and extended to other domains (Candy, 1999). Characteristics of creativity that coincide with findings from other studies were identified, in particular: investigations into high profile engineers (Maccoby (1991), studies of innovative product development (Roy, 1993) and studies of designers, (e.g. Cross and Cross, 1996). From this work, requirements for computational design in support of creative process were identified and a system was developed in order to demonstrate what a creativity support environment might offer. The Vehicle Packager Knowledge Support System (Edmonds and Candy, 1996) was designed to aid designers at the conceptual stage of the design process. Graphical interactive techniques enabled the designer to interact with the domain knowledge in specific concept vehicle design terms. An important aim was to provide that knowledge support to the designer as the design activity proceeds.

The studies illustrated how, in creative work, exploratory ideas and acts arise *during* the process and sometimes as side effects rather than from the explicit objectives being pursued at the time. By their very nature, creative acts cannot be described in advance and this makes the modelling task somewhat challenging. In particular, the application of knowledge that is highly expert, distinctive in character and constantly evolving is a feature of the way creative people work. These findings and the prototype systems developed to exemplify the ideas were extended to a criteria-based approach to designing creativity support systems. In HCI, the dominant approach to user-centred system design of the time was based upon using hierarchical representations of tasks, providing sequencing information and identifying the objects and actions relevant to the user (e.g. Benyon, 1992). Task analysis presumes that we know in advance what the user might want to do and how, in some sense, it might be done. The criteria-based approach, on the other hand, does not make the same assumptions and, instead, provides an evaluation framework within which the software designers are able to develop alternative designs that meet the criteria for supporting the creative user (Candy and Edmonds, 1997).

At the time, the challenge was to create support environments that went well beyond current concerns for better interaction techniques and the emulation of human cognitive processes. The role that computers might play in the enhancement of creativity is an area that has engaged the authors of this paper for a long time but our experience has demonstrated that the tools in themselves are not the only factors to be considered. Whether or not creativity can be enhanced in some way may be significantly influenced by the conditions in which it takes place. These conditions might be defined in terms of the environmental (including organizational) factors, and indeed the materials or tools used to achieve the creative outcome. One might hypothesize that the characteristics of any resources, materials, tools or techniques that form a part of the creative work are in themselves critical factors that influence the way it takes place, i.e. the process. It follows that the characteristics of the support environments, whether computer-based or not, ought to be determined on the basis of what we know about creative process.

In the research referred to above, a form of systematic knowledge about creative processes was generated and applied to the design of user centred digital systems. The aim was to create tools that provided the user with better support at two levels: first, flexible and more "intuitive" user interfaces that did not disrupt the flow of thinking and action, and second, access to domain knowledge that could be used to augment the generation of ideas and solutions. The system would provide a conceptual framework of knowledge modules, communication pathways and visualization methods for multiple representations of source material. The framework, we argued, could be adapted to different domains by changing the knowledge in the system and tailoring or customizing the user interfaces.

The aim of enabling a genuinely user led agenda was not sufficient, however, to satisfy the needs of the creative user. The creative user had a variety of requirements and did not aim to create new technology systems but rather new creative forms and artefacts for which certain kinds of technology were required. The technology was part of the method for making rather than an aim in itself. Once user pull becomes a real possibility, the fact that the pull is in a different direction has to be acknowledged and worked with. As a matter of fact, from the start, the research intention was to create conditions for creative work and leave open the kinds of technology that would be selected and developed. Of course, this did not mean that the creative users were entirely in control of the choice of technologies because they were inevitably influenced by their own level of expertise and that of the technologists whose job it was to seek out options based on their understanding of the creative users' needs.

In the mid 1990s, after a successful launch of the Creativity and Cognition conference series (http://www.creativityandcognition.com), we began a series of artist residencies that set in motion the enterprise that in time became the C&CR Studios. Those first residencies with artists who had never before used computer technology in their work were the beginnings of a redefinition of the notion of "environment" which up to then had meant "technical environment". The foundation work and its outcomes are described in the following sections of the paper.

3. The studio as laboratory

The investigation of creativity as it takes place in naturalistic settings has been difficult to achieve and most studies of creativity draw on retrospective accounts of the creative process. The experience of conducting studies of creative people led us to believe that what was needed was an entirely different approach, one that would be able to study situations and activities involving creativity in circumstances as near as possible to the real thing. To do that, we sought ways to carry out research by combining two key ingredients: creativity in naturalistic settings and actual creative work in progress. This gave rise to the concept of the *Studio as Laboratory* for creativity research. Realizing the concept as an actual place for practice and research to coexist was a process which involved considerable effort to bring to fruition, not only because it required significant human and financial resources, but also because it transgressed the boundaries of subject disciplines and demanded new ways of thinking.

In the creative arts, the Studio is the 'natural' working environment where the artist dreams, explores, experiments and creates. It is usually a closely guarded personal space in which the works in progress are brought into being, assessed and made ready for exhibition or sometimes discarded. The point at which the works become publicly available is the choice of the individual concerned. Another kind of studio, more akin to those of earlier times is the kind of studio, which is populated by many people, from master artists and apprentices to visiting patrons or prospective buyers. The main point of the Studio is that it is an experimental or a development space, as distinct from an exhibition space. The existence of studios of whatever kind, are as essential to the artist as the laboratory is to the scientist. The challenge was to take the characteristics of the studio and migrate them to a research environment where people from different disciplines could collaborate on creative work.

3.1. Combining creative practice and research

From the 1980s onwards, there was a surge in the growth of experimental digital art. Organizations were formed to facilitate developments and the number of artists involved multiplied. The organizations promoting such work came from a wide variety of backgrounds, including the visual arts, music, performance and film. Defining what makes an appropriate environment for creativity involving digital technology presents more problems than for traditional crafts with thousands of years of maturity and experience to bring to bear. For one thing, the digital world of today is still very new and what will come to seem very primitive technologies in the future are continuously evolving. In computing, the term *environment* is often used to refer to a set of software facilities for assisting the development of a digital system. The precise nature of the *software development environment* influences the ease with which programmers can work and shapes the way that they approach that work. However, an environment for creativity requires more than the technical facilities and expertise if it is to meet the needs of the creative user. A development environment for creative exploration was established at the Creativity and Cognition Research Studios with the express intention of assessing its role and identifying requirements for creativity support.

A fundamental requirement of an environment for creative practice is that it supports and enables the development of *new* forms and the new knowledge that is required to achieve such outcomes. The point is that creativity requires circumstances that enhance development possibilities. The question is how do we ensure that both the creativity and the technology development are fostered in tandem? The technology requirements gathering for creativity must be a highly responsive, iterative process where new insights are fed back quickly into the development process. This co-evolutionary process is a form of practice-based research where the existing technology is used in a new way and from which technology research derives new answers: in turn, the use of new digital technology may lead to transformation of existing forms and traditional practices.

