Feature

Darwin and creationism reconciled

When computers should surprise us

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Could computational approaches to creativity facilitate the understanding of creativity? Is it worth investigating computational tools and environments that might help humans being creative? And is it feasible to build programs that we could classify as “creative” — or are computational approaches to creativity a waste of time and resources?

It depends on the view you take of what creativity is. Does it find its origin in some kind of divine inspiration or innate talent (what Margaret Boden (1990) called the *inspirational* or *romantic* views of creativity)? Or is it a fundamental part of human intelligence, one of the most remarkable characteristics of the human mind? Like many others, the authors of this article take the latter view, and argue that, on such a view, it is inconceivable to research intelligence (natural or artificial) without studying creativity.

Creativity is hard to measure, observe and interpret. Its study has been a challenge for many scientists and researchers, particularly for those from areas such as Cognitive Science and Psychology. In recent years, the subject has attracted a growing number of AI researchers who have been working towards abstract explanation theories and adequate computational models of creativity. This interest comes from the belief that computational creative systems are potentially effective in a wide range of artistic, technical and scientific domains where innovation is a key issue. Scientific discovery, theorem proving and technical design are just a few examples of application problems suitable for them. Moreover, the endeavour may contribute to the overall understanding of the mechanisms behind creativity.

Process and product

When studying creativity it is useful to consider two distinctive, complementary aspects: the creative *process* and the creative *product*. The creative process is central to creativity modelling, and several explanatory models have been proposed for the human creative process (see Brown (1989) for a survey). Models adopting an information processing approach (e.g. Wallas (1926)) are particularly useful for computational creativity. Roughly speaking, these models describe the process as a stepwise procedure of problem acquisition and knowledge assimilation; conscious or unconscious search for a solution; proposal of a solution; and verification of the proposed solution.

But analysis of the creative *product* is also of prime importance, as creativity is most often recognised on the basis of its outcome: a symphony, an invention, or a theorem proof are commonly accepted as creative products on the basis of what they are, rather than the specific process that produced them. Although we may not agree with a view of creativity that focuses solely on the product, it is hard to imagine an assessment that does not consider the product as one of its main components.

Two main properties are accepted as characterising a creative *product*. One is *novelty*: for a product to be recognised as creative by some evaluator, it must have a substantial degree of originality. However, novelty alone is not enough: closely related to creativity is also the notion of *value*. A random sequence of symbols may be quite novel but it will not be accepted as creative if it doesn’t have meaning in some shared, accepted language.

In her framework for interpreting creativity, Boden (1990) distinguished between two forms of creativity: *exploratory* and *transformational* (e-creativity and t-creativity, for short) . Wiggins (2001) proposed a formal way of characterising creativity that accounts for this distinction. In rough terms, *e-creativity*, the most common type, may be described as a search in a conceptual space C, constrained by rules R, using a search strategy codified by rules T. C is typically very convoluted, and some of its points are difficult to reach by regular search strategies; hence, a particular T will be more successful in producing novel solutions if it is able to reach such points. Achieved concepts will be valued using another set of rules E.

While e-creativity is described as an exploration of a conceptual space, t-creativity refers to the transformation of the conceptual space itself: great creative breakthroughs like paradigm shifts fit into this class. Under Wiggins’ formalisation, transforming

C implies changing the rules so that points outside C become reachable. This may be attained by changing one of the rule-sets R or T, which results in a new conceptual space C'. In other words, t-creativity may be described as an exploration in the meta-space of rule-sets.

The Creative Systems Group at the University of Coimbra has devoted itself for years to the study of and experimentation with computer models of creativity. Much of the work so far has focused on e-creativity, but, as we will see at the end of this article, recent developments point to even more ambitious goals.

Computer models of creativity

As stated in many writings in the area of cognitive psychology, the creative faculties of the human mind are highly correlated to the ability to search through spaces or "viewpoints" that are different from the ones immediately involved. For example, according to Marin and de la Torre (1991), our capacities for abstraction, symbolic analysis and finding not-so-obvious relations are associated with creative production.

