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Promoting Creative Computing: origin, scope, research and applications

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ABSTRACT

Human creativity needs improvement in contemporary society. Due to the fast development and pervasive utilisation, computing has been a good servant to support creativity. It is not only utilised to facilitate creativity research, but also leveraged to assist creative activities in everyday life. Up to now, people have never stopped exploring the great potentials of computing to facilitate human creativity. Various new concepts of computing are currently emerging, especially creative computing that inspires a novel approach to improving human creativity. This paper presents a comprehensive review of Creative Computing, including its origin, scope, research and applications.

1. Introduction

Human creativity has presented its great capability to improve our living conditions and advance worldwide civilisations (e.g., light bulbs, airplanes, and smartphones). Nowadays, humanity is even defined by creativity in not only artistic fields like literature and music, but also virtually every other domain. Due to its mysterious power, humanity has never stopped pursuing the ultimate answer of creativity. Although an enormous number of valuable results about creativity have been discovered, there is still a long way to go. Especially, in recent years, creativity has been the core competitive advantage [1]. Various kinds of creative products, activities, and services have been the key concerns all over the world [2].

Computing has already been the seemingly perfect tool to support human creativity. In the academic field, it helps researchers to understand human creativity in a truly scientific way. A variety of platforms, systems, and apps are continuously developed to assist creative people. Recently, the Guardian has selected the top 50 apps for creative minds [3]. A project named DevArt (art made with code) is commissioned by Google to push the possibilities of creativity and technology [4]. Various kinds of computing technologies are combined and utilised to create digital art installations. For instances, Wishing Wall enables people to turn their wishes into beautiful butterflies. Colour of World is able to allow people to discover unknown places through the exploration of colours. This kind of new tendency of computing technologies has attracted great attention from both developers and artists all over the world. There is even an exhibition held in London Barbican named the Digital Revolution filled with various creative installations [5].

Other good efforts also have been made to use computing to generate not just simply creative work, but “creativity” itself. The field is known as computational creativity, which aims to generate machine creativity through imitating human creativity [6]. Computational creativity has gone up from the facilitation level into the cooperation level,with respect to supporting human creativity. The computing in computational creativity could work as a “partner” to cooperate with creative people in some kind of creation process, such as music improvisation and dance performance [7]. For now, the relationship between creativity and computing has entered into a new era [8]. Due to the crucial difficulties within creativity, such as uncertainty and vagueness, there are still inevitable limitations within the simulation of human creativity [9]. New or novel approaches to improve human creativity are still urgently demanded.

That is why various new concepts are continuously emerging, especially Creative Computing. Based on the persistent exploration of the possibilities between computing and creativity, computing could finally be deemed as truly creative, rather than appearing to be creative. By doing computing in creative ways, Creative Computing may be able to go further from the cooperation level into

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Tab. 1
Levels of Computing on Creativity.

Levels	*Computing on Creativity*
Facilitation	Creativity Research Technologies
	Creative Tools
	Creative Installations
Cooperation	Creative Installations
	Computational Creativity
Inspiration	Creative Computing

the inspiration level (see in Tab. 1), to stimulate creative ideas for people.

Due to the diversity of human behaviours, there inevitably exist a lot of difficulties. Creative Computing could allow us to think from the perspective of computing. Because of its objectivity, computing could exclude the subjectivity of human, to concentrate on the pure rules governing creativity, in other words, objective rules of creativity. By doing so, Creative Computing might be able to promote human creativity in a more essential way. On the other hand, based on the great power of computing, such as the tremendous computing capability and vast amount of data, it could provide a great space for our creativity to perform. Creative Computing may not try to explain the ultimate nature of creativity but it tries to explore the mechanical rules of creativity and utilise them to improve human creativity.

This paper is organised as follows. Section 2 explains the origin of Creative Computing in details. Then the concrete research topics and initial results are presented in Section 3. Section 4 introduces three example research topics that are currently being studied in the realm of Creative Computing. A small number of application fields, directions, and typical examples are given in Section 5. Finally, a brief summary is presented in Section 5.

2. The origin

In this Section, the origin of Creative Computing will be articulated, including the studies of computing itself, computing for promoting creativity, and the worldwide trend of knowledge combination.

2.1. Latest evolution of computing for inspiring creativity

Due to the fast development and pervasive utilisation of modern technologies, there are not clear boundaries between hardware, software, and web any more. More and more computing tends to or is required to be integrated together, such as the Internet of Things (IoT). Changes have been made to the most basic and indispensable infrastructure by the Internet, which is trying to connect everything in the world [10]. This kind of connection feature has prepared an almost unlimited platform for the future computing to do whatever it wants, such as Creative Computing.