By creating situations and conditions that were conducive to creative work from the practitioners' point of view, we sought to investigate how creativity takes place in naturalistic scenarios. Our aim was to investigate work in progress drawing on first hand reports rather than retrospective accounts of the creative process and its products and outcomes. This led to the creation of an organizational framework dedicated to facilitating and investigating creative practice and, with that the practice-led research approach. The first Creativity and Cognition Research Studios (see C and CRS) were established as a joint venture between the art and design and computer science faculties at Loughborough University, UK, expressly for the purpose of developing new art and technology projects in tandem with research into the creative process. The development of the residency study as a vehicle for practice-led action research was the primary mechanism for facilitating creative projects and also gathering data. In this way, a series of investigations into creativity and digital technologies based on the co-evolution of research and practice was put into place.

A number of issues were identified about strategies for providing creative technology environments. These concern the network infrastructure, the hardware and software platforms and the tools and applications. For example, the environment must be heterogeneous and support communication and data exchange between the different systems. Equally, it must be relatively easy to extend or add to the facilities. Often, we found that what existed did not match what was eventually needed. Producing creative work is a kind of exploration that needs flexible support (see Candy and Edmonds, 2002a).

3.2. The COSTART project

The research described in this paper was conducted in the UK where, in the mid 1990s, the importance of computer support for creative practice was identified by the EPSRC Human Factors Programme. At about the same time, the Technology Foresight initiative identified Creative Media as a strategically significant area and recommended activities as such artists-in-residency programmes to develop and promote both technological and organizational initiatives.

COSTART (COmputer SySTems for Creative Work: An Investigation of ARt and Technology Collaboration) was the first major research project funded from a scientific source in the UK that explicitly undertook to carry out research into creativity between artists and technologists (COSTART). The project used the facilities of C and CRS as its base-line provision for exploring a specific research agenda. The infrastructure that supported this process was extended and adapted to meet the needs of user goals and a diversity of technical requirements. Technology to support the rapid prototyping of distributed, multi-user support systems was used to enable creative exploration by artists in collaboration with technologists. The approach adopted was to investigate creative practice and to establish conditions for exploring and observing the implications of, and for, new digital technology. The specific objectives were as follows:

- To conduct studies of the processes by which artists develop new creative media in collaboration with technology experts during a series of residency programmes.
- To test and extend the process models of creativity, building upon an existing criteria-based model developed by the applicants from studies in design and science, and testing its general applicability.
- To develop and promote practice-based research in computer supported collaborative creativity.

Twenty case studies of art and technology collaborative creativity were carried out in the two phases of the project. The lessons from the first phase about achieving successful partnerships were applied in the second phase and the way the collaborative process developed was monitored. In assessing the level of success compared with the first phase studies, there was a similarly high degree of satisfaction amongst the artists. One test of whether or not the approach was successful is in the number of projects that were exhibited in one form or another at the Creativity and Cognition (2002) exhibition just 2 months after the period of residency. The outcomes ranged from a near exhibition ready interactive installation to new grant proposals for acquiring funding for further work (Candy and Edmonds, 2002b).

3.3. Methodology

Over the life of three rounds of the artist-in-residence studies the methodology for the Studio as Laboratory developed as a significant research area in itself and the development of the research methods form one of the contributions arising from the work. The complex, unpredictable and apparently unstructured nature of the art and technology collaborations studies provided a significant challenge to the research process.

The research approach that evolved was based on the notion of *co-evolution* of research and practice. This involves two complementary and interdependent processes that, nevertheless, have discrete goals and outcomes. Whilst the aims of the practice are to create new forms and artefacts, the aims of the research are to generate new knowledge and understanding. However, in the case of this work, one cannot achieve the research outcomes without striving for the practice ones. Thus, the co-evolution leads to multiple outcomes. A key point here is to notice that this approach ensures that the research studies are of *real* practice with *real* outcomes respected in the domain of practice. For all of the methodological difficulties that field studies of this kind bring, they avoid the fundamental flaw of laboratory studies where the subject of study is not, in fact, creative practice at all but the simulation of such practice, often in artificial contexts.

Another feature of the method is the use of a small number of expert professional creative practitioners who work in the essentially creative domain of art, rather than a large number of, for example, students training to become artists or designers. The point was to study creative practice in an undeniable form and in a context where the creative endeavour is the central pursuit. This is working at the edges of creative practice, with small numbers of experts rather than at the human population norm where creative skills may be limited and certainly are likely to be masked by other more pragmatic considerations.

The complex, unpredictable and apparently unstructured nature of the collaborations need not imply ragged and unstructured research. In fact, the COSTART research programme developed an eight stage structured process for the research. This life cycle process mostly extended over about twelve months not all of which was a linear sequential set of activities. Rather, most of them took place in parallel or were jointly conducted.

The staged process is illustrated in Fig. 1 and we now briefly describe each stage.

Preparation: create teams and environment—The first stage is the formation of a core team with expertise in computer systems, programming languages and devices. The physical environment into which the artists come is designated primarily for

