Creative Visualization and Visualizing Creativity: An investigation of the relationship between creativity and visualization

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Abstract

The paper presents an interdisciplinary analysis of the relationship between creativity and visualization. It explores the potential for new visualization technologies to represent, communicate or interactively engage with theories of creativity to extend our understanding of creativity and its application across differing domains. By giving an overview of the definitions of creativity, it demonstrates that the understanding of creativity is a continuous process of interpretation. Such an understanding involves many personal and environmental elements such as social and cultural context - culture as well as different perspectives on the relationship between "old" and "new" technologies in the form of case studies raise questions on how to understand the"machine's creativity" and what is the role of the "machine's creator", or in other words, the potential of the machine to participate as a non-human agent in creative practice to new knowledge of creativity. The analysis indicated that there is a gap in a creative technology-based approach to creativity. The result of the study also suggests some future directions for research in this emerging interdisciplinary field.

Keywords: Creativity, Data Visualization, Art Practice

1. Introduction

Creativity is understood here as a concept fundamental to all people and cultures that involves a mental process of producing new ideas and products. Since there is a wide range of different disciplinary perspectives on creativity and different understandings of creativity through historical periods and over time, there are many different concepts of creativity. For example, in many arts-related fields, creativity is often regarded as mysterious; or learned or developed tacitly and evaluated through interpretive methods such as reviewing and critique. In more technical fields such as engineering and robotics, however, creativity is often regarded as akin to problem-solving and capable of being subjected to well-defined methods for development and quantitative evaluation. In psychology, creativity refers to "solving problems, communicating with others, and entertaining ourselves and others" to generate ideas, alternatives, or possibilities (Franken 2001, 394). In the field of cognitive science, research on creativity has been related to brain function and the development of computational models. In addition, different cultures have exhibited diverse understandings of the concept of creativity. From a Western perspective, creativity can be defined as the capacity to produce work that must be novel and appropriate (Barron 1988).

However, in Eastern cultures, the concept of creativity emphasizes personal attachment to a

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primordial realm or a personal expression of an inner essence (Kuo 1996). Nevertheless, in many fields, any understanding of creativity remains limited.

In recent years, research has explored how new visualization technologies represent, communicate or interactively engage with theories of creativity. This paper aims to extend the understanding of creativity and its potential application across differing domains. Visualization has been proven as an effective process of the transformation, translation, or interpretation of certain forms of information into another (visual) form. For the scientist, visualization is an important tool for observing. understanding or representing complex scientific data. During these interactive processes, visualization techniques and dos manipulations play a key role in discovering and communicating knowledge or findings. However, the translation and interpretation of complex mathematical data into visual media is often limited by both technical and perceptual issues. For example, many scientists may have a limited engagement with visual communication techniques, and conversely, designers often lack an understanding of scientific forms of information. Scientific visualization, which emphasizes quantitative interpretations of data, can be monotonous and unsatisfactory to post-industrial society. Therefore, how to effectively represent data or information in clearly understandable visual form has become an important issue for both scientists and designers.

This study discusses the different definitions and criteria for creativity and examines how those different concepts contribute to the understanding of the topic. It provides an overview of the definitions of creativity that attempts to explore a range of possible explanations of creativity from many different angles. The limitations of such different definitions of creativity will be investigated to explore new approaches to the understanding of creativity.

Furthermore, this study focuses on examining the relationship between artistic creativity and technology. In this study, art refers to visual to such as paintings, sculptures, and media art, but not music or writing. It argues that artistic creativity often engages with new technologies through - or frequently as - new media. Hence, there is a focus in this discussion on artists' engagement with emerging computing technologies in the processes of modem art. This creative engagement with computing techniques is divided into three parts: computer as a tool, computer as a creator, and other computing applications. This paper emphasizes the computer as a creator, as some artists have been interested in designing and developing machines for visualization, in which machines can make a drawing or painting with or without human instructions. Here the paper raises the question of what role "machine as creator" plays in the process of creativity. In addition, the paper also discusses artistic data visualization, which might not accurately represent scientific data and might not be a tool to translate or communicate data in any scientifically meaningful sensors. Some artistic representations of data to communicate but may not necessarily be able to communicate, - nor are tightly connected to - scientific data.

This study also addresses a gap in research into the kinds of practices of creativity that engage with computing techniques and the deficiency in theoretical explanations of the role of technology in the mental activity of creativity. This paper examines this gap in terms of what role we can say the machine's "creativity" plays and whether that may also be indicative of a new concept of "creator"? It is predicted that the study on "machine creativity" indicates a new approach to creativity. The paper aims to explore how to broaden and link differing understandings of creativity and how technology may contribute to applications of creativity across differing fields.

