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Original Paper

Artificial Intelligence as a Substitute for Human Creativity

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Abstract

Creativity has always been perceived as a human trait, even though the exact neural mechanisms remain unknown, it has been the subject of research and debate for a long time. The recent development of AI technologies and increased interest in AI has led to many projects capable of performing tasks that have been previously regarded as impossible without human creativity. Music composition, visual arts, literature, and science represent areas in which these technologies have started to both help and replace the creative human, with the question of whether AI can be creative and capable of creation more realistic than ever. This review aims to provide an extensive perspective over several state-of-the art technologies and applications based on AI which are currently being implemented into areas of interest closely correlated to human creativity, as well as the economic impact the development of such technologies might have on those domains.

Keywords

artificial intelligence, human creativity, future of arts, future of science, future of medicine, human evolution

1. Introduction

Creativity represents one of the most fundamental human characteristics, regarded and discussed in many fields of interest, being defined as a phenomenon whereby a new physical object is created (sculpture or painting) or the created item may be intangible (musical composition, invention, poetry). Creativity is studied in medicine, philosophy, psychology, sociology, pedagogy, and cultural sciences and has long been considered a capability unique to humans. These disciplines have developed many theories of creativity. Creativity has applications mainly in arts, stage performance, science, economics, social interaction, and commercial innovation, but in a more precise analysis, creative skills are to be found in many human activities (Stein, 1953; Mullen, 2017; Mumford, 2003; Ivcevic et al., 2007).

In social sciences, the definitions of creativity involve four primary characteristics: the process, the result, the set of necessary conditions, and the creator’s personality. Available studies insufficiently explain creative ideation and the underlying neural mechanisms; however, understanding the basis of the brain circuitries and central neuromodulator systems has made significant progress during the last decades (Stein, 1953; Mullen, 2017).

During the last century, it began to spark more interest, as it became a feature widely searched in almost every domain, consisting of the ability to produce novel and appropriate work (Stein, 1953). Although it has always been strictly perceived as a human trait, the recent development of AI technologies and increased general interest in AI has led to several projects being capable of performing tasks that have been previously regarded as impossible without human creativity.

Artificial intelligence (AI) is defined as a wide-ranging field of computer sciences concerned with systems capable of performing automatic tasks using a constellation of technologies working together (Hamet & Tremblay, 2017). If AI was initially associated with a wide range of activities characterized

by repetitive tasks and applications in medical diagnosis, robot control, optimization of airport and airline processes, electronic trading platforms, and remote sensing, now, a transition to a broader spectrum of ideas and applications of AI takes place (Hamet & Tremblay, 2017).

In recent years, developments of AI have been outstanding. Due to increased data storage capacities and ultra-fast computer performance, systems based on AI are expected to perform tasks or create previously impossible things. Could AI be creative? We observed slow-moving but prodigious progress in creativity: computers can create music, paint, and write novels. To simulate and further substitute creativity, considerable progress in understanding human imagination and emotions is required because the creative process does not follow systematic, general, and precise rules. It is possible to create new content by transforming, producing novel combinations, or exploring a new path.

Creativity involves generating new ideas (cognitive dimension), but also motivation and emotion. It is linked to a frame of reference and, very important, to personality factors. From this point of view, artificial neural networks are also experimental and unpredictable. They can teach themselves and do not depend on the amounts of the information uploaded and programmed to be replicated; that is why they could be more genuinely creative.

For this reason, this narrative review aims to summarize the available studies about AI applications in creative fields. More specifically, this paper aims to explore and discuss AI models related to arts and science.

2. Musical Composition

The first recording of sound was made in Paris by Édouard-Léon Scott de Martinville in 1857, with a phonautograph, more than two decades before Alexander Graham Bell's first telephone call in 1876 or Thomas Edison's phonograph in 1877 (Maxfield & Harrison, 1926). The result of this innovation had countless applications in entertainment, social interaction, and communications. However, the long-term effects on the scorebook and live performance industry were unfavorable.