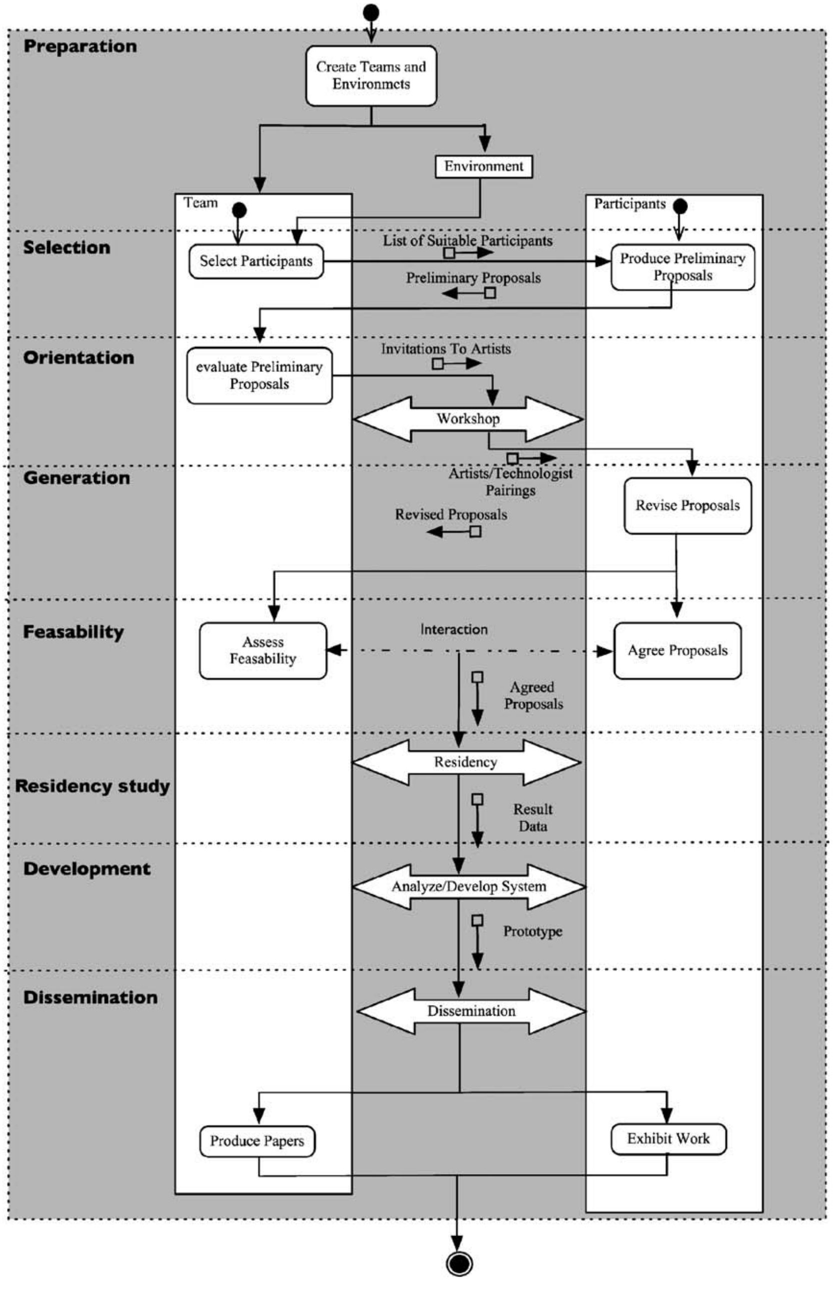

Fig. 1. Practice-based research life cycle.

their use rather than on a guest access basis and the essential equipment, computer hardware and software are selected and acquired specifically to meet their requirements. Good technical capabilities are vital but it is equally important that appropriate attitudes to collaboration and familiarity with the language of the selected creative practice domains are well founded.

Selection: identify participants—Finding and agreeing the creative practitioners to work in the studies is an important activity that must be carefully conducted. The selection process is carried out according to established criteria. Some criteria are research specific: e.g. willingness to discuss work, whilst others are based on the need to have external measures of a candidate's suitability: e.g. evidence of public recognition: commissions, exhibitions. It should be noted that the selection criteria do not include a value judgement about the aesthetic quality of the artists' work but are designed to ensure that appropriate projects are undertaken from a research point of view.

Orientation: evaluate preliminary proposal—Once prospective participant artists have been identified, they are invited to submit an initial proposal for a residency and attend an orientation workshop. The team then carries out a feasibility exercises on each in advance of the workshop on the basis of:

- The project concept and what the art outcome will be.
- The type of expertise and skills required.
- The technical requirements for realizing the work.

This is a process whereby the expertise of the team is crucially important to the selection of suitable technology. It is not assumed that the artist will have all the requisite knowledge. At the workshop the basis for collaborative relationships is established. Artists are then requested to revise their initial proposals and complete a survey form.

Generation: produce project proposal—The proposals outlining initial ideas for a residency formed the basis of the pre-residency preparation and were used as a baseline for the developing work. The type of project ranged from real-time interactive works and correspondences between sound and image to the interaction possibilities of sensor systems. Each project provided different challenges for both the technical requirements and the artistic intentions: these were developed prior to the residency on visits or by email and telephone.

Feasibility: assess requirements—The feasibility studies are crucially important both to the future progress of the individual work and the research outcomes and until they are completed no residency can be finally confirmed. Each project is considered in terms of the degree of challenge it poses technically and the criteria for acceptance are revisited and checked in the light of all the information at hand. In the light of the results, detailed preparations begin.

Residency study: develop project and gather data—The artist-in-residency was chosen as the main vehicle for the research data collection because it provides as near a realistic context in which to develop a creative project as is normally available to artists. The research study introduced special conditions, however, as it is the primary opportunity for gathering data about the collaborative creative process. Throughout the five days all participants documented events, thoughts and experiences: whether the ideas were workable, interesting or challenging were recorded and whether the solutions worked well, and if not why not? The data was comprised of a set of protocols kept as sound files and text transcripts, experiments, images, sounds, prototypes and video snapshots of work in progress. From the practitioner's point of view, the primary goal was to develop the proposal work as far as it could be done within the time frame. However, most found the reflection that arose from the need to document a valuable contribution to their thinking.

Development: create work and analyse data—The creative work did not stop once the residency was over. In keeping with the aim of providing real support to the practitioners, if an opportunity to continue the work was sought, it was made possible. Each artist had a formal association with the institution, which gave them access to the facilities and further development took place in preparation for exhibiting the outcomes. At the same time the research team began the process of collating and assessing the documentation. The many types of data were compiled and structured in chronologically ordered transcription records for each case. This provides the primary evidence for the derivation of results.

Dissemination: exhibition and publication—The final stage of a complex and carefully managed process described only briefly above, is that the outcomes are made publicly available. The methodology that has been developed gives rise to two main outcomes: creative works for public exhibition and research results for knowledge creation. The results of the collaborations, the art works and art systems were presented in a public exhibition at the ACM SIGCHI conference (Hewett and Kavanagh, 2002; Candy and Edmonds, 2002d; Candy, 2005).

4. Opportunities for creative technologies

In this section, we discuss some of the main outcomes of the COSTART research beyond the methodological developments described in Section 3.3. From the investigations that took place, opportunities for enhancing collaborative creativity and the creation of technology-based artefacts were identified. Characteristics of technology environments for creative collaboration are discussed. Several strands of research were undertaken in order to establish a broad understanding of the field and its context. The state of the art investigations provided a sound basis for the identification of suitable technologies to meet the requirements of the collaborative art-technology projects. An account of how the technology was developed to meet the needs of creative practice is provided. The research into the general context of art and technology-based creativity comprised:

- on-line creative communities,
- interactive art environments,
- support for collaborative creativity,

- software environments for creative practice,
- image-sound systems in digital art practice.

An overview of the results of this work follows.

The research on online communities in support of creativity exposed some of the differences between virtual communities and our conventional real-world communities. Dreyfus suggests that the way that we relate to other people and events in the virtual online world is not the same as the way we conduct ourselves in the physical world (Dreyfus, 2001). While embodied interaction with others involves some personal risk and therefore requires a degree of personal commitment, in the virtual world we can, within just a few minutes, leave (or be ejected from) one community and join another. This impermanence and abstraction in our involvement in online communities leads us to behave in a different way in the virtual world. Of course, our physical interaction with others is also very different when it is mediated by digital technology. Mamykina et al emphasize the importance of free flowing communication as a 'necessary condition for reaching a creative vision'. (Mamykina et al., 2002). Even using the latest videoconferencing technologies, for example, communication with a remote collaborator is not the same as a face-to-face discussion (Olson and Olson, 2000; Kraut et al., 2002).