2. The Definitions of Creativity

What indeed is creativity? How can we identify a creative product? To be certain, most researchers believe that defining creativity is difficult because creativity has been "changing throughout history and creative ideas usually appear unexpectedly, with little conscious awareness of how they arose on the part of the people who have the ideas" (Niu and Sternberg 2001). While some scientists and researchers have attempted to seek a definition, that can cover all expressions of creativity, there are multiple ways to define creativity and many versions of creativity have been proposed and discussed.

Creativity is not exclusively a modem concern. In ancient Greece, Plato discussed society's need for creative people and suggested ways of fostering their development (Cropley 1999). From ancient Greece until the Renaissance, it was widely believed that all desirable innovations were inspired by divinity. Since the Renaissance, this viewpoint began to give way to the idea that creativity is a "matter of genetic inheritance" (Dacey 1999, 310). In the nineteenth century, there was a theory widely accepted that creativity was closely aligned with madness (Cropley 1999). At the beginning of 20. century, the debate "turned to an argument over the relative contributions of nature versus nurture" (Dacey 1999, 310). However, shortly after the Second World War, researchers began to explore creativity in mathematics, the natural sciences, and in professions such as architecture in which creativity has "strong aesthetic connotations, and was largely seen as a medium for beautifying the environment, a form of self-expression and communication, or a way of understanding, opening up or coping with the previously unknown" (Cropley 1999, 512). Furthermore, in recent years, them has been growing acceptance of biopsycho social theories, that is, the belief that all creative acts are "born of a complex interaction of biological, psychological, and social forces" (Dacey 1999, 310).

Guilford (1967) believes that creativity is kind 51 divergent thinking, in which "the quantity (fluency) and quality (flexibility and originality) of information people generated from given information has been used to represent Noplc's divergent thinking" (Niu and Sternberg 2001). However, researchers such as Amabile (1996), Sternberg and Lubard (1995) argue that the actual processes of creativity are much more complex than the processes of just generating information. For them, the more important consideration is that people must accept the products of creativity as valuable or useful.

According to the research by Cropley (1999), creativity is defined as "a social phenomenon that is facilitated by some social factors, and inhibited by others" (Cropley 1999, 511). He points out that a workplace is an important social background in which "an interaction between the person and the environment affects the process of innovation" (Cropley 1999,511). Franker (2001) defines creativity as "the tendency to generate or recognize ideas, alternatives, or possibilities that may be useful in solving problems, communicating with others, and entertaining ourselves and others" (p.394). He believes that the reason people become motivated to be creative is out of the need for new. different and complex stimulation, communication of ideas, value, and problem-solving (Franken 2001). Meanwhile, Weisberg (1993) argues that the term "sensitive' refers to novel products of value. as in “'The airplane was a creative invention.' Creative also refers to the `person who produces the work, as in, Picasso was creative.' 'Creativity,' then refers both to the capacity to produce such works, as in 'How can we foster our employees' creativity?' and to the activity of generating such products, as in 'Creativity requires hard work'” (Weisberg

1993, 4). Sternberg and Lubart (1999) define creativity as "the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)" (Sternberg and Lubart 1999, 3). By considering the personal elements of creativity, the term can be defined as "an aspect of thinking, as a personality constellation, and as an interaction between thinking, personal properties, and motivation" and that "contradictory elements have to coexist for creativity to emerge" (Cropley 1999, 511).

Different cultures have different definitions of creativity. For example, a Western viewpoint on creativity for the most part is very different from the one held by an Eastern culture. From a Western viewpoint, creativity can be defined as the ability to produce works that are novel and appropriate (Pope 2005). The conceptions of Eastern creativity believe that "re-creation" of the "the old" is valued or "nand" and must be based on the "previous one/the old" (Pope 2005), which may be similar to "neo-Classicism" or other kinds of traditionalism in the West (Pope 2005). In other words, neo-Classical creativity depends on the old for the new. In addition, Bodes (1996) argues that "novelty may be defined with reference either to the individual concerned or to the whole of human history" (Bodes 1996, 351). Boden's principles of P-creativity and H-creativity are two sensors of creativity P-creativity is that which makes a discovery or experiences a personal break-through and H-creativity is what is known already or had been known before (Pope 2005). Furthermore, based on Pope's "original and fitting" terms, a conception of creativity may be formulated as follows:

> Creativity may be "original" in the sense both of drawing on ancient origins and of originating something in its own right; either way, the overall aim or end is a fitting' - an active exploration of the changing proportions, measure, ratios- between older modes of understanding and newer ones (Pope 2005, 59)