Nowadays, the rapid development of AI-based systems capable of autonomous musical composition, arrangement, holographic representations of musical icons, and even humanoid robots performing live is transforming the music industry once again, after digitization has been massively affected by streaming and free download. Furthermore, the most important studies on AI-based systems capable of autonomous musical composition are analyzed.

The most popular deep learning algorithm developed in 2016, AIVA (Artificial Intelligence Virtual Artist), also known as the first recognized nonhuman composer, acknowledged by the Society of Authors, Composers and Publishers of Music (SACEM), an authors' rights society, looks for patterns in an immense musical archive and through machine learning and algorithms produce a new composition in less than a minute (Zulic, 2019; Drott, 2021; Caramiaux & Donnarumma, 2021; Morreale, 2021). The result is that AIVA can completely replace a human composer, regardless of chosen musical genre. The system was not programmed to compose music but instead to analyze available music composition

and, based on the learned information about a musical style and composer, to create music from scratch (Zulic, 2019; Drott, 2021; Caramiaux & Donnarumma, 2021; Morreale, 2021).

Amper Music represents another AI software where artists can request a specific style, and the AI-based system generates a musical composition that can further be modified to obtain a composition perfectly adapted to the artist's lyrics and vocal melody (Zulic, 2019; Drott, 2021; Caramiaux & Donnarumma, 2021; Morreale, 2021).

Following the success of those systems, a considerable number of systems were developed, including Jukedeck, Ecrett Music, Virtutes Occultae, Melodrive, ORB Composer, Amadeus Code, Humtap, Muzeek, and Skygge (Zulic, 2019; Drott, 2021; Caramiaux & Donnarumma, 2021; Morreale, 2021; Brook, 2020; Avdeeff, 2019; Mantaras & Arcos, 2002; Hallur et al., 2021). Furthermore, SaxEx is a system that transforms inexpressive music into an expressive one, using examples of human performances (Caramiaux & Donnarumma, 2021; Morreale, 2021; Brook, 2020; Avdeeff, 2019; Mantaras & Arcos, 2002). All the available systems for musical composition generate original, copyright-free music (Morreale, 2021). The user can also combine their musical composition with AI-based compositions. Humans and computers have constantly been interacting during the past three decades; similarly, co-creation will become not mandatory but one feasible and more practical option, opening new possibilities for composers and audiences.

Machines make new pieces of music; however, the quality of these creations is still up for debate. One unique use of AI in musical composition is the completion of Beethoven's 10th Symphony, which remained unfinished for almost two centuries (Tigre & Maw, 2021; Shang, 2019). With this last example of the application of AI in music, the listeners can decide whether music created by AI has the same meaning and emotion as the one created by humans. AI-based systems can produce an unlimited number of music compositions for free, but the economic impact on the music industry is not significant because there are already 97 million songs online, adding 24,000 new songs every day, to which the public has free access.

3. Literature

Ongoing development of AI technologies meant a broader area for them to be implemented into. Along with other fields of interest tied to human creativity, new AI programs have also influenced the writing aspect of creation. During the late 1970s, Cercone and Murchinson (1985) conducted a study regarding the contributions of AI to literature, concluding the usefulness of AI as a process in which computers help to make generalizations to determine whether AI techniques can simulate the typical language of a writer.

Increased research in Natural Language Processing made it possible for new and more sophisticated language models to emerge. Bowman et al. (2016) developed a variational autoencoder suited for imputing missing words in regular sentences. One significant milestone in implementing AI technologies into day-to-day writing was the development of GPT-2. Radford et al. (2019) created four

language models, among which GPT-2 proved to be one of the most effective. It showed great promise in analyzing texts and completing tasks such as reading comprehension, translation, and memorization. Although more research and further improvements are needed, the study shows the high capacity of projects trained using language modeling (Radford et al., 2019).