In the work on interactive environments, the debate about interactive art is placed within a wider and problematic context that both constructs and explores relationships between technology, culture and creativity. The research showed how many of the themes raised in a study of interactive art can be applied to wider debates about technology, creativity and culture, and to show how such a model is flawed. Similarly, interactive art practice is placed within a framework of other artistic practices such as digital art and time based media

Another area of explored is that of image-sound systems in art and technology, including the historical background and the state of the art of the subject. Two factors are the main motivations for such a research. The first is based on the recognition that new digital technology has given us, for the first time in history, the means for technically "equating" the visual and the aural world by mapping both sound and image to digital information. The research addresses the question of what are the consequences, both in art and technology, of this "equation" and if it is possible to consider the audio-visual field as a whole rather than the combination of two different artistic and sensorial fields. In almost all of the COSTART studies, both sound and image were used, indicating that the integration potential of digital technology is vital to innovative creative systems.

The research into creativity brought a rather new perspective to visual art practice. The model that best fitted the work observed was more similar to film production than to traditional artwork. The team-based processes of film making require not only different roles, but also specialized expertise dedicated to achieving specific outcomes. In the technology-based creative process, there are similarities. The matching of one to one participants was not the only form of collaboration that was necessary. The project partners were working within a larger context of other available expertise and this proved to be a contributor to the success of the work for both artist and technologist. The total collaboration was close to the heart of the creative process aspects of the work and not just in production. Another finding was the importance of the inter-relationship between the creative process and the software tools employed in that process. In particular, visual programming environments turned out to be significant in enabling a flexible development process and encouraging close collaboration at every stage between technologist and artist.

The outcomes of the COSTART project research are described in a number of papers as follows:

- Support for collaborative creativity through digital technologies (Weakley and Edmonds, 2004).
- Image-sound systems in digital art practice (Edmonds and Pauletto, 2004).
- Software environments for creative practice (Edmonds et al., 2003).

In the following sections, these research outcomes are described.

4.1. Collaboration in creativity

John-Steiner (2000) has found that, despite our tendency to think of creative work as being the pursuit of the solitary individual, new ideas are more often than not generated through a process of shared struggle with others. In the case of digital arts, the tendency for artists to collaborate with others in order to access skills and expertise has generally been increasing since the field's inception in the 1960s. Meanwhile, Candy and Edmonds (2002a) have also noted that explicit and recognized collaboration is increasing in the digital arts. Fischer (2000) tells us that creative activity grows out of an individual's relationship with his or her work and with other people, and that the power of the unaided individual mind is highly overrated. Also, see Fischer et al., this issue.

The COSTART Project (2002) was established on the basis that support for creativity implied collaboration with technologists. A notable realization was that there are many forms of collaboration and different kinds are required for different types of work and people. The nature of the collaboration observed in all cases studied varied significantly. One of the key factors in those variations was the allocation of *responsibility* for different parts of the creative process. The question is, who in the team is in control of what aspect of the work?

Three models of collaborative creativity were derived from the COSTART case studies reflecting important variations in the nature of collaboration itself. The variants on collaborative creativity were evident even where the participants were the same individuals but matched with different collaborators. The bringing together of different personalities, motivations, backgrounds and skills resulted in a rich set of collaboration models. This enabled us to consider the implications of the different models for supporting creativity and their relationship to success factors.

Fig. 2 represents a simplified model of the collaborative process consists of three main activities: Creative Conceptualization (the ideas and motivations of the work), Construction (implementation or making) and Evaluation (of the outcomes whether

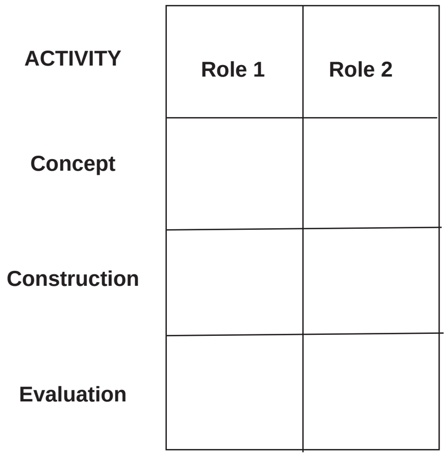

Fig. 2. Role/activity matrix.

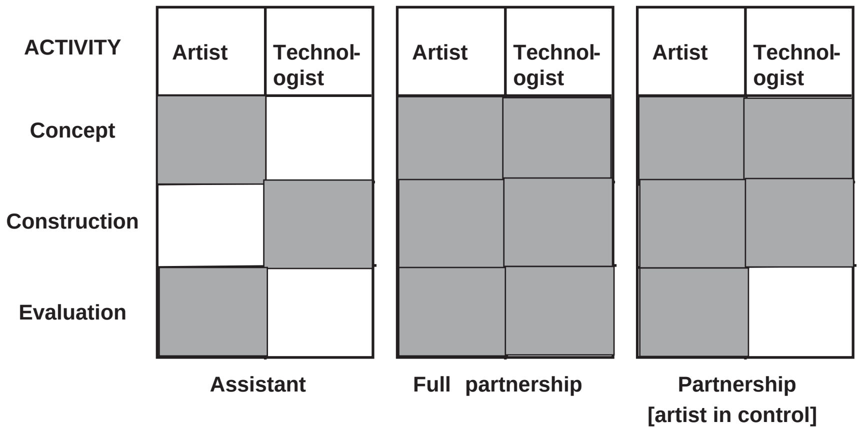

Fig. 3. Assistant, full partnership and partnership with control.

product or process). The primary point is the differentiation between the roles played by each party to the creative collaborative process. Within the three activities, people in collaboration tend to adopt certain roles. Three types were identified as follows: assistant model, a full partnership model, and a partnership model, as depicted in Fig. 3. Factors such as strong involvement, influence and leadership by a collaborator, are indicated by the grey shading associated with each stage of the creative process.

In a full partnership situation, complementary interests exist even where the outcomes by each individual party may differ. Indeed, one of the most successful ongoing partnerships observed in the artist in residence studies operated in such a way as to serve convergent interests though it produced quite distinct artistic outcomes. The partners are able to achieve mutual benefit but at the same time, retain ownership of their individual achievements. Such mutual benefit requires the relinquishing of individual 'control' of the creative process and different, but complementary, roles appear to be best suited to achieving that end.

The nature of the collaboration observed in all cases studied varied significantly. One of the key factors in those variations was the allocation of responsibility for different parts of the creative process. The question is, who in the team is in control of what aspect of the work? By studying the behaviour of different teams, several models of collaboration were derived. For example, the technologist role might be an assistant to the artist. Alternatively, they might be a partner and share the responsibility for making decisions.