Instead of presenting a standard definition of creativity, Pope (2005) introduces a conception called "re...creation". He believes that re...creation is "the ongoing of making afresh" (Pope 2005, 84). The prefix "re..." can moan "afresh" as well as "again", and denotes repetition with variation, not just duplication. The concept of "... creation is considered to comprise many different meanings of the "creativity" including God as Creator, -the creative artist' and the various `creatures' of the imagination, along with such processes as 'creative evolution' and `heterogenesis' ..." (Pope 2005, 84). This conception shows people to "see through the exciting possibilities to words beyond as well as between; and it encourages a view of `difference that is genuinely otherwise... it is an invitation to keep on jumping or bridging the gap..." (Pope 2005, 88). The new concept leaves more room for "conserving and sustaining as well as recasting and refreshment while resisting conservative, reactionary impulses of an unthinking and merely reflexive kind" (Pope 2005, 88).

At last, the concept of creativity needs continual reinterpretation and rewriting in current terms because creativity will always be "something more and something different" (Pope 2005, 88). As technology has been widely used in contemporary society, how creativity could be interpreted in the context of technology is key. The next section will discuss the relationship between creativity and computer-based visualization technology.

3. Visualization Technology

In the global information society of today, people are often required to comprehend or understand the meaning or implications of data or information. How to efficiently present data or information has become a key issue in achieving this comprehension. The basic function of visualization is transforming data or information into "a visual model capable of revealing its essence", which people can easily understand, such as maps, paintings, movies, photos, charts, and diagrams (Wildbur and Burke 1998). The result of the visualization itself may muse scientific findings. Hamming (1973) believes that the purpose of visualization is "insight" and not simply picture The main goals of this insight are discovery, decision making and explanation.

3.1 visualization technology as artistic creative

Technology plays a most important role in the process of visualization, and determines whether data can be successfully transformed into certain visual forms that reflect the designer's 4, purpose. Before the invention of computing technology, most visualization works were completed by hand the most common technique is illustration or drawing by using traditional tools such as paper, ink, pen, and brush. However, since the application of computing technologies, visualization has largely relied on computer technologies that can facilitate the comprehension of large and complex data in two, three, or even more dimensions.

A computer hardware system needs software to support the process of visualization. In this study, software refers to computer software achieved through different programming platforms. Computer software receives commands from computer operators and passes these instructions to the hardware to execute certain tasks. Compared to hardware, software is imaginable, and it includes application software, programming languages, and operating systems. An operating system is basic software for the hardware, such as Microsoft Windows, Linux, and DOS. Programming languages define the syntax and semantics of the programs, such as C/01-F, BASIC, Java, and Processing. Application software is software that the computer users to communicate with the computer to achieve certain tasks. For example, these include word processors, games, online chat tools, and browsers such as Internet Explorer. The design and development of computing software is the most important part of visualization that directly impacts the effects of visualization. The process of designing computer software usually involves designing, writing, implementing, testing, debugging, and maintaining the source code of the programming. Algorithms are key steps in the process of software design. The implementation of the most efficient algorithm is a major concern in academic computer programming.

Scientists seek patterns and trends from complex data through efficient visualization processes. Not only does it allow scientists to recognize the information or pattern behind the data, but the process also contributes to a better understanding of the data itself. Scientists may wish to

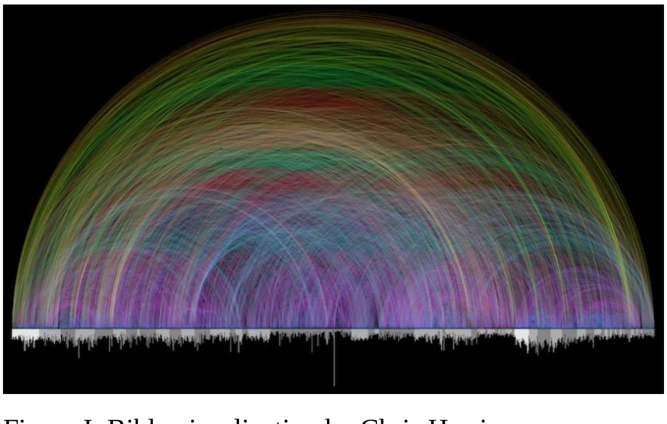

Figure I: Bible visualization by Chris Harrison

"engage the reader or spectator in a wonderful journey of imaginative visualization", and, after analysis, they wish to "communicate an interpretation that unambiguously embodies testable content" (Valle 2008). However, artistic visualization tends to employ ambiguous interpretational methods that facilitate the expression of hidden information behind the data patterns (Figure 1).