Because of the extreme complexity of social life nowadays, computing, as a loyal servant, has been expected to do more and more work for people. Consequently, computing professionals like Tim Berners-Lee continuously create new technologies like Semantic Web (Web of Data) to meet the urgent requirements. As the inventor of the famous World Wide Web (WWW), Tim is able to foresee the great potential of the Semantic Web. Its core components, such as vocabularies or ontology, RDF data and inference engines, could enable the computer to “think” for people, thereby providing further analysed results that might be more precise and comprehensive [11,12]. In this next step, more terms, like Web OS and Intelligent Webare starting to gain greater attention from around world. This tendency of the growth of “computing intelligence”, to some extent, proves the possibility and probability for the computer to compute in creative ways – Creative Computing.

2.2. Computing for accelerating creativity

There is no doubt that human creativity needs to be heavily improved in modern competition. Because of the highly advanced technologies and infrastructures, human creativity or the flash of creative ideas has been the hot pursuit in recent years. Globally, due to the oversupply of the market, not only the quantity and quality, but also the novelty and uniqueness of products have become the key concerns of contemporary companies and enterprises. In order to seize the great opportunity, many organisations or people dedicate to providing various kinds of services about creativity, such as coaching strategies. One of the most famous is Edward de Bono and his popular lateral thinking techniques and methods [13].

As computing is leveraged almost everywhere, it also starts to present its great potential in the creativity field. In fact, because of the great power, creativity has been studied for a long time and in various domains. As the rise of disciplines like Neuroscience and Cognitive Psychology, scientists eventually start to study creativity scientifically, through utilising computing technologies like fMRI and EEG. Except that the very explanation for creativity still remains a mystery, a lot of valuable results, for example, where and when the creativity occurs in our brains have been investigated. In the meantime, specific studies about how to improve human creativity based on these scientific discoveries is starting to be conducted, such as the utilisation of unexpected experience. Accordingly, totally experiencing a new or even absurd environment could, to some extent, improve human creativity. Technologies of virtual reality have been the perfect tools to facilitate these methods.

Besides the facilitation in creativity research, computing also devotes itself to supporting creativity in daily life, be it for work or entertainment. There are complicated intelligent platforms like Gold fire, which are able to generate comprehensive creative solutions. There are also professional systems or applications like Mind Genius with mind mapping functions to support divergent thinking. Even relatively simple apps also make their own contributions for the creative mind, such as Magic Piano. It could provide a creative way for people to learn how to play music. As can be seen, various kinds of computing have been the concrete foundation for the improvement of human creativity.

However, through zooming out, it can be seen that most of the different forms of computing mentioned above are still concentrating on the virtualisation of tools for creativity. According to the previous analysis of the evolution of computing, we know that computing is becoming more and more“intelligent” over time. Therefore, it is reasonable to believe that computing could be more active and illuminative in the enhancement of human creativity. The key question is how to do it.

The inspirations also come from continuously emerging creative products like the Apple iPhone, which enlightens us to do computing in creative ways. The development of the iPhone has no longer been the common development of the mobile phone. It is more like the creation of some kind of artwork. Even the design of the inner structure of the iPhone is very elegant and beautiful. The great success of the iPhone benefits a lot from this kind of artistic and/or aesthetic designing or developing approach.

Therefore,we finally endeavour to find a new way to improve human creativity that is to compute in creative ways [14], which we called Creative Computing. Through computing creatively, Creative Computing might have more possibilities and

probabilities to improve human creativity. Through being more close to creativity, Creative Computing could narrow down the critical gap between subjectivity of human and objectivity of computing. Through being more active, Creative Computing may be able to much better deal with the vagueness and uncertainties within creative process.

The most important problem, as being well accepted, is how to enable the computer to compute in creative ways. Accordingly, creativity is heavily associated with or even grounded in knowledge [15–17]. According to Sternberg's Triarchic Theory of Intelligence [18], creative intelligence is based on the utilisation of existing knowledge to deal with new situations. The very possible way to currently make the fullest usage of knowledge can be to "Unite and Conquer" [19], in other words, knowledge combination.

2.3. Calling for knowledge combination

The increasingly complicated societal life requires knowledge to be combined together. Worldwide, knowledge combination is demanded by global cooperation (e.g., prevention of disasters or diseases) to make the work more efficient. Recently, Ebola is one of the most horrible virus diseases in the world and huge amount of effort will be made to control its outbreak. Due to its great complexity, many vital elements are to be considered, including humanistic care, community engagement and financial assistance. If knowledge in those different fields could be combined together (e.g., mapping figures of financial assistance with strategies of humanistic care), more operations might be able to act automatically (e.g., the quantity of healthcare teams might be suggested automatically according to assigned financial assistance).