The assistant and partner relationships may vary over the activities involved in a project. The artist might be fully in control of the conceptualization of the work but might be a partner with the technologist when it comes to evaluating the outcome. On the other hand, the partnership may be in relation to the creative concept but the technologist might take no part in the final evaluation. Whichever model of collaboration is adopted, certain characteristics of successful collaboration can normally be observed. These include the development of a common understanding of the creative vision, the development of a shared language and the engagement in extensive exploratory, and 'safe', What-if discussions.

The very complexity of the undertakings probably dictates that a shared understanding of the vision is important if only to reduce the need for extensive and exhausting debates. Similarly, the use of a shared language enables a smoother collaboration in which discussion can take place at something like the pace of the creative development of ideas. Trust and openness are important components in enabling exploration and What-if debate. From a support point of view, ways of recording such debates can be very valuable when it comes to re-visiting and reviewing ideas as a project progresses. This going back over the thinking in the project's life is certainly important and so worthy of support.

A particular point about collaboration that came out of an analysis of the technical component of the COSTART studies was the need to find ways of discussing the software development decisions when some members of the team are not programmers or only understand programming at a surface level. Major aesthetic decisions may be embodied in fairly deep programming decisions and they need to be open for full debate in the team. This seems to come down to finding representations of the code that can be used to facilitate such debates. The artist does not have to program if they have a representation of the detailed code in a form that enables them to discuss its operation and implications with the technical team member(s).

A significant aspect of using digital technology in art works is that it becomes natural to use it to support the art making process. In relation to collaboration, it turns out that the technology often plays a major role in shaping that collaboration. Even in the small teams of COSTART, when working primarily in the same building, email was a common form of communication. Working late at night, a note can be sent from the machine someone is sitting at. It can be picked up when another team member sets to work in the morning. A simple way of passing information to someone is often to email it to them and this is often done even when both people are sitting in the same room at the same time. In the case of the projects studied, the teams were formed initially when geographically spread and the work generally continued, after the intense residency, when again the team was distributed. Email was, then, a form of communication that provided continuity.

Beyond the simple use of email, as mentioned above, the World Wide Web provides extensive opportunities for the support of distributed creative teams or communities and these opportunities are important to study and exploit.

The different levels at which people may work together and how well these mesh with levels of communication offered by current technologies. John-Steiner (2000) presents four modes of collaboration among people engaged in creative work:

- *Distributed collaboration*: characterized by participants who are linked by similar interests. Roles are often informal and fluid but as John-Steiner notes, out of such informal connections some lasting partnerships may be built.
- *Complementary collaboration*: characterized by a division of labour based on complementary expertise, disciplinary knowledge, roles and temperament. As Mamykina et al. (2002) point out, the multidisciplinary nature of such collaborations can be particularly advantageous as the partners may help each other to see new possibilities and step out of their familiar territory.
- *Family collaboration*: John–Steiner describes this type of relationship as a dynamic integration of expertise, painting a picture of relationships that are at once fluid and intense.
- *Integrative collaboration*: here the joining of forces between the collaborators forces major changes, which they might be unable to bring about alone. Integrative partnerships are motivated by the desire to transform artistic knowledge, thought styles, or artistic approaches into new visions.

This work has implications for the design and development of support systems. John-Steiner points to the *dynamic integration of expertise* as an important factor in the closer types of creative collaboration and it has been suggested that this may be brought about by *fluid and open communication* (Mamykina et al., 2002). Olson and Olson suggest, though, that unless we can establish a high level of common ground, our efforts at remote collaboration may never succeed. These close collaborative relationships are based on mutual respect and trust (Mamykina et al., 2002). The common ground that is required for effective communication consists not just in shared experiences or acquaintance although these are extremely important. In the face-to-face situation, communication often relies on mutual access to artefacts in the environment (Luff et al., 2003) and indeed, to the environment itself: quite literally 'common ground'. The contextualization of our conversation within our environment is something we rarely express explicitly; we use artefacts that are near at hand to illustrate the points we are making, and we draw inferences from casual observation of our surroundings, or from casual 'overhearing' (Rosenberg, 2000).

With remote communications systems, of course, the ability to pick up on these cues which, where they are expressed at all are usually expressed nonverbally, is greatly compromised. Access to this nonverbal, contextualizing and background information, is nevertheless important in sustaining a close working relationship remotely.

Kollock (1999) has suggested that one factor which can engender commitment to an online community and trust in the people we meet there is persistence of members' identity. Where we can identify a person's activities within the group over time, we can repay favours and build long-term relationships. As Meyrowitz (1985) has pointed out, we may adopt different personae in different places and therefore consistency in our sense of 'place' is important. Of course, with modern wireless technology, for example, the 'place' we are in may be constructed more from our ability to communicate with others than from our physical location (Wellman, 2001). Indeed, we may move from 'place' to 'place' in this sense (from a social environment to a working one, say) without travelling at all.

We can therefore start to compile a list of desirable characteristics of Web-based support systems for creative collaboration. The earlier research in the literature together with the COSTART project suggests a number of important issues, as follows:

- Support for synchronous communication—this should include support both for verbal and nonverbal communication.
- Support for the establishment of common ground.
- A way of establishing trust between users.
- A way of recording and reviewing past decisions.
- A stable identity for group members.
- A user profiling system for finding suitable collaborators: a way of establishing who knows about what.
- Support for the development and sharing of prototypes.

A prototype system has been developed embodying some of these characteristics. The system is aimed at facilitating the creation of collaborative partnerships as well as supporting the generation of new associations leading to creative work. It has shown promise as a means of sharing tacit knowledge about 'who knows what' and establishing common ground. It also embodies facilities for recording past work and reviewing these recordings. It is possible to identify the actions of individual users of the system and, in the limited domain of organizing snippets of, knowledge the system facilitates the sharing, and the shared development of conceptual groupings (Weakley and Edmonds, 2004).

4.2. Interactive art systems

The nature of audience interaction with art works and the implication for the consequential nature of the interactive art system is itself important and the studies led to a number of refinements in this area. Further, during the progress of COSTART, the importance of audio/visual work grew considerable and so the interaction between and across media now must be added to the direct interaction between the audience and the work: for example, the relationships between sound and image in a work now often very important.

4.2.1. Categories of interaction

Turning to the specific context of art and generative technology, we can envisage several situations that characterize the relationship between the artwork, artist, viewer and environment. The core categories devised by Cornock and Edmonds and elaborated by Candy and Edmonds, are applicable to current examples of interactive artworks. They were defined as: *static, dynamic-passive, dynamic-interactive* and *dynamic-interactive (varying)* (Cornock and Edmonds, 1973; Candy and Edmonds, 2002c).

Static: the art object does not change and is viewed by a person. There is no interaction between the two that can be observed by someone else, although the viewer may be experiencing personal psychological or emotional reactions. The artwork itself does not respond to its context. This is familiar ground in art galleries and museums where art consumers look at a painting or print, listen to tape recordings and talk to one another about the art on the walls and, generally speaking, obey the command not to touch.