3.2 Artistic Based Studies on Creativity and Technology

What we understand as "modern technology" has been applied to the creation of artworks at least since the Industrial Revolution. Between the late nineteenth century and the early twentieth century, the modern art movement pushed traditional art to its limits by probing the whole concept of what constitutes "art" through engagement with new electronic technologies and, later, new digital media. During this time, art also addressed and absorbed developments in modern science and related social changes. Since then, the understanding of to has been continually shifting and has produced many art movements. A key change in understanding artistic creativity involved bringing new technologies into artists' processes of creation. For example, artist Eadweard Muybridge used photographic techniques to capture the actual sequence of movement on animal locomotion.

In the postmodern period, artistic creativity largely involved artists using new computing technologies - including computing software and hardware systems, internet, video, photography, and multimedia technologies - in the creation of artworks. For example, art based on notions of interaction allows audiences to participate in the communication between as works and the audiences themselves. The open-ended works evolve through this form of audience participation. This points to "a process that becomes possible only through the new technological devices that create a situation in which questions by the user/spectator arc effectively answered by the artwork itself' (Popper 1993, 8). In such artworks, technique plays a key role in the process of artistic creativity. It focuses on the different scientific and computing techniques and analyses the relationship between technology and aesthetics under different technologies. Such "technological art" has been "the most important source ... related to the new interpretation and use of light and motion ..." (Popper 1993, 12).

In general, there are three main categories of art-based creativity engaging computer technologies. One is a computer as a tool, one is a computer as a creator and the third might be defined as any other areas of creativity using computer techniques but not included in the first or second categories.

3.2.1 Computer as An Agent in Artistic Creativity

Using the computer as a creator means that artists develop computer-controlled visualization machines -Artificial Intelligence-based techniques. The special drawing machine can create artwork such as a painting or drawing, without human interruption or ideas. The use of computer technology "changes the strategy of image-making" and raises, questions concerning whether "the computer creates art itself" (Popper 1993, 80). Therefore, we really cannot just classify computers as a tool but as something like "a creator" or "a simulator of memory, of reasoning and the brain inch" (Popper 1993).

The first artist who explored this area was Harold Cohen who developed an Artificial Intelligence program called AARON, a computer system that can make a drawing. It took Cohen more than 30 years to develop the drawing system in which the computer became a "creator" of art. From the early 1970s to now, AARON has been refined from simple shapes and curves to colored abstract forms to realistic figures with its robotic arm. The works created by AARON mom and mom resemble paintings drawn by humans. How the AARON system makes a painting is decided by a computer program implemented in its "brain."

AARON has been programmed with two types of knowledge. The first type of knowledge encodes all kinds of different shapes into its programming, such as the human body and a simple tree. The programming of the knowledge about the world parallels human memory in which information is stored. This part of the programming is called "declarative knowledge". The second type of knowledge is called "procedural knowledge" which allows the robot to move from a start to an end through a series of inter-connected steps during the process of making a painting. Those two types of knowledge in AARON programming comprise the soul of the computer as an artistic creator. The artistic aim of AARON is "shaped by the historically long-standing dream of a 'thinking machine' and he looks forward to a time when computers will be able to surprise him, not only by drawing something he did not anticipate but by producing a drawing only possible through the computer's modification of the program" (Popper 1993, 80). However, there are still many limitations in the AARON system. It is believed that AARON's creativity is not enough so the machine cannot examine the process of understanding creativity in abstract terms, although computing technology brings a new platform for artists to understand creativity. This example clearly shows that technologies adopted in the various modes of creativity are best described under the banner of "visualizing creativity." The following section discusses the notion of creative visualization, which emphasizes aesthetic approaches to visualization and new visualization techniques.

3.2.2 Artistic Data visualization

Creative visualization models novel, varied and complex simulations, to communicate ideas and values and solve problems, leading to knowledge acquisition. Creative visualization includes the aesthetics of visualization, the invention of new visualization techniques, and the artistic representation of data.

Artistic data visualization can be defined as "visualizations of data done by artists with the intent of making art" (Viegas and Wattenberg 2007). Actual data provides to basis for the works that include "the metaphors or surface appearance of visualization" (Viegas and Wattenberg 2007). The works might not be as beautiful as people's expectation but aesthetics is not only about beautiful net works visually presented. For example. microscope photography is not artistic visualization, insofar as scientific images merely present quantitative findings. Although some scientific visualization is presented as beautiful images, they lack the creative intent of artists. The difference between artistic visualization and scientific visualization largely focuses on how to explain or explore the data in certain ways. In other words, the way of seeing the data distinguishes between artistic and scientific visualization. Scientific visualization presents a highly data-accurate picture whereas artistic visualization needs free creativity with less of a view towards representing data (Lau and Moere 2007).