One cognitive psychology theory (Guilford, 1967) concentrates on the idea of "*divergent production*". In computational terms, exploring convoluted spaces with the aim of getting to points that are difficult to reach requires flexible search mechanisms, preferably with the possibility of searching disparate areas of the search space in parallel, finding the local maximum without getting locked into it, and diverging as needed.

So flexibility is a key issue, and it is for knowledge representation as well. In our own work we have, from our first experiments, used tree-like structures for representing knowledge, and adopted mechanisms that process those structures by reassembling knowledge fragments into novel combinations (Cardoso at al. (2000)).

For instance, *SICOM* (a Music Composition System) resorts to Case-Based Reasoning to construct hierarchical descriptions of musical pieces — much in the same way as in Lerdhal & Jackendoff (1983), where an entire piece of music can be represented analytically by means of a hierarchical structure defined by grouping, time-span and metric rules.

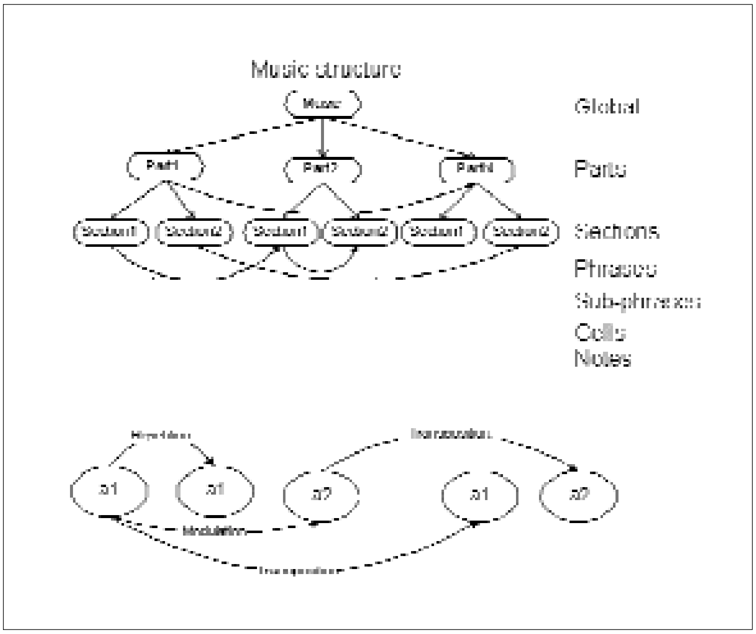

Figure 1: A Music Structure – a structured case in SICOM

The SICOM structures were built in a top-down, iterative sequence. The system used pre-elaborated analysis of music coded as trees, with non-hierarchical links between nodes for establishing relations among them. In the act of producing new structures, SICOM used these links as "suggestions", with a "strength weight" associated to search space reduction to keep some coherence throughout a piece (for example, in figure 1 Repetition may be strong and Transposition may be weak).

IM-Recide, *CREATOR* and *MuzaCazUza* are other examples of case-based experiments conducted in the domains of Design and Music, and were all inspired by human models of creativity.

But we have also looked for other sources of inspiration. One of these is the *Neo-Darwinist theory*, which revises Darwin's first ideas in the light of modern genetics and gives us a scientific framework that explains how life forms survive by adapting themselves to environmental changes. At the core of this process is a mechanism that selects the "fittest" individuals and recombines their genetic material. Putting together "good" parts of different individuals can give rise to a new and better one. This is clearly a way of producing innovative solutions (Goldberg (1998).