Dynamic-passive: the art object has an internal mechanism that enables it to change or it may be modified by an environmental factor such as temperature, sound or light. The generative mechanism is specified by the artist and any changes that take place are entirely predictable. Sculptures, such as George Rickey's kinetic pieces that move according to internal mechanisms and also in response to atmospheric changes in the environment fall into this category (Rickey, 1979) The viewer is a passive observer of this activity performed by the artwork in response to the physical environment.

Dynamic-interactive: all of the conditions of the dynamic passive category apply with the added factor that the human 'viewer' has an active role in influencing the changes in the art object. For example, by walking over a mat that contains sensors attached to lights operating in variable sequences, the viewer becomes a participant that influences the process of the work. Motion and sound capture and analysis techniques can be used to incorporate human activity into the way visual images and sounds are presented. The work 'performs' differently according to what the person does or says. There may be more than one participant and more than one art object. An example of this work is the 'Iamascope', a work, which includes a camera looking at the viewers and is connected to a controlling computer. The work reacts to human movement in front of it by changing a kaleidoscope-like image and making music at the same time in direct response to the viewer's movements (Fels and Mase, 1998) (Fig. 4).

Dynamic-interactive (Varying): the conditions for both 2 and 3 above apply, with the addition of a modifying agent that changes the original specification of the art object. The agent could be a human or it could be a software program. Because of this, the process that takes place, or rather, the performance of the art system cannot be predictable. It will depend on the history of interactions with the work. In this

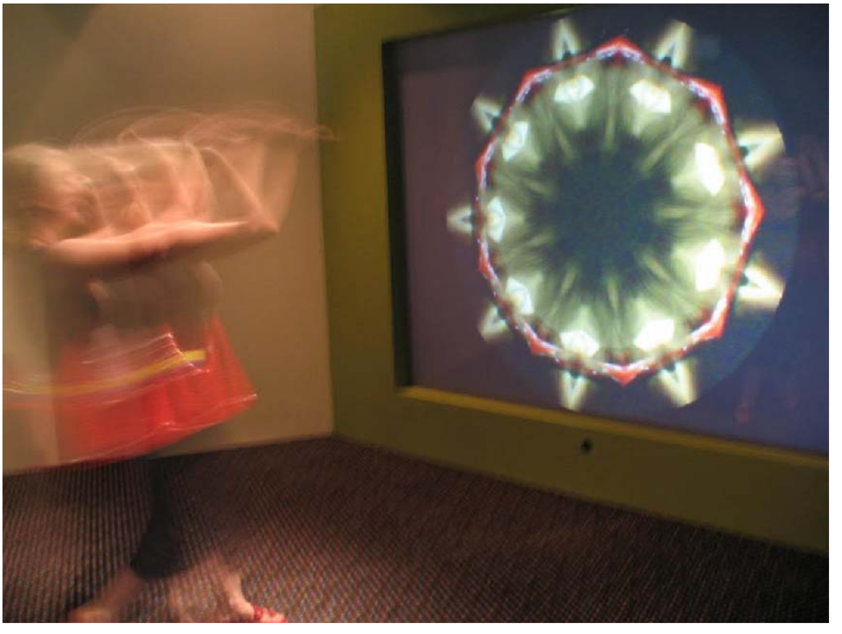

Fig. 4. Interaction with the Iamascope at the Play Zone, Millennium Dome 2000.

case, either the artist from time to time updates the specification of the art object or a software agent that is learning from the experiences of interaction automatically modifies the specification. In this case, the performance of the art object varies, in addition to case 3, according to the history of its experiences.

When defining these categories, Cornock and Edmonds proposed that rather than talk about 'artworks' it was helpful to think in terms of 'art systems' that embraced all of the participating entities, including the human viewer. It follows from this that the role of the artist is not so much to *construct* the artwork, but rather to specify and modify the constraints and rules used to govern the relationship between audience and artwork as it takes place in the world. This is a view that includes the generative arts as a central concern.

4.2.2. Interaction between media

As the COSTART project developed through its stages the importance of multimedia audio-visual artworks grew significantly. The relationship between audio and visual material, in an art piece, can be mathematical, metaphorical/intuitive or intrinsic.. The relationship is mathematical when the connection between audio and visual parameters can be described with an equation. The process of establishing mathematical relationships between different parameters is often called "mapping" (e.g. Jack Ox's works made using the Colour Organ). In films, the relationship between audio and visual material is normally metaphorical or intuitive. Finally we call intrinsic the relationship between audio and visual when the same source is used to synthesize both images and sounds (e.g. Yasunao Tone's Musica Iconologos).

In terms of interaction between the viewer and the works, we can distinguish between interactive works and non-interactive works. Films are examples of non-interactive works in which the audience cannot change the flow of the audiovisual material, while, for example, Abbado's *Interactive Noise* is a piece centred on the possibility for the audience to interact with the audio and visual material and, therefore, experience how these two aspects of the same piece interact with each other. There are different ways for the interaction to occur: the audience or the performer can be allowed direct interaction with only the audio or the visual material, and then, respectively, visual and audio is generated as a consequence. There can be interaction with the audiovisual object as a whole, or direct interaction separately with the audio or the visual material can generate a combined response.

These different approaches represent ways of exploring, using and manipulating the same theme: that is, the relationship between audio and visual and how we perceive it as a whole. In this context, the computer appears to be a very flexible and open instrument for manipulating and integrating audiovisual material. The computer can be considered the audiovisual instrument *par excellence* because of the transformation of both audio and visual material into the same type of digital information. This sort of new equation of the two fields allows the treatment of audiovisual material as a whole and, as such, opens new exciting challenges for digital artists. The recent development of software for the integration of audio, visual and interaction is also a proof of the contemporary interest in multimedia or "intermedia" art works. The audiovisual works developed during COSTART do not only represent different creative approaches to the audiovisual theme, they also explore the flexibility of digital technology in this context.

There is a significant history of the evolution of the relationship between the aural and the visual realms. It is a history of scientific discoveries, evolution of technology, perception studies and artistic outcomes. The developments of technology in the twentieth century and, in particular, the development of digital technology, have made explicit what we call the *audiovisual discourse*. The panorama of artistic works that can be placed inside this discourse is not at all uniform either in terms of form, content or media used. From the research and case studies in COSTART, a broad classification was derived in order to show how very different art works might be considered to be part of the same artistic discourse (Pauletto, 2002; Edmonds and Pauletto, 2004).

4.3. Software environments for creative practice

In this section, some of the main HCI issues that have been observed to be important to the COSTART creative projects are discussed. The importance of programming, rather than the use of application packages, was evident in the projects but, at the same time, programming skills were variable. Considerations of, for example, end user programming became important and a visual programming approach was often deployed. In particular, the system Max/MSP was widely used and provides the key example in the discussion that follows.