Solaimanet et al. (2019) used GPT-2 to generate different outputs of an already existing article in The New York Times, using the first two paragraphs as a starting point, managing to write texts deemed credible by human readers 66% of the time. Apart from writing pieces of text and putting them together to form coherent writing, AI has also found use in checking and correcting other people's work. Park (2019) evaluated the performances of an AI-based grammar checker, *Grammarly*, compared to human raters for people who learn English as a foreign language. Although the study found that the program could not recognize some tenses and also failed to identify specific types of errors, it is still worth mentioning that *Grammarly* is one of the most regarded AI-based grammar instruments used by many people who want to check their writing (Park, 2019).

Natural Language Processing is also of great use in archaeology, where machine learning managed to decipher ancient cuneiform texts written in Akkadian, the method achieving an accuracy of almost 97% when used for transliterating and segmenting cuneiform glyphs into words (Gordin et al., 2020). However, such an increase in the quality and range of services provided by AI in writing does not come without concern over how this type of technology would be used in the future. As Belz (2019) stipulates, automated generated news could easily mislead readers due to the possible unreliability of the sources they are based on. One could misuse the benefits of an automated text generator to fulfill specific agendas or deepen the fake news phenomenon seen nowadays on the rise.

4. Visual Arts

Until recently, the concepts of "visual arts" and "AI technology" have been regarded as two separate entities that were not likely to interfere with each other, let alone evolve together as we have seen in the past decades. However, recent studies have revealed a close correlation between them and significant advancements of AI technology in this domain. A new self-supervised approach proposed by Sabetsarvestani et al. (2019) uses deep neural network algorithms to improve the x-ray images of polyptych wings and other artworks painted on both sides. Thus, it uses two inputs for each side of the painting, reconstructing corresponding x-ray images, whose quality depends on the order of the inputs. The combined methods resulted in a single reconstruction consisting of the best images obtained in each approach, with significant results (Sabetsarvestani et al., 2019).

A study showing how trustworthiness changed over the years was performed by Safra et al. (2020) using machine learning analyses of facial cues in paintings by constructing a random forest model type of algorithm for assessing trustworthiness and dominance evaluations. To do so, it uses avatars, each one being based on an original face and tested to elicit ratings of trustworthiness and dominance in participants. Thus, the algorithm's accuracy was evaluated on 768 distinct faces of four different face

databases, showing a significant correlation between the modeled trustworthiness and dominance estimates and actual participants' ratings (Safra et al., 2020). Moreover, the team also tested the algorithm's ability to reproduce classical findings of trustworthiness and dominance concerning social cognition, i.e., gender, emotion, and head orientation effects. These effects were successfully replicated regarding trustworthiness and dominance, both modeled independently and correlated to one another (Safra et al., 2020).

Shi et al. (2018) developed a method for spectral reproduction of paintings using a pair of neural networks, combined with an algorithm to find the best ink layout and color quantities, regardless of the type and spectrum of the illuminant. Using a 3D printer, this model can accurately reproduce spectral reflectance and solve problems tied to the illuminant and classical ink (Shi et al., 2018).

Kudoh et al. (2009) developed a painting robot with multi-fingered hands and stereo vision to reproduce the act of human painting. The robot used images generated by multi-view cameras that built a 3D model, from which a human silhouette was extracted. However, the robot could only draw the curves; the authors have not yet developed the model to fill the drawn picture (Kudoh et al., 2009).

GANs (Generative Adversarial Networks) have recently become a popular subject in machine learning and computer vision. Liu et al. (2018) managed to create an auto-painter model that generates colorful cartoon images from black-and-white sketches, using accurate colors and allowing users to indicate preferred ones. Although more detailed images take more time to complete, the algorithm allows the output image to have both information of the sketch and learned high-level color information to satisfy the color taste of different users (Liu et al., 2018). Unlike other models whose results are dependent on the input, Xue A. (2021) proposes the Sketch-And-Paint GAN (SAPGAN), a complete end-to-end model that creates Chinese landscape paintings without conditional input. The model is trained on Chinese landscape paintings, and a 242-people Visual Turing Test was performed, showing that artworks created by SAPGAN were mistaken for human artwork with a frequency of 55% (Xue, 2021).

