

IS EVOLUTION CREATIVE?

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Abstract

Can evolution demonstrate some of the properties of creativity? This paper argues that it can, and provides examples which the author feels illustrate some of the awesome power and feats of design which resemble creativity. Is evolution, then, truly creative? This is clearly a much harder question, for it requires a definition of creativity – that most subjective and controversial of words. This paper explores and discusses various aspects of creativity, attempting to determine to what extent evolution satisfies each definition. The paper ends by summarizing the discussion, and presenting amalgamations of four different worldviews.

1 Creativity

Creativity is somehow almost magical. We all recognise manifestations of creativity without effort, yet this mysterious property or ability remains aloof from our attempts to understand it. Creativity is another ‘fuzzy’ word, a word with vast connotations, many inextricably entwined with the pride of individuals. It is a very ‘humanistic’ word, used primarily to describe human skills and abilities, and almost without exception, it is used as a positive descriptor. And it is clear to see why the label ‘creative’ is one to be proud of. With meanings such as *aesthetic, lovely, poetic, beautiful, skilled, proficient, inventive, elegant*, surely this deceptively simple word is overflowing with compliments.

But not only does this word allude to admiration, it also implies genuine ability. Our most creative members of society are often regarded as our highest achievers. Whether the accomplishment is a new form of art that shocks in its radical novelty, or whether it is a theorem that describes the physical laws of our universe in a more concise and elegant manner, there can be little doubt of the creativity involved.

Yet creativity does not necessarily mean the creation of a tangible *something*. To be creative often appears to be the ability to find a solution where others fail. Again, an extremely useful ability; it can be argued that many of

the best leaders in history gained their successes through creative political (or military) thinking. Certainly, many of the remarkable feats of survival and rescue can be attributed to the quick thinking of creative individuals – a classic example being the recovery of the Apollo 13 crew from the brink of tragedy.

Being creative is clearly a good thing.

2 Evolution

Evolution is not a person. It is an unthinking, blind process, a relentless procedure, a harsh and unconscious fact of life. How can we possibly call something so inhuman, so brutal, *creative*?

Perhaps we should not, but delving past such moral prejudices, evolution can be seen in a different light. Evolution has been hard at work creating the myriad forms of life that have lived and died on our world for hundreds of millions of years. In that unimaginably vast amount of time, designs of life wholly beyond our current comprehension have emerged. From the complex miniature chemical factories contained within every cell of your body, to the immensely complicated organisation of your brain, which even as you read this, performs unfathomable chemical and electrical changes, evolution is a master of design.

Examples of aesthetic, lovely, poetic and beautiful evolved solutions surround us, are contained within us, and are us. Every living thing cries out proficiency, elegance, inventiveness and skill in design. The abilities of natural evolution far surpass our most creative problem solvers. Moreover, as biologists uncover more information about the workings of the creatures around us, it is becoming clear that many human solutions have existed in nature long before they were thought of by any human (French, 1994), for example: pumps, valves, heat-exchange systems, optical lenses, sonar. Indeed, many of our recent designs borrow features directly from nature, such as the cross-sectional shape of aircraft wings from birds, and Velcro from certain types of ‘sticky’ seeds.

Of course our own achievements are remarkable and many do not exist in nature. Even something as simple as the wheel is not used in the natural world. But it must be remembered that natural evolution is constrained to the creation of life – all of its designs must be capable of self-replication, and nearly all must grow from a single cell, following the evolved instructions contained within the genetic makeup of that cell (Dawkins, 1986).

But now, for the first time, this constraint is no longer valid. Evolutionary computation allows us to harness the power of evolution for non-living designs. In this new virtual world, evolution can evolve the wheel or the electronic circuit. We can use evolution to generate music and art. Evolutionary algorithms permit us to exploit the remarkable properties of natural evolution, endowing our computers with skills which suspiciously resemble creativity. Even for such mundane tasks as evolving the design for a coffee table, evolution shows surprising originality. To illustrate this, figure 1 shows twenty coffee table designs, evolved by the author’s generic evolutionary design system (GADES). From the same set of functional criteria, and without any human intervention, twenty very different solutions were evolved (Bentley, 1999). Figure 2 shows the design that was ultimately chosen, and a photograph of the final table, built according to this design.