A flexible and dynamic approach to requirements and the collaborative discussions covered above are inevitable aspects of creative work and this must be supported by a software environment that is readily changed. It is equally important that the implications of those changes can rapidly be assessed. In technical terms, the system must be *interpreted* rather than *compiled* and data values must be persistent to enable easy investigation into the behaviour of the code.

The way in which the graphical representation is set down is, at least in part, in terms of domain specific representations, i.e. in a form that is meaningful to, for example, a sound artist. Thus, the representation is close to a model of the system being implemented that can be understood and absorbed by the creative practitioner.

The interests of end users in programming were initially addressed by Alan Kay and the developers of the Smalltalk system which was developed at Xerox-PARC, primarily from 1972 to 1980 (Goldberg and Robson, 1983). The aim of Smalltalk was to provide the operating environment that would enable any user, including children, to use a small portable machine about the size of an A4 pad. Visual programming languages have a long history during which there have been many different languages developed with the common goal of ameliorating the difficulties of programming. A useful definition is "Visual Programming (VP) refers to any system that allows the user to specify a program in a two or more dimensional fashion." (Myers, 1990). Visual programming languages have had considerable academic interest, but do not appear to have had a significant impact on professional programmers and their use is mostly restricted to specific application domains. The reasons for this are not immediately obvious. A CHI workshop concluded, "There is a common belief that visual languages are easier to use and better suited to end users. However, there is no scientific evidence that visual is generally better or easier than text. Using a visual metaphor still entails understanding the characteristics of what you are generating. So, visual metaphors are not necessarily the answer, and can prove to be more difficult to use than text." (Goodell et al., 1999).

Empirical studies of programmers using Visual programming that have been carried out (Baroth and Hartsough, 1995; Whitely, 2000) have been with users of LabVIEW. LabVIEW was developed by National Instruments and has enjoyed wide success and has been available commercially for over 10 years (National Instrument Corporation, 1990). It uses the dataflow paradigm and is designed for use by end-user engineers and scientists for the development of data acquisition, analysis, display and control applications. In addition to the fact that it was developed by specialists for specialists, LabVIEW has many characteristics in common with Max/MSP which was used by several COSTART projects (Max/MSP).

Max/MSP is a dataflow development tool used widely by digital musicians. The development of the Max graphical environment began at IRCAM, a music research institute in Paris, France, by Miller Puckette in the late 1980s. Puckette programmed an editor for the realization of composer Philippe Manoury's piece Pluton (Puckette, 2002). This piece needed a system to allow the computer, and therefore the electronic part of the piece, to follow in interpreted the score during a performance (Puckette, 1998). It is built round the concept of Max patches (or objects) that communicate using messages. It is object-oriented in some, but not all, senses. Hence, there is not full agreement about its classification as an object oriented language (Puckette, 2002). While the Max system was in general a set of classes that define objects and how they interact, this editor represented the graphical environment in which Max objects could communicate by passing messages. It was created for making interpreted computer music, initially only using MIDI controllable synthesizers. The Max paradigm is "a way of combining pre-defined building blocks into configurations useful for real-time computer music performance." (Puckette, 2002). However, Max is not a musical composition language as such, but an instrument design language (Lyon, 2002).

Since 1999, Max/MSP has been published and supported by Cycling '74 (Cycling '74). In 2002, Cycling '74 published another set of objects for Max: the Jitter objects. These objects allow processing of video, images and 3D graphics. Jitter sees the visual data as matrices, and the processing of the visual material happens through the manipulation of these matrices. Jitter can be used for video processing, custom effects, 2D/3D graphics, audio/visual interaction, data visualization and analysis. In the work discussed in this paper, the use of a β version of Jitter was a significant aspect of the activity.

In order to meet the requirements of each of the COSTART projects, various options were explored and evaluated until a best-fit solution was found. In a majority of the COSTART case studies, new software was designed, implemented and evaluated. In each of these, the outcome was an interactive artwork, performance or installation. In many of the projects, use of visual programming allowed the artists, although often not expert programmers, to take an active role in the development of the systems. Hoeben and Stappers identify this as a key requirement for computer-based tools supporting early stages of design (Hoeben and Stappers 2001).

Max/MSP was used with varying degrees of complexity, and, therefore accommodated different levels of ability. When an artist-programmer begins with Max, there is a tendency to start with simple systems and gradually adopt and develop personal approaches, strategies and conventions for dealing with recurrent ideas and problems. In some cases this promotes diversity, and encourages unusual approaches to familiar creative or technical problems. It was noted by both artists and technologists that Max is easier to pick up by the novice than the text-based systems with which they were familiar (even if certain tasks are easier to write in text code), if the user is not new to the language. It also allows more people to take part in developing technology-based works. Even at an elementary level, users are rewarded with instant results and can readily understand the nature of the processes that they build.

It was observed that the diagrammatic layout of the Max/MSP window is effective because it represents the underlying computational or logical process; the user derives a sense of engaging directly with this process. The Max interface functions much like the traditional desktop. However, there are important differences. For example, rather than simply organizing files and documents in a graphical representation, Max provides the user with graphical means to organize processes. To extend this point, this representational system functions also as an organizational and cognitive system in the sense that it readily matches the user's cognitive model of the system.

In terms of layout, different styles, programming approaches and conventions can be adopted. In Max, the user is presented with a window called a 'patcher' window. Within the patcher window user can connect various boxes, called objects that represent processes. This configuration is referred to as a *patch*. Patches can contain many levels of sub-patches. It was noted that the layout enabled the user to see the entire process in one go, rather than having to scroll along different lines of code. The entire process was still visible to the user, yet the detail of each process was only visible when a particular sub-patch was opened. The ability to create sub-patches was useful because many sub-patches were used in more that one work.

Max/MSP is an interpreted programming environment. This enables the user to try options without having to stop, compile and re-start processes. The sense of spatial directness is augmented by temporal immediacy. Changes to patches have immediate consequences, often while the patch itself is still running. This enables the user to try options without having to interrupt their train of thought, let alone stop, compile or re-start processes and this creates a sense of continuous and undifferentiated action, feedback, and evaluation. This characteristic affects the way the work is made; it makes the process more fluent, adding a sense of enjoyment and pleasure to the process itself. In this way, it enables much more intuitive, creative and rapid exploration. One technologist describes how 'The idea got more precise in a process of continuous feedback with the technology chosen'. She also comments that using Max is much more like using a physical object. Such 'physical-world modalities of interaction' (Baroth and Hartsough, 1995) emphasize a perceptual coupling between representation and control that mirrors real world objects and are becoming increasingly popular.