Sun et al. (2019) developed a co-creative drawing system based on GAN that enables a human being and a machine to collaborate in cartoon landscape painting. SmartPaint learns many images, semantics, and the style of a particular type of painting, creating output paintings while building on input sketches (Sun et al., 2019). It was tested by more than 300 participants to assess its performance and to see whether it supports artists or designers in actual art/ design practice (Sun et al., 2019). Many participants thought positively about SmartPaint, although it does not support many styles and types of painting, and it often returned unexpected and different results (Sun et al., 2019). When it comes to potential help for artists and designers, the illustrator considered SmartPaint tempting to use, even though it generated lower quality images than the ones usually created by himself (Sun et al., 2019). However, it simplifies the artist's work and helps him focus on other aspects in order to achieve his goals.

5. Engineering

AI algorithms are used in structure engineering and architecture too, but usually they are assistive technologies, that cannot be considered as creative (Dimiduk et al., 2018; Kolata & Zierke, 2021). Assemblies of rods can form complete structures like bridges, towers, or the resistance structure of an engineering element. Raina used multiple deep neural networks to work together (a convolutional autoencoder to encode raw image data into meaningful semantics coupled with a transition network to convert it to a new design) to predict the next design of assemblies of rods in a series of sequential design images fed to the AI (Raina et al., 2019). The AI did not only perform design by emulating the human approach, but it also created new designs altogether. Creativity can manifest also in the design of structures. Chen proposes an approach to enhance design ideation semantically and visually based on computational creativity (Chen et al., 2019). A generative adversarial network can be used to generate images that combine two (distant) concepts to obtain new ideas: houses and mushrooms, spoons and leaves. Thus, novel designs can be created.

6. Science

In the sections above, we have seen multiple use-cases where AI composed new music, wrote exciting stories or painted beautiful pictures. In this section, we will present the different technical solutions to build innovative AI algorithms. We need objective metrics to evaluate the value of different outputs and results in science, but art is a very subjective field. One of the biggest problems when talking about AI creativity is the evaluation of it.

Margaret A. Boden (1996) defines creativity as “the ability to generate ideas or artifacts that are new, surprising and valuable.” Most of the available AI algorithms used to create some artworks are evaluated by these three criteria: value, novelty, and surprise. To objectively evaluate the creativeness of an AI model, the next step is to understand the different types of creativity. Boden (1996) distinguishes three types of creativity: combinatorial, exploratory, and transformational. Making new combinations of known concepts is what combinatorial creativity is all about, and this is the type of creativity in which AI is thriving. Exploratory creativity implies exploring the organized conceptual space, whereas transformational creativity reshapes the conceptual space, so that previously unimaginable concepts become possible.

In most of the research presented above the creativity is imitated by creating and training an AI model with access to an extensive database of known examples. The new art is created as a combination of the know patterns, which means combinatorial creativity. The usual technical solutions for this kind of creativity are the Generative Models (GM). The most popular GMs are the Variational Auto-Encoders (Kingma & Welling, 2019), Autoregressive Models (Dalal et al., 2019), like PixelRNN (van der Oord, Kalchbrenner & Kavukcuoglu, 2016), PixelCNN (van der Oord, Kalchbrenner, Vinyals, Espeholt, Graves, & Kavukcuoglu, 2016) or more recent models like DALL-E (Ramesh et al., 2021) and GPT-2

(Whitfield, 2021); and the third very popular GM is the GAN (Generative Adversarial Network) (Goodfellow et al., 2014).

In the case of the Variational Auto-Encoders, the creativity results from the latent space alteration; this way, the decoder which generates the result returns new artifacts, but these artifacts are very similar to the training examples.

Autoregressive Models are built on probabilistic predictions; thus, they can create new outputs in the same space, but they can also reuse sequences of pixels from previous or other works by merging them. The results of the Autoregressive Models are new but not very impressive. In the case of Autoregressive models, we can talk about exploratory creativity because they can combine and reuse data from different spaces to generate something new.