In terms of the daily life, the pervasive usage of the mobile phone is the most obvious evidence of knowledge combination. Mobile phones, especially smartphones, might be the most remarkable invention in modern times. Featured with apps, it has the unlimited potential to do a variety of tasks for people. In order to put all of the functions into only one package, various kinds of knowledge definitely needs to be combined together. Just as Steve Jobs once said "I like living at intersections of humanities and technology [20]."

Knowledge combination can be the best way to make the fullest utilisation of the abundant knowledge today. While learning and utilising existing knowledge, people are continuously creating new knowledge [19]. How to make the best utilisation of knowledge has been one of the key concerns in modern times. One specific discipline, known as Knowledge Management (KM), specialises in leveraging organisational knowledge, especially expert knowledge. One of the important stages of KM is the combination of knowledge [21,22].

As the modern society is becoming increasingly complicated, more and more disciplines and knowledge tend to be fused together, such as Biochemistry and Cognitive Science. Furthermore, most of the time, different disciplines and knowledge have something in common. One thing might be studied in different fields within different contexts. For instance, robustness could be studied in a variety of different fields, such as Computer Science, Biology, and Economics. The Internet, in computing, is studied for ways to improve it. In business, it is studied for how to conduct business transactions. In sociology, it is studied for how people's lives are affected [19]. In order to have a more comprehensive point of view, a uniting perspective should be adopted.

It is time now to use knowledge from other disciplines to address problems in the computing field. Most of the researchers are used to doing explorations only within their own professional fields. However, since computing could be used to facilitate the development of other fields, what if knowledge in other fields also could help to address problems in the computing field? Here we need to mention that the "other disciplines" do not mean the conventionally associated fields like Mathematics and Physics, but the areas with different features like Art, Philosophy, and Psychology. In the field of Creative Computing, the most important problem is to support human creativity through computing in creative ways. Therefore, the combined knowledge might be the main resource of the computing approaches that Creative Computing seeks.

Creative Computing aims to do knowledge combination. Evolution of computing has prepared a useful foundation for Creative Computing, where various kinds of computing are like a "glue" to stick different knowledge disciplines together. Therefore, through connecting those computing technologies, different knowledge and disciplines might be combined. In order to enable computing to be "intelligent", there should be some particular knowledge components, such as knowledge representation, which is a tool to do knowledge combination. Depending on the relationships between knowledge, information, and data, knowledge combination will eventually depend on the processing of data. A current demanding aspect is that with enough data, Creative Computing might be able to find something surprising, which is strongly connected with Big Data.

To summarise, the advancement of computing has already prepared a basis for Creative Computing to emerge. The urgent requirement for a new approach to improve human creativity genuinely leads to the advent of Creative Computing. To prove it further, the social calling for knowledge combination eventually certifies that the emergence of Creative Computing is inevitable and necessary.

3. The scope

3.1. Revisiting creativity

In order to improve human creativity, information or knowledge about creativity should be known in the first place. There are various kinds of concepts on creativity over time, such as:

- In the research field, creativity could be studied as ability, personality, process or even just a state of mind [9].
- In everyday life, creativity is always associated with creative thinking methods, such as divergent thinking and lateral thinking [23].

Nevertheless,one of the appropriate theories that Creative Computing depends on was proposed by Professor Margret Boden [6].As an expert in Cognitive Science, her research includes various kinds of disciplines like Computer Science, Artificial Intelligence, Psychology and Philosophy. Therefore, through thinking across different areas, especially computing fields, her theories on creativity could be more operable for Creative Computing. Accordingly, there are three forms of creativity: combinational, exploratory,and transformational creativity [24].

Our work so far pays more attention to combinational and transformational creativity, more specifically.

- Combinational creativity is to do the unfamiliar combinations with familiar things [24].The most common example of it is analogy. The reason for paying attention to combinational creativity is that it is the most common way to do creation nowadays, which is backed up by Steve Jobs, who believed that creativity is all about connections [20]. Due to the diversity of creative products and vast amount of available knowledge, innovation totally from scratch is not needed. In contrast, people are focusing more on how to make the best use of the

utmost abundant materials, technologies, and societal knowledge. That is to link them in creative ways. Hence, Creative Computing devotes itself to facilitating people's combinational creativity.