3.2.3 An Example of Artistic Data visualization

Jason Salavon is an artist working in data visualization-based artistic practice. His work "The Class of 1988" (Figure 2) was created through computing techniques that take the mean average color of every photo, pixel by pixel, and then represent those photos as totally different new images. He attempts to express "the collective aggregation of human experience" through the process of blue-coloured individuals (Viegas and Wattenberg 2007).

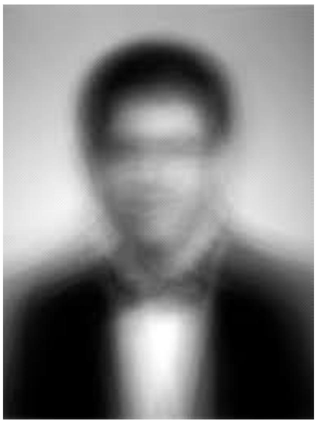

Figure 2: The class of 1988 by Jason Salavon

4. Discussion and Conclusion

The purpose of this paper has been to develop an analysis of the relationship between creativity and visualization through a discussion of the seemingly disparate domains of creativity and the technologies of visualization. The understanding of creativity depends on two basic key points: novelty and value. Typically. the concept of "novelty" is described in contrast to the "old". The "value" of creativity is usually interpreted as useful or defined as appropriate for some domain-specific goals. However, in practice, what we recognize as creativity has been found to emerge as the result of a much more complex process of interaction between psychological, environmental, social, and biological actions and other criteria. Instead of proposing a standard definition of creativity, Pope's (2005) new concept of creativity. "re...creation", indicates an ongoing understanding of creativity as a quality that develops emerges, and changes concerning the evolution of societies or fields.

The results of this study indicate an insufficiency in the study of creativity; specifically, in its engagement with technologies.. While most understanding of creativity focuses on human perceptive, psychological, cultural, social, and neuro-scientific domains, there are few approaches to theorizing creativity through technology, partly because technology itself is often considered a product of creativity rather than an agent of creativity.

This study has demonstrated that visualization software plays a key role in mediating between users and hardware devices. The software receives commands from the user and then interprets human instructions and passes the instructions to the hardware to execute tasks. In different software, algorithms are the most important factor. Different algorithms generate different effects to represent data or information. Most visualization integrates many different techniques, both in terms of hardware and software. Virtual Reality is a typical application using different techniques to create immersive and embodied environments.

With computer-based art, there are two key questions: is the computer-based artwork, in itself a "new" form of creativity? How can we evaluate the novel role or value of the "autonomous mechanism" or "thinking machine" model of production offered by computing technology, in terms of creativity? This paper has suggested that computer-generated work is a "new" form of creativity because those "assisted" or "created" paintings or drawings have an autonomous or automatic character that distinguishes them from traditional hands-on works. In addition, artists in traditional forms of practice often directly participate in works and determine, rather than pre-determine, each step throughout the whole process of creativity. However, it is also evident that the role of the computer as a machine in the process of creativity has been largely expanded beyond the role as a tool or medium to a new concept of "creator". This agentic view of the machine suggests a new approach to the creativity of the future. To evaluate the autonomous quality or contribution of technology, we need to net up a theoretical model based on an understanding of the human relationship to these "creative technologies".

The problems of how to understand the concepts and manifestations of creativity are of critical importance in many fields. One of the key functions of visualization is the effective and efficient transformation, translation, or interpretation of data into a visual medium. This paper on theoretical models of creativity and their application contributes knowledge about the relationship between and the effect of expression on visualization. It has been shown that the model of an approach to creative expression involving new technology is effective in discovering, understanding, and representing the value of ideas and data across scientific and artistic fields. Creative visualization has significance for scientists, as it seeks new creative models of expression and uses creative technologies to translate and interpret data into visual form in order to facilitate understanding of often complex concepts. On the other hand, this paper has contributed to the evaluation of creativity or creative practices. For example, artistic data-based visualization has been defined as an example of the relationship between creativity and visualization. First, artistic data visualization emphasizes "artistic" concepts other than conventional visualization models that attempt to represent data with limited, • unchanged, unambiguous techniques and methods. In contrast, data-based artworks represent data in ambiguous, different, and intentional visual foams open to multiple interpretations. Second, this new "creative" (artistic) concept of the machine as a creative agent rather than a technological medium not only improves the effect of visualization but also leads to new creative practices to explore the understanding of creativity.

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