As the simple illustrative example shows, evolution certainly seems to exhibit some of the properties of creativity. It is still unclear, however, if evolution can truly be termed creative.

3 Creative Evolution?

There are an almost unlimited number of different definitions that exist for creativity. To determine whether evolution can be considered creative, it seems appropriate to explore some of those definitions that deal with creativity in terms of computers and evolution. There are two main types of creativity that are considered here: similar to Gero’s (1996) ‘cognitive’ and ‘social views’: an individual can display creativity when performing some action, and the physical result of some action can display characteristics which may be regarded as being creative. The first three definitions refer to the results of evolution. They explore whether such evolved results can be considered creative, and if so, whether this implies evolution is creative. The next six definitions refer to the process itself – does evolution generate solutions to problems creatively?

3.1 Turing Test

One approach to the task of identifying whether the result of evolution is creative is to use a Turing Test. According to this idea, by showing the results of evolution and the results of creative human endeavour to people without telling them which is which, if the people cannot distinguish between the two, then the results of evolution must be creative.

The author is involved in a project to evolve music using computers. Although details cannot be published, a series of three ‘Turing Tests’ were performed recently to private audiences. The first minute of three songs were played, and after having listened to all three, the audiences were asked which song they thought had been evolved by a computer. The results are shown in Table 1.

Table 1: A ‘Turing Test’ for evolved music.

Song:	Numbers who thought song was evolved:		
	Test 1: Audience: 10	Test 2: Audience: 10	Test 3: Audience: 18
1	4	2	2
2	3	5	5
3	3	3	11

The evolved song was number three, and as Table 1 shows, only the final audience was able to detect the difference between computer-evolved music and human-composed music. Interestingly, the first two audiences were composed of art and design M.Sc. students and staff, the last audience comprised computer scientists.