- Transformational creativity is a kind of deeper creativity [24], which is to discover possibilities within a new conceptual space through transforming the old one. A conceptual space likes a knowledge system or thinking style within a certain field, such as theories in Biology, styles of painting, and so on. As opposed to transformational creativity, exploratory creativity inquiries about the possibilities within only one conceptual space. Through comparing the two, as the conceptual space of transformational creativity is new, there should be more possibilities for people to explore. Therefore, Creative Computing also aims to assist people's transformational creativity.

Our approach to improve human creativity with Creative Computing is through deep knowledge combination. In order to comprehensively combine different knowledge, a more macroscopic perspective should be engaged. Since knowledge is commonly grouped into disciplines, Creative Computing will use discipline as the basic unit to do knowledge combination.

As for the selection of disciplines, our studies especially emphasises on the availability, dissimilarity, and diversity of disciplines. The availability is to do with the generality of disciplines. For example, compared with Medicine, Philosophy is relatively easier for us to access. In terms of dissimilarity, it is to do with the "distance" between different disciplines. For instance, Computer Science is a more logical discipline. On the contrary, Art relies more on feelings that are full of uncertainties. It seems that the distance between Computer Science and Art is extremely remote. However, the approach of Computer Science could be radically changed through artistic thinking. The success of Apple is the most obvious evidence. As for diversity, it has to do with the various kinds of features of disciplines. For example, Psychology is the most specific way to study human-related things.Philosophy, as the origin of all the disciplines in the world, might contain the deep relationships between different disciplines. Art has the closest associations with creativity.

We take a less known discipline Pataphysics as an example to illustrate how it is used in our research, which can be seen as a feature of Creative Computing. Pataphysics is the science of imaginary solutions, which examines the laws governing exceptions [25]. Seemingly unexpected exceptions might contain great value for creation. Furthermore, Pataphysics has special relationships between Metaphysics and Physics. Pataphysics is to Metaphysics like Metaphysics is to Physics [26]. It enables people to be able to see beyond the physical and metaphysical world and think something unthinkable before (e.g., building relationship between atom swerve with people's free will). Therefore, it might possess a more essential or novel point of view about the world. In this way, Pataphysics provides an innovative approach for Creative Computing to help with human creativity.

There are three types of knowledge combination: multidisciplinary, interdisciplinary, and trans-disciplinary combination [27].

- Multidisciplinary combination could be deemed as "Divide and Conquer", which is, most of the time, used for extremely complicated projects like space programmes or world health projects. The knowledge in multidisciplinary approaches may collaborate, but they maintain a separation of their disciplines. When the problem is solved, those disciplines go back to where they came from.
- Interdisciplinary combination is a kind of boundary-crossing cooperation. It could fuse different knowledge deeply and finally end up with the extension knowledge of existing disciplines. It even could form new disciplines such as Cognitive Science, which makes it a very promising approach for Creative Computing.
- Trans-disciplinary combination is similar with interdisciplinary combination. The main difference is that trans-disciplinary combination focuses on all the disciplines in the world, which makes it a more holistic approach than interdisciplinary combination. The ultimate goal of Creative Computing is to try to combine all of the knowledge in the world and *improve* human creativity.

Our study proposes to differentiate Creative Computing from computational creativity, though they are both about computing and creativity. The difference can be that Creative Computing requires computing to be creative. However, computational creativity is to generate machine creativity through simulating human creativity, which does not necessarily require computing itself to be creative [7,28].

Creative Computing also deploys continuous creative stimulations, including both creative ideas and creative interactions. Unlike some creativity training tools, such as Six Thinking Hats, attempting to provide a framework to facilitate people to think differently, Creative Computing tries to induce and illuminate people themselves to think creatively through the stimulations between the inputs and outputs of Creative Computing. Through recognising the hidden logics of Creative Computing, it is exciting to encourage people themselves to find the creative inspirations and think creatively.

The creative stimulations of Creative Computing are based on the creative rules, also known as rules governing creativity. In both societal life and academic field, there are always some particular things, associations, activities, or phenomena that are closely related to creativity, such as task-irrelevant distractions [29]. Behind them, there might be valuable rules about creativity, such as randomness [30]. Based on rules like this, a variety of tools, techniques, and methods have been developed for humans to be creative, like lateral thinking. However, in Creative Computing, the creative rules will be fused into computing to improve human creativity. The vital difference is that the former only needs to tell people, say, "think like a child" and the latter also demands to guide or inspire people to think how to "think like a child". In other words, the concrete stages or logic which is more motivate and instructive to enhance human creativity.