During the course of the case studies referred to here, the rapid creation both of prototype systems and methods of data analysis that proved useful in 'scoping' the projects. It is often the case when developing new systems and products that the requirements are ill defined at the start. Visual programming, we have found, is a useful approach to the programming of interactive systems. It is a method for exploring and demonstrating ideas and supports the creativity of the user. In contrast to many text-based programming languages, development using visual programming involves the simultaneous creation of an algorithm and graphical representation of it. Whereas it may be hard to follow the logic of a text-based program when debugging, these programs are in this way self-explanatory. From the above points it becomes clear that in the process of making interactive artworks the programming environment should not only be a means of implementing predetermined ideas, but also an exploratory and creative tool that enables both the artist and technologist to push the boundaries of their work into previously unexplored or un-conceived of areas. It should promote a style of working that is flexible, fluent and engaging. It should enable new users to adopt earlier undeveloped approaches to old ideas, and to possibly articulate new ones.

One issue arises from the important practice of generating software prototypes that the user (in this case the artist) can evaluate. The prototype is typically not something that can or does evolve into the delivered system. It is built in a fast development environment and typically does not attempt to offer all of the functions or performance desired. Instead, it allows something that looks rather like the intended end result to be made quickly—and then thrown away. The issue is that a good looking prototype may lead the user to believe that the work is largely completed when, in point of fact, it has hardly started. One possible answer is to use an evolutionary approach by working in a software development environment that allows rapid change and also provides easy to read representations of the code. This was the method used in the majority of the COSTART case studies and in all of those that used Max/MSP.

In COSTART, the graphical representation of the program, was helpful as a shared form to facilitate the collaboration. The software being developed could be discussed and considered in itself and its definition, as well as in terms of simply what it put into effect. The need for a shared language in support of collaboration has a very particular implication for complex projects that include significant software development. For the technologist, the implementation language is important and it, or something close to it, is treated as if it was also the description of the design of the system. The team, however, may need the code to be represented from different viewpoints in different notations for the different collaborators. Collaborative creativity requires sharable representations that allow each party to understand the system design issues in detail and thereby take an active part in the decision-making. Thus, an important feature of a software environment for creative work is the ability to facilitate discussion between the collaborating team.

Some form of visual representation of the program code enables this to take place. However, there is a disadvantage to the use of such shared representations. One of the technologists did not find Max/MSP a representation that gave him sufficient information about the details of how the computer was going to do each task, for example concerning timing issues. That was offered in a more acceptable way by languages such as C or Java. These languages, on the other hand, are inappropriate for using as shared representations in multi-disciplinary teams as we find here. This is a familiar problem concerning the level of abstraction that a programmer prefers to work at. Thus, we see a tension between the preferred shared representation and the preferred technical representation. One answer is to facilitate multiple views of the same code: an example that can be sited is the alternate views of html code in web development environments, such as Dreamweaver, where the user can switch between looking at the web page design, as it will appear to the user, and the code that generates it (Macromedia Dreamweaver). They may also see both views side by side.

5. The challenge

“The challenge in creating a program designed to explore the nature of the relationship between artists and scientists is to create circumstances that engender the kind of communication that leads to a successful exchange of knowledge and perspectives and to an opportunity to explore new territory. The symbiotic merging establishes a pattern of exploration, development, and innovation, as each participant responds to the other's viewpoints and areas of expertise'' (Harris, 1999, p. 5).

The Studio as Laboratory approach described in this paper represents a new avenue of exploration in the field of creativity research and creative practice. In respect of the process aspects of the collaborative work, a number of issues were identified which provide insight and understanding about how to enhance the collaborative creative process and the kinds of technology appropriate for this kind of work. That understanding has implications for the future design of digital technologies that explicitly embrace an understanding of the needs of the creative user.

From our experience, we believe that a methodology for studying the creative process should be able to combine the rigour of a laboratory study with the realism of a residency experience. The development of good methods for practice-based research, employing both single and multiple perspectives, is essential if credible results are to be generated.

Placing the practitioners at the centre implies making them more than visitors for short residencies. Continuous development work is not conducive to the intensive kind of data gathering that was possible in COSTART and that is essential for data analysis. However, an alternative is to put in place practice-based research projects either as PhDs or as funded projects in which the practitioners carry out the primary data documentation and analysis. This requires more rigorous forms of data collection methods than is currently being used in practice-based research.

The original C&CR Studios have now been developed further as the Creativity & Cognition Studios (CCS) at the University of Technology, Sydney. A new model for practice-based research based on the lessons learnt from the COSTART project has been put in place.

CCS is organized as a multi-disciplinary collective of practice-based researchers, many studying for PhDs. The artists are integral members of the group holding the same status as the technologists. The focus is on practice in two respects. The art research is practice-based, relying on reflection in practice and evaluation of art systems in action. The technology research is conducted in the context of building and evaluating systems used in real creative practice. The ethos is one of openness and flexibility within a well-defined framework and of regular distribution and display of the outcomes. The work in the Studios is being shown and explored in a public setting through a partnership with the Powerhouse Museum in Sydney in which an exhibition space has been allocated and equipped to present the results, and interim results to the very broad public that visits Powerhouse.

In the wider world, the Creativity and Cognition conference series, sponsored by the Association of Computing Machinery Special Interest group for computer–human interaction, is a gathering point for key researchers in computer systems for creativity. It also brings together key figures across the disciplines that inform and extend the study of creativity and creativity support tools. Creativity and Cognition, as a field of research, has evolved and matured since the starting points in the early 1990s. It offers much that is relevant to the development of the new HCI and its application to IT artefact design. The conference series provides a means to strengthen and extend the international community of researchers who are delivering new interaction tools for creative users and extending out understanding of the role of such tools in creativity.

6. Conclusions

In the paper we have discussed interaction tools in the context of software environments for creative practice. The key point here is that we found that it was normal in the projects studied for programming, rather than just the use of well-defined applications, to be necessary. Thus, in order to accommodate the creative user and support the processes involved in their practice certain requirements had to be met in the software development environments used. These included the need for visual representations of the code, persistent data and interpreted, rather than compiled, systems. In addition we found that the form of code representation should not be decided purely in terms of its utility for programming. It has a second function, which is to facilitate detailed discussion and decision-making about the intended behaviours amongst the multi-disciplinary team.

Another important facet of the work described is the strategy it represents for shaping the agenda for a new form of creativity research. In order to further the development of this field, a number of key areas to be addressed are identified by Candy and Hori (2003) as part of a review of the development of the Creativity and Cognition conference series:

- Influences on the content and direction of research.
- Strategies for obtaining resources.
- Environments for implementing new programme of practice-led research.
- Developing practice-based research methods.
- Conferences and workshops to promote practice and research.
- Towards creativity inspired HCI/interaction design.

We have described an innovative approach to the study of creativity in practice and the development of digital technologies to enhance the generation of ideas and artefacts. The outcomes of the COSTART project lead us to believe that a methodology for combining research and practice can be successful in generating both research results and creative artefacts. In the 2 years since the end of COSTART, development work is ongoing such is the interest and enthusiasm for Studio based collaboration of this kind.

Most important of all is the promotion of research into digital technology and creative practice and the development of structures and methods that will enable significantly more research and discovery to take place.

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