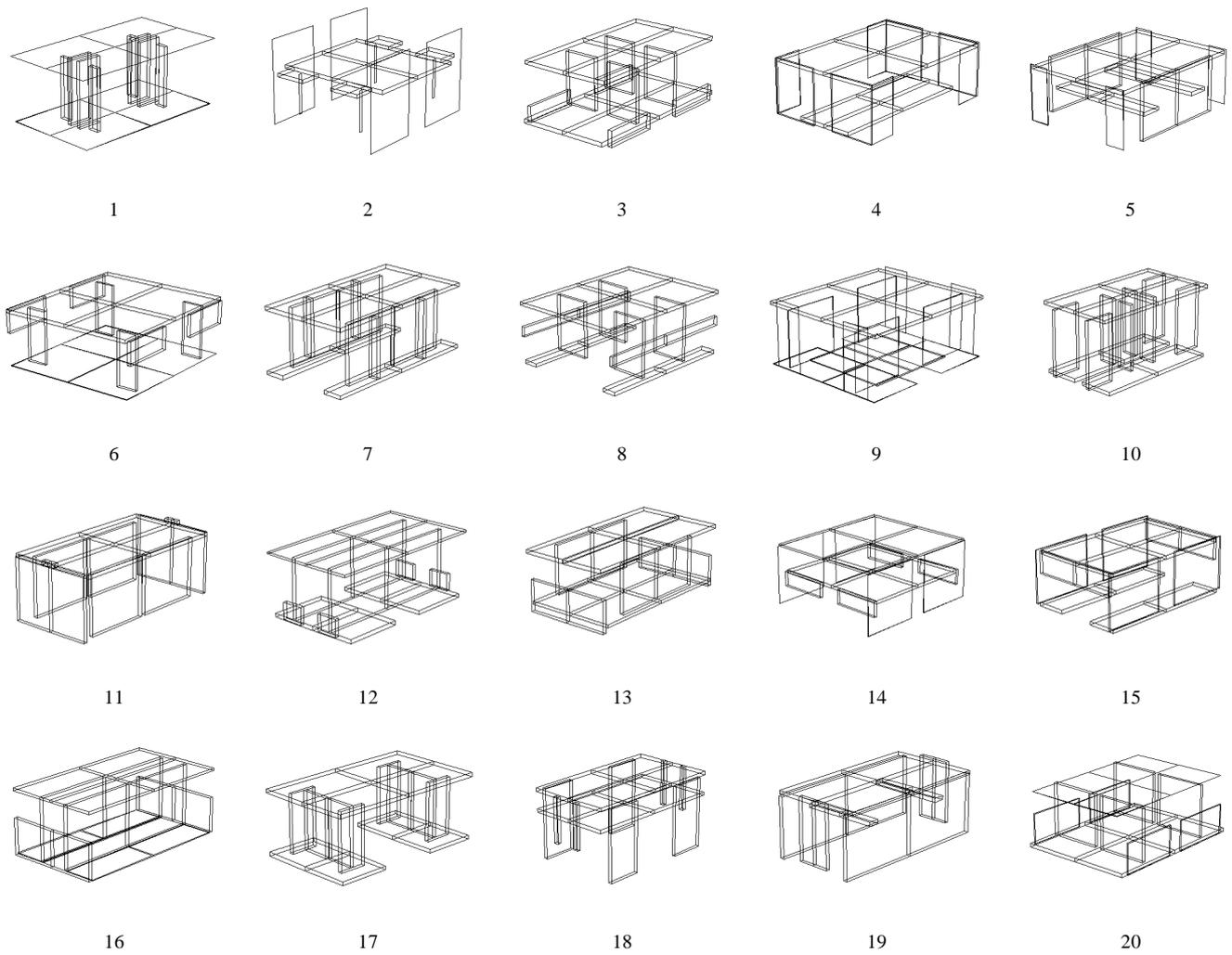
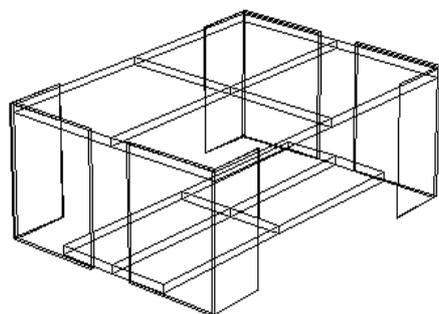


Figure 1: Twenty coffee table designs evolved by *GADES*.



The chosen design (number 4)



Photo of actual table

Figure 2: The evolved design of a coffee table and a photo of the actual table.

These results show that, at least for some audiences, it is difficult for people to distinguish between the fruits of evolution and creative humans. This demonstrates that, when prejudices against computers and evolution are removed by blind testing, it is possible for the results of evolution to be unwittingly termed creative by people. However, it must be recognised that this is a weak form of Turing Test, for audiences could not interact with the subject of the test, and the music was within a limited domain.

3.2 Generating ‘surprising and innovative solutions’ (Gero & Kazakov, 1996)

As previously discussed, there can be no doubt that natural evolution is capable of innovation. It is also clear that evolutionary computation displays surprising levels of novelty. As was shown in figure 1, even for very simple problems evolutionary algorithms are capable of finding unusual and original solutions.

Consequently, according to this definition, there can be no doubt that evolution is creative, but it seems that the definition may be too general. The patterns of frost on a window, snowflakes, sand dunes, and formations of eroded rock can all be described as surprising and innovative, so if evolution is called creative, then according to this interpretation, the laws of physics and the four elements must also be creative. Perhaps there is some justice to this, for if the blind process of evolution is creative, then why shouldn’t the blind forces of nature such as tides and winds also have the same linguistic honour endowed upon them? However, the difference between the evolution of life, and the erosion or formation of inanimate objects seems too great to ignore.