It is worth mentioning that Creative Computing not only utilises creative rules, but also proactively discovers potential rules of creativity. To some extent, it also could be deemed as a new approach to do creativity research. Our studies so far only focus on discovering and utilising creative rules, rather than studying the ultimate nature of creativity. There are many areas for Creative Computing to be involved but we chose to start with software development [14], as software development is full of flexibilities and possibilities, which requires ever great creativity.

3.2. Research methods

Due to the creative features of Creative Computing, some modifications might be made to the general research process. A potentially new research process (see in Fig. 1) in Creative Computing might be featured with the utilisation of creative thinking and the emphasis on the importance of knowledge. After the research idea stage, there should be a creative ideation stage to think about the research idea differently and creatively. By doing so, the whole research might be able to generate a creative solution for the given problem. It strongly encourages people to touch different knowledge and to engage different perspectives.

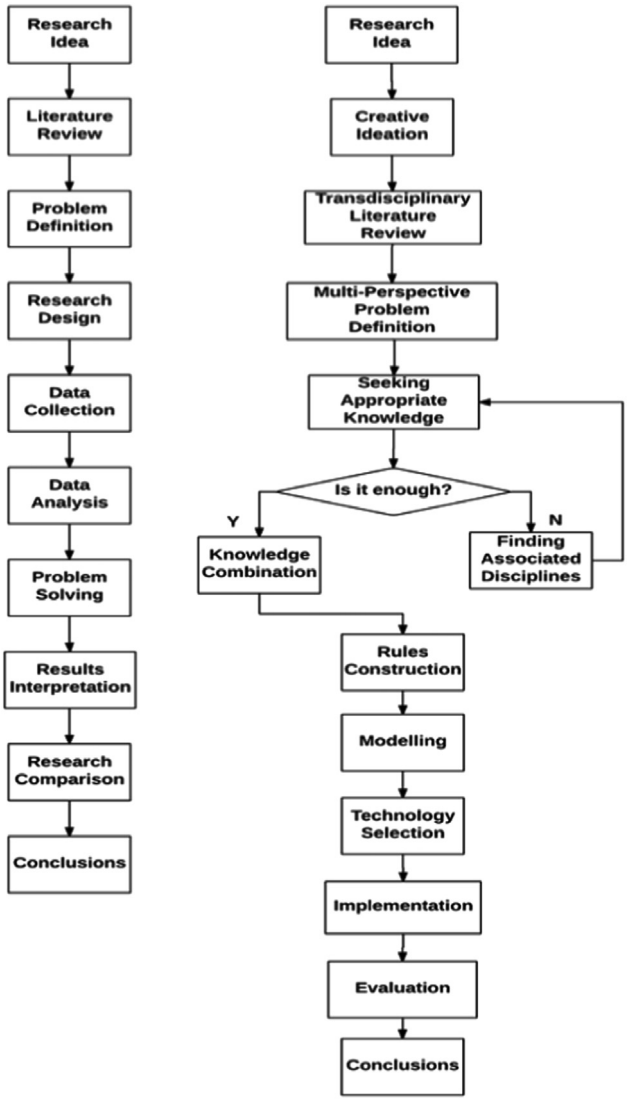

Fig. 1. A general (left) and new (right) research process.

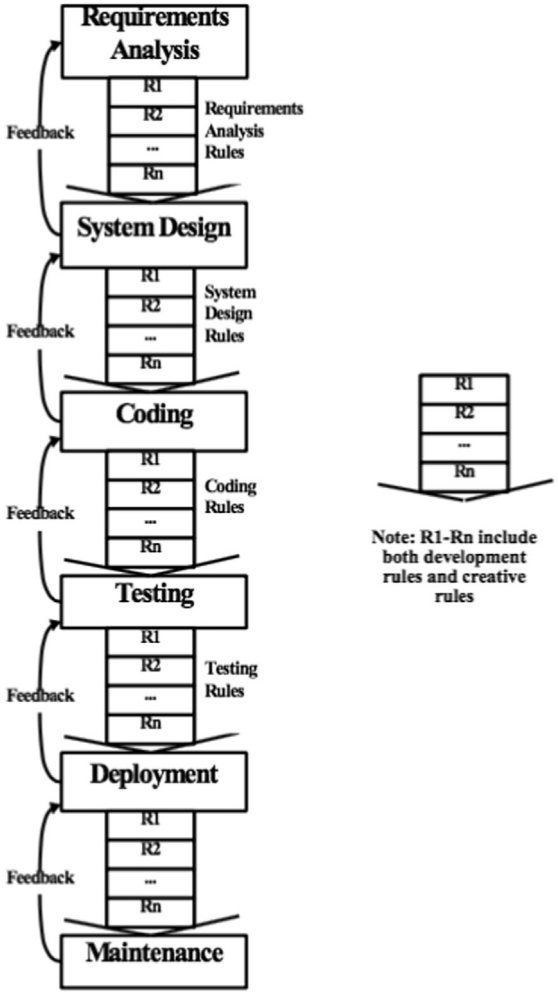

Fig. 2. Creative software development based on a modified waterfall model.