On the other hand, the GANs are not using accurate, historical data to create new ideas or artifacts, but usually, the starting point for them is just random noise. One of the most impressive results of GAN models is the so-called Deepfake system (Masood et al., 2021), which can transform facial images into video sequences based on a single image taken by a simple mobile phone. Another impressive work is based on OpenAI's GPT-2 model, which can generate synthetic content indistinguishable from the human-written text.

Nowadays, we can see a new trend, a new category of AI models, which are creativity oriented. The most obvious use-case of these creativity-oriented models is automatic game content generation. A representative example of these creative models is the DeLeNoX model (Deep Learning Novelty Explorer) (Liapis, Martinez, Togelius, & Yannakakis, 2021).

This model combines an autoencoder that measures the typicality of generated patterns and an evolutionary algorithm called Feasible-Infeasible Novelty Search (Liapis, Yannakakis, Georgios, & Togelius, 2013), which aims to maximize the distance between the artifacts that were already generated.

Today's AI models and algorithms are just imitating human creativity, they can achieve combinatorial or exploratory creativity, but transformational creativity remains a challenge for the future. Transformational creativity means creating something new, which does not combine known artifacts or ideas but differs from everything we know. This kind of creativity needs general intelligence, which is currently not available, and it is a real challenge for the future.

7. Economic Impact

Nowadays, it is becoming more and more apparent that AI will keep playing an important role in many aspects of our lives, considering the continuous research and improvements in this domain. However, when it comes to certain aspects of human creativity and professions directly tied to it, the question about how artists and AI are going to evolve and develop together is still up for debate.

Although there is genuine concern regarding the job market dynamic in parallel to the development of AI, technology has proved to have a substantially positive effect in many areas of expertise, including art.

The AI broadens the artist's imagination and enables him to achieve it through technical advancements, encouraging the artist to develop new ideas and projects and providing the facilities to fulfill them (Liu, 2020). Moreover, it is also of great help regarding the time management of the artist, with the latter being able to focus more on the creation and imagination process while delegating the technical part to the AI, thus increasing his productivity and volume of work that he can complete. When it comes to the public attitude towards AI artworks, Chamberlain et al. (2018) conducted a study analyzing the feelings produced by both human-created and non-human-generated artworks.

Even though the people could not distinguish between these two types of art, the study revealed a bias towards non-human-generated art (Chamberlain et al., 2018). The participants were more likely to leave this bias aside when presented artwork created by anthropomorphized agents (Chamberlain et al., 2018). Another study conducted by Hong and Curran (2019) showed that such biases relate to how people feel overall regarding AI, not necessarily how they feel about the artwork. So far, there is no significant evidence that the artists' job market will be negatively affected by the development of AI regarding art projects, even though the progress of the AI technology revealed both economic growth potential and concerns regarding job losses in other fields of interest (Felten et al., 2019).

Moreover, recent technological improvements and groundbreaking inventions have also changed the traditional image of art, with digital art heavily gaining ground in the past years (Potts, 2014; Quirion, 2021; Ante, 2021; Wang et al., 2021). The evolution of blockchain type technologies has led to the emergence of NFTs: Non-Fungible Tokens, with a great cultural and economic impact on the art market (Potts, 2014; Quirion, 2021; Ante, 2021). The NFTs market has recently hit a record level, with sales volume surging to $2.5 billion in the first half of 2021, with a number of 4.7 million NFTs being traded between June 23, 2017 and April 27, 2021 (Nadini et al., 2021).

Certain properties of the NFTs make them very useful in the current art environment, such as verifiability, transparent execution, availability, usability and tradability (Wang et al., 2021). Regarding the art market, there are several sectors that could benefit from the emergence and development of NFTs (Wang et al., 2021). Development of blockchain technologies have led to the creation of Metaverse, a shared virtual space between various users, allowing many types of digital activities such as games, concerts, displaying art, purchasing and using digital property, trading assets, all with the help of NFTs, further diversifying the Metaverse (Wang et al., 2021). Various virtual events taking place in the Metaverse also benefit from the NFTs sale and trade, extending the usefulness and spectrum of certain applications (Wang et al., 2021). NFTs are also highly valuable in newly developed games on different blockchains, with more and more people having an interest in "play to earn" type of blockchain games.