3.3 Creating ‘novel solutions that are qualitatively better than previous solutions’ (Gero & Kazakov, 1996)

This is a more rigorous definition, and it overcomes the problems discussed above. No snowflake or rock formation is better or worse than any other, they simply exist, and may or may not be elegant and attractive. In contrast, the essence of evolution is *improvement* over time. Evolution does generate qualitatively better solutions, because unlike inanimate objects in nature, evolution generates solutions better able to survive. Whilst the task of survival is constantly changing and the success rate of each living design constantly varies, useful survival skills such as the ability to fly, see, run, swim and so on, have improved. Natural evolution, without doubt, generates qualitatively better solutions than previous ones.

In evolutionary computation, the same is true. Generation by generation, solutions are improved. Particularly in applications where evolution is permitted to vary aspects of the representation, the final evolved solutions are qualitatively better compared to the initially random solutions. When comparing designs evolved by computers with our own designs, evolution is also capable of providing substantial improvements, and in some cases, genuinely original design concepts (Bentley, 1999).

So evolution, once again, seems to be creative. But still the definition seems incomplete. Rather than focussing on the results of evolution and attempting to determine by proxy whether their generation implies creativity, it seems more appropriate to concentrate on *how* the solutions are found. Are they found *creatively*?

3.4 The lesser the knowledge about existing relationships between the requirements and the form to satisfy those requirements. (Rosenman, 1997)

This definition of creativity states that by generating good solutions even when very little or no information about the fundamental nature of the solutions is provided, the generation process must be creative. Natural evolution always satisfies this, for there is no knowledge provided anywhere about which solutions should be favoured – the fittest simply survive (unless one believes in divine intervention). Evolutionary computation does not always satisfy this definition. When using evolution to optimise given parameters in a predefined structure, considerable knowledge is embedded within that representation, hence there can be no creativity. However for problems which employ evolution as a generative technique, such knowledge can be reduced to a bare minimum (e.g. a design grammar which provides a means to define designs without indirectly providing knowledge of which designs are best). Because of this greater discrimination, the author employs this definition of creativity for *creative evolutionary design* (Bentley, 1999). However, some regard this as insufficient to capture the essence of creativity.

3.5 Exploring a search space in an innovative and efficient way

From a computational point of view, evolution is simply a special kind of search algorithm. Some argue that for evolution to be considered creative, it must traverse its search spaces in a creative manner, i.e. it must be innovative or efficient in its search. Exhaustive search and

random search are examples of noncreative techniques. Evolutionary algorithms are good examples of creative search. Although we have few proofs that coherently describe the behaviour of evolutionary algorithms, through experimentation and analysis we have learned that evolutionary techniques have excellent abilities as general-purpose problem solvers. Indeed, as Goldberg (1989) states, the genetic algorithm is ‘a search algorithm with some of the innovative flair of human search’.

In a sense, this definition draws a parallel between the innovative thinking by a creative person, and the innovative searching by a creative algorithm. However, the application of this definition remains difficult, for although it seems that evolution probably is creative, it would seem to be just as hard to define the boundaries between creative and noncreative search as it is to define them between creative and noncreative thought.

3.6 Exploring alternative search spaces

(Gero, 1996)

By redefining the search space, or indeed, constructing new search spaces in which to find solutions, a search process can be considered creative according to this definition. Just as our creative thinkers find alternative ways to look at problems, if evolution can enhance or change its search space, it will be creative.

This is another, more discriminative interpretation, which is a little harder for evolution to satisfy. Using evolution as a simple optimiser of fixed parameters is clearly not creative. However natural evolution and some of the more advanced evolutionary algorithms are capable of varying their representations. Such evolutionary approaches can have considerable freedom to modify their representations in parallel to the evolution of solutions. They can alter the coding, vary the length, employ redundant genetic material, select useful functional elements and even create higher-level building blocks. Once again, at least some of the more complex forms of evolution can be considered creative.