It is proposed that a creativity element is to do with the paradox of creativity. In order to improve human creativity, we need to know how to be creative in the first place. However, if we know exactly how to be creative, can it be called “creative”? One logical solution is to promote human creativity without “knowing” it, but “feeling” it. The feelings for creativity mainly come from two aspects: the absorption of a variety of knowledge and the attention to seemingly ordinary things. Through thinking across different disciplines, some deep nature and relationships might be discovered, which might be helpful to promote human creativity. Besides various kinds of knowledge, interesting phenomena on creativity in social life are another kind of representation of human creativity. Some seemingly ordinary things might contain great power for creativity. i.e., never taking anything for granted. Always thinking one step further might be able to enable us to find something interesting.

In order to guarantee the results of the “creative feelings” are valuable to improve human creativity, an efficient validation method is required. The detection of brain gamma waves are utilised in Creative Computing to do the validation, in our study. Gamma wavesare positively connected to the Aha moment [31]. Physically, when a creative idea suddenly comes into someone's mind, the gamma waves will increase. Based on the neuro-imaging technologies today, it is possible to see if Creative Computing could, to some extent, stimulate the emergence of sudden insights for people, thereby improving human creativity.

3.3. Research directions

Currently, there are three main areas being studied in the realm of Creative Computing: creative development, creative computing products, and computing platforms for creativity.

1) Creative Development is to develop a computing product creatively. it is worth mentioning that creative computing not only aims to improve user creativity, but also devotes to facilitating developer creativity. the creative development of a computing product is specialised in doing that. there are generally two aspects within the development: Activity and human. In terms of the aspect of activity, as Creative Computing currently centres on the software aspect of computing product, the whole life cycle of software development will be studied to fuse with creative contents, such as creative rules (see in Fig. 2). Generally speaking, the development rules (e.g., the earlier problems are discovered, the less the overall cost will be) are used to directly guarantee a good quality software development. However, what Creative Computing particularly concerns itself with is how to do a creative software development with the aim to produce software with better quality. Therefore, creative contents will be added into the common rules, which might be called creative rules (e.g., trying not to address a certain

problem directly, but to utilise it as a stepping-stone to achieve goals indirectly).
As for the human aspect, how to foster versatile individuals will be studied in Creative Computing. Developers of Creative Computing are encouraged to learn various kinds of knowledge from diverse disciplines. By doing so, different thinking styles can be engaged, which is very helpful to cultivate individual creativity for the development of Creative Computing.

2) Creative computing Products centre on enabling computing products themselves to be creative, in other words, developing creative software. there are generally two main approaches being considered in creative computing to doing that: System design and quality control.

Due to its great significance to software development, system design is currently the main way to enable software to be creative, especially the algorithm design and architecture design. Algorithm, as the "soul" of software, it gives step-by-step instructions for software to operate in creative ways, which enables it to be the most direct way to develop creative software. In order to better support the unique features of Creative Computing, specific architecture has also been studied in the realm of Creative Computing. For example, the development of Creative Computing particularly relies on the uniting power of knowledge. In order to deal with the difficulties of knowledge (e.g., subjectivity), specific supporting technology may be required (e.g., Semantic Web).

The quality control is the other promising way to enable software itself to be creative. Through manipulating the measurement and improvement towards a creative direction, the software can become more and more creative. Currently, there are two kinds of quality control studied in the realm of Creative Computing.

- One is specifically for the quality guarantee of Creative Computing.
- The other is for controlling the novel features of various computing products in recent years.

As stated previously, software has becoming increasingly playful to satisfy people's spiritual demands today, which has led to the emergence of new software quality control aspects (e.g., enjoyableness). As the relationship between creativity and computing become even closer, especially after the advent of Creative Computing, the creativity aspect should be considered to add into the common software quality control model. Furthermore, due to the fast development, the elements that can impact conventional software quality are becoming increasingly novel. Taking security as an example, some hackers have started to steal information by analysing user behaviours, such as browsing habits. Correspondingly, creative measurement and improvement are required to deal with these new phenomena.