When it comes to art development, a combination of artists' imagination and creativity and AI technology and technical analysis should provide an accurate solution for producing valuable artworks. The continuous development of AI-based systems is closely correlated to future changes and the disappearance of most jobs implying repetitive functions in certain occupational domains, such as industry, agriculture, transport, and commerce. Nevertheless, recent technological advancements in fields implying human creativity and jobs using complex functions such as synthesis, abstraction, originality, imagination, and invention have not proven immune to the job market's dynamic nowadays.

8. Future Perspectives

So far, many studies have shown that AI has already made a positive impact in the fields closely correlated to human creativity, with new emerging models making it harder to differentiate between human and AI-created artwork. The strength of AI technology in art lies in its ability to fulfill repetitive, time-consuming tasks, which, in turn, allows the artist to focus on the creative part of the process.

With all the recent development in AI technology, it is still an emerging field, and more research is needed to make reliable predictions regarding the future of AI in art. The AI technology sparks the curiosity of many, including artists and art enthusiasts, who, in turn, started to experiment and test the relationship between AI and art, thus diversifying the classical art as known today.

The recent years' advances in the AI domain are generally focused on neural networks. It is well known that the human brain works differently than transistors in computers. The neurons are interconnected with each other in mingled layers. To mimic creativity, computer scientists have been working lately on artificial neural networks (ANNs) inspired by the brain. ANNs are asked to perform tasks by learning from examples without being given task-specific rules. This approach has good results in pattern recognition, facial recognition, and speech recognition. Neuroscience researchers suggest that to facilitate creativity, neurons have to be also connected with neurons in the other regions of the brain, not only with neurons from the vicinity. Thus, to overcome neural networks' limitations, the scientist needs to discover how to assemble neural networks connecting more specialized neural networks.

Many questions need to be addressed regarding the implementation and evolution of AI and the art industry, such as whether art created by AI would still be considered original art or if mass adoption of this type of technology will be seen in the future.

Until now, AI techniques have proved optimal in assisting in different branches of human activity such as healthcare, sales, finances etc. Therefore, it can be expected that AI's role in creative efforts will be stimulated because it offers many benefits serving as an inventive, efficient aid.

However, the human condition itself, with its creativity, imagination, perception, and taste in art, is one factor that would be crucial in determining the extent to which AI would be implemented in art and other professions implying human creativity.

If human creativity is described only in terms of information processing, it is not difficult to foresee AI replacing it entirely. However, creativity is much more than the cognitive part, more than just

transforming inputs into outputs. Recent developments in AI indicate a new rapport between humans and machines. When human creativity is combined with the power of AI techniques, we can expand the limits of our understanding of the world.

The continuous development of blockchain type of technologies has boosted the use and popularity and NFTs, further extrapolating and extending their applicability. Nevertheless, NFTs have managed to diversify certain aspects of the Metaverse so far, while also steering away from the known traditional art, building a whole new concept of digital art.

Current studies have demonstrated that intelligence requires more than logical reasoning. It also involves creativity, emotions, interaction, cultural background. Human creativity is the outcome of processes that involve multiregional interhemispheric interactions. The area of AI creativity has been developing in the past few years but is still in its early stages.

Unfortunately, there are many questions without answers yet. Could a product be considered creative if a computer conceives it? How will the collaboration between human and computer creativity develop? Can we use artificial intelligence to augment human creativity? Will the evolution and improvement of AI technologies influence human evolution, eventually leading to the birth of a new species?

9. Conclusions

Human creativity is the outcome of processes that involve multiregional interhemispheric interactions. Certain AI technologies have been inspired by the mechanisms of the human brain, with the progress of AI-based systems in the field of human creativity is already substantial, with applications in music composition, visual arts, literature, engineering, science and all related fields. Multidisciplinary research including neurosciences, informatics, mathematics, and arts, well balanced by international collaboration are able to overcome current limitations. With current AI technologies being able to exhibit human behavior, it is safe to say that humans and AI are likely to evolve together, each one influencing the other.

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