3.7 Transferring useful information from other domains (Goldberg, 1999; Holland, 1998)

Goldberg (1999) makes the distinction between innovation and creativity with this definition. He feels that innovation involves discovery *within* a discipline, whereas creativity requires a transfer of knowledge from *without*. Holland (1998) makes a very similar point in his discussion of metaphors, and how knowledge in one area can

be applied to a different subject in order to change the perceptions and understanding of that subject.

In nature there are no clearly defined domains of knowledge. Perhaps different species could be regarded as distinct archives of knowledge, but natural evolution does not transfer such information, for interbreeding is usually unsuccessful. Some argue that knowledge of previous solutions that were successful during alternative environmental conditions is held in junk DNA for future reuse, but this is hardly knowledge transfer from a different domain. Goldberg does suggest that the transfer of knowledge about better knowledge representation may be one aspect of creativity, and it is argued that natural evolution does evolve such evolvability (Dawkins, 1989). However, this seems a somewhat contrived argument. Consequently, according to this definition, natural evolution is probably not creative.

Evolutionary computation does not currently include methods to identify and transfer knowledge from other domains to aid search. Goldberg feels that it is conceivable in the future, but it seems unlikely that evolution will be used to perform this, rather that the ‘creative’ process according to this definition would be performed by the knowledge identification, transfer and conversion software.

3.8 Going beyond the bounds of a representation (Boden, 1992)

Boden (1992) feels that to be creative it is necessary to find a novel solution that simply could not have been defined by a representation. She suggests that this is the nature of a paradigm shift, where entirely new approaches to the representation of problems are found. This precludes the transfer of knowledge into the current representation as suggested by the previous definition. Instead, a different representation would be required. Boden does not feel that computers will ever be capable of such creativity (Boden, 1992).

Whilst this may appear analogous to the behaviour of creative thinkers in our society, it seems to ignore the fact that our own brains are fundamentally single-representation devices. At the lowest level, they must always use neurons, chemical and electrical signals, so whilst many alternative higher-level representations can be expressed, they must always be defined using this ‘wetware’.

Evolution (natural and computational) is similarly constrained to a low-level representation, this time genetic,

but equally capable of defining higher-level representations of immense diversity and complexity. It therefore seems that, with respect to this definition, evolution and the human brain are equally likely (or unlikely) to be capable of creativity.

3.9 Expressing your soul

Some insist that creativity is an expression of your soul. This one of the more controversial definitions of creativity and one of the hardest to satisfy for nonhuman activity. Whether you believe in the soul or not, few would argue that a computer or the process of evolution possesses one. Clearly, evolutionary computation cannot satisfy this definition – unless we ever construct living machines, whatever they might be. However, natural evolution is a special case – for if it is the working of God, then it must be creative.

4. Summary

This paper has explored the question of whether evolution is creative. Nine alternative definitions were discussed, with the conclusion that, according to six of the definitions, the more advanced forms of evolution can be considered to be creative.

In the end, it seems that the magical property of creativity is simply too subjective and anthropocentric a word to allow its unequivocal usage for evolution. The final judgement must be a personal one, but it is possible to give four responses from people with different outlooks on the world. These views are amalgamations of the views presented to the author during a number of discussions on this subject. Although titles for each type of view have been given, this is more for convenience of reference than an attempt at accurate generalisation.

The Atheist

Does not believe in creativity. All novelty is as a result of random chance, complexity is a result of physical laws and natural selection. 'Creative' individuals are simply individuals with brains that are better able to process information.

The Religious

If natural evolution is considered to be the way in which God designs the living world, then it must be creative. However, a computer performing evolution does not involve God in this way, or a human soul, so it cannot be creative.

The Artist

Often inspired and awed by the forms evolved in nature, finds evolution to be very creative.

The Scientist

Finds the results of evolution to be creative, but expresses doubts as to whether the process can be given the human descriptive word 'creative'.

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