3) *Computing platform for Creativity* is a special type of creative computing. its goal is not to develop creative software, but to support common computing to be able to provide creative services for people. due to the diversity and multiple abstraction layers of computing platforms, there are, currently, two main aspects being considered in the domain of creative computing: Library and middleware, which correspond to two general types of common computing (i.e., codes/programmes and software/applications). In terms of the library, it facilitates coding or programming to simplify the development of creative services. For middleware, it aims to support more complicated software or applications to be able to provide creative services for people.

4. The research

In this Section, three example research topics currently being studied in the realm of Creative Computing will be described.

4.1. Creative algorithms

A direct way to do Creative Computing is to design creative algorithms. The research topics on creative algorithms being studied in Creative Computing include general creative algorithms, creative searching algorithms, creative decision-making algorithms, and creativity analysis algorithms.

- The general creative algorithms are especially designed for the creative middleware. Due to the generality, they could be applied in a variety of domains. Based on the creative logics, common computing is able to provide creative services for people to stimulate their creativity.A typical example is named Syzygy. The term originated from an astronomical phenomenon of the alignment of celestial bodies (e.g., eclipse). Based on the idea of Syzygy, general creative rules have been composed to creatively connect different types of concepts, things or words [32].
- Creative searching algorithms are kinds of meta-searching algorithms. Different from big search engines like Google, instead of providing something exactly expected by people, a creative search engine might want to provide something unexpected but valuable for people to be creative [33].
- Creative decision-making algorithms are another important topic that Creative Computing emphasises. People need to do decision making at almost every single moment. It is one of the most basic cognitive processes of human beings. A creative decision might be able to generate surprising results, especially in the business field.
- Creative Computing might be able to design a new kind of creativity analysis algorithms. Through studying from the perspective of computing, creativity in Creative Computing is more quantitative or objective. This new point of view might be able to help people to see something on creativity overlooked before, which may be helpful to construct a new type of creativity analysis algorithm.

4.2. Software architecture design

Architecture design can also be creative. The topic on the architecture design of a Creative Computing systems currently being studied is to deploy the Semantic Web. The Semantic Web is one of the most popular technologies to enable computing to be intelligent. Based on the component of ontology, computing is able to "think", even creatively. Therefore, in order to do Creative Computing, the combination with technologies of the Semantic Web is necessary. In particular, as Creative Computing relies on the uniting power of knowledge, ontology, as a knowledge representation method, is a good tool to support the development of Creative Computing. Based on the semantic web architecture, a specific architecture for Creative Computing canbe generated.

4.3. Mind measuring and controlling

Mind control is a future research topic in Creative Computing. With the fast development of Neuroscience and Cognitive Psychology, more and more neuro-imaging devices are available for use, such as the EEG biosensors like the Brainwave Reader from NeuroSky. The conventional input of computing has been dramatically changed, which provides a great space for creative processing algorithms to emerge.

Both creative algorithms and architectures based on biological data, such as brain activity, are studied in terms of creativity. There have already been some EEG biometric algorithms, such as attention and meditation measurement algorithms. However, most of them are focused on quantification of the brain signals. How about the creative mapping with user models or creative utilisation of the brain data? There might be a day that computing could communicate creatively with people's mind.

5. Applications

Having conducted research in Creative Computing for a period of time, we feel ready to apply the research results in the real world. In this Section, a small number of application fields, directions, and typical examples are listed here.

5.1. Fields of art

The first ought to be considered is the fields of Art, which, in common sense, is deemed as possessing the closest relationship with creativity. According to the great philosopher Hegel, there are five individual arts that are necessary to represent Art: Architecture, Sculpture, Painting, Music, and Poetry. Over time, they could be summarised further into three categories: Visual Art, Music, and Literature, where Creative Computing works for making contributions.

Creative Computing not only aims to help people to generate creative ideas, but also centres on producing illuminating inspirations (enlightenments), which might be an excellent assistance for artists. When a creator, say a musician, is stuck in some place while playing or composing a piece of music, Creative Computing may be able to provide some surprising but valuable suggestions to gradually induce them to find the potential directions to achieve creativity.

A typical example of Creative Computing developed for the fields of Art is named The Imaginary Voyage [34]. It is an online opera application (digital opera), which aims to supply creative stimulations for musicians or people who are fond of operas. The whole organisation of the application is based on a pataphysical novel written by Alfred Jarry who was the inventor of Pataphysics (i.e., science of imaginary solutions and laws governing exceptions). Depending on pataphysical logics, there are five islands within the application and each island has its own character and interactivity. For instance, on the island named Land of Lace, there are various kinds of creative combinations of materials like music, animation, and even language. Every time a user enters the island, there would be different contents to trigger different feelings or inspiration for the user.

5.2. Digital Heritage

Recent research has shown that we have encountered the digital revolution, which also influences and triggers the utilisation of digital technologies in Heritage – Digital Heritage. Nowadays, people are no longer satisfied with only using them for preservation and conservation any more. New use of digital technologies (3D heritage virtualisation) or use of new digital technologies (Syzygy Surfer) has been the key concern in Digital Heritage, where Creative Computing might be very helpful.

Creative Computing could bring creative services and experiences for Digital Heritage. Computing services, in modern time, tend to be more interesting, enjoyable, and playful than conventional ones, as such in Digital Heritage. People nowadays prefer to seek a kind of “fantastic voyage”, such as deliberately getting lost in London, rather than following pre-set rules, like sightseeing lines.

A typical example of Creative Computing developed for Digital Heritage is called London Streets. It is an app for the iPhone/iPad and Android devices, which allows users to access the past through the images of the present, by utilising various multi-layered navigation techniques. At the very heart of London Streets is the idea of providing novel approaches for people to explore the origins and histories of the old streets of London, such as “seeing through time” by simply using a virtual lens. By moving a virtual lens over an image of the present, users are able to see what the exact same place might have looked like in the past.

5.3. Health and Wellbeing

The domain of Health and Wellbeing pays particular attention to people with terminal or life-restricting conditions, such as chronic illness. Their life could be complicated, difficult, and even desperate. It is highly anticipated that creativity is beneficial for people's health and wellbeing. Living in creative and meaningful ways may be a promising approach to healing the “wounds” and also a good way for personal development.

As the advent of Creative Computing is to improve human creativity, it can bea suitable platform to achieve that. Through creatively manipulating the relationship between the input and output of Creative Computing, creative contents may be produced by Creative Computing to stimulate the creative potential for people with difficult conditions.

A typical example of Creative Computing in the domain of Health and Wellbeing is a project named Creative Skills for Life (CSL). The project aims to achieve measurable health benefits through acting on users’ creative potential, which encompasses making and sharing creative contents.The project utilises the creative contents as a medium to encourage people with difficult conditions, such as isolating conditions, to find the creative ways to live, such as virtually interacting with others by doing creative tasks together.

5.4. Education

In the field of Education, creativity is always one of the most important concerns. Not only are students encouraged to think creatively, but also the educators or related institutions are required to be creative. Due to the fast development and pervasive utilisation of various computing technologies, a specific field called Educational Technology (ET) has been formed for a long time. This is dedicated to improving the quality of education, by efficiently leveraging highly advanced technologies like multimedia, electronic white board, electronic schoolbag, or even Virtual Reality (VR), Augmented Reality (AR), and Mix Reality (MR). In recent years, various computing technologies from ET have also been adopted to support creativity education, such as iPad apps like Educreations, Popplet, and Idea Sketch. As a new type of computing, Creative Computing not only uses pre-existing technologies, but also makes new technologies to improve human creativity, which makes it a perfect tool to facilitate the education of creativity.

The first thing that Creative Computing could do is to support the creativity cultivation in Education. Not only the product of Creative Computing itself could provide stimulations or inspirations for creativity, but also the methods used in Creative Computing to foster the creativity for developers might be beneficial for creativity education. As not paying attention to certain group of people but the people with great desire to be creative, Creative Computing could be widely used and extended to facilitate various kinds of people, no matter male or female, young or old, expert or outsider, and artist or non-artist.

Creative Computing also could support creative approaches to

education; on top of that various computing technologies have already been widely used in Education, such as a variety of educational software. Based on technologies like that, new approaches to educating start to emerge, such as the micro classroom, which further inspires us to think more creatively. It might not only focus on the creative utilisations of pre-existing technologies, but also concentrate on leveraging novel ones like Creative Computing. The platform provided by Creative Computing, itself,incorporates creative features, such as the generation of “abnormal” output based on normal input, which might be able to facilitate the creative educating approach better.

Currently a typical example of Creative Computing in Education is conducted through leveraging the religion, emotion, motivation theory, etc., where a creative inspiring model is proposed. It helps people to creatively explore their potential ability and give the corresponding advice for their future development.

6. Conclusions

The urgent social requirements of human creativity stimulate the advancement of Creative Computing. The inspirations offered by Creative Computing are very close to the nature of creativity, thereby could provide a more efficient way to improve human creativity. Creative computing combines a variety of knowledge together to form a comprehensive and powerful tool for the enhancement of human creativity. This new approach provides a better way to reconcile the contradictions between creativity and computing, but also makes the fullest use of the abundant knowledge today.

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