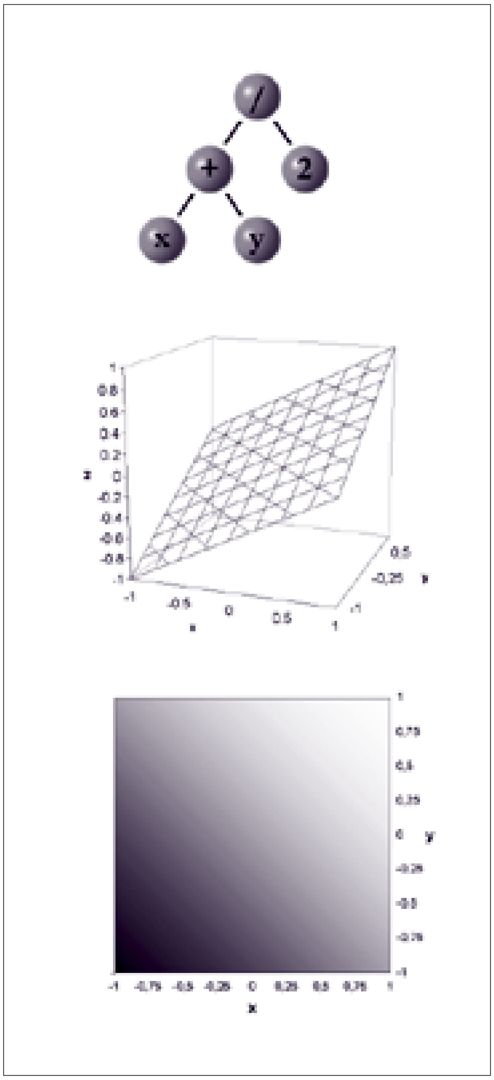

Figure 2: On the left, the expression f(x)=(x+y)/2 represented in tree format. In the middle, a 3d-graph of the mathematical expression. On the right, an image generated by assigning a greyscale value to each f(x) value.

NEvAr

NEvAr (Neuro Evolutionary Art) adopted Genetic Programming as the search mechanism for exploring a conceptual space of images.

NEvAr is an Evolutionary Art tool, i.e. a program that allows the evolution of a set of images, based on the aesthetic preferences of the user. NEvAr follows an evolutionary paradigm; in other words, it tries to mimic the mechanisms underlying natural selection, namely: survival of the fittest, recombination of their genetic material, and slight and random modification (mutation).

In its basic form, NEvAr operates as follows:

a) the program generates a random population of images;

b) the user evaluates the images, assigning a "fitness value" to them;

c) the program "breeds" a new population of images trough the recombination and mutation of the genetic code of the images of the current population; images with higher fitness values have higher probabilities of being selected for breeding;

d) return to point b).

In NEvAr, the characteristics of the individuals (images) are determined by their genetic code. So we have a *phenotype* (the individual) and a *genotype* (the genetic code that, once expressed, results in the individual). The genotypes are trees constructed from a lexicon of functions and terminals. The function set is composed mainly of simple functions such as arithmetic, trigonometric and logic operations. The terminal set is composed of a set of variables x and y and random constants. The phenotype is generated by evaluating the genotype for each (x,y) pair belonging to the image. Thus, the images generated by NEvAr can be seen as graphical portrayals of mathematical expressions (see Figure 2).

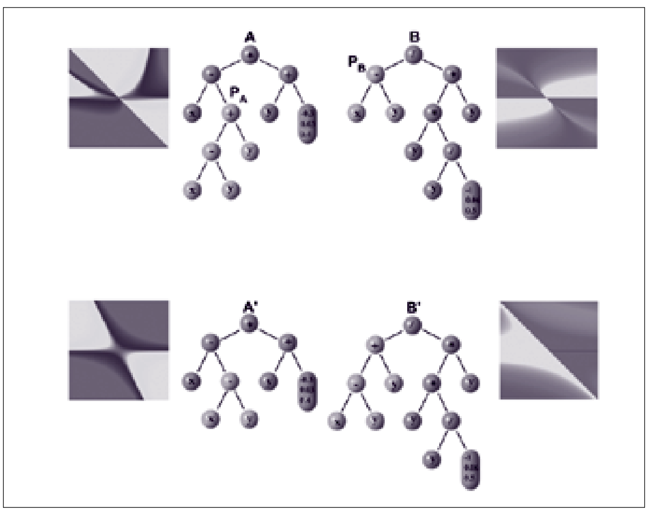

Figure 3: An example of the recombination operation. The code of the individuals A and B is recombined by exchanging the sub-trees implicitly defined by two randomly chosen points PA and PB, giving rise to the individuals A' and B'.

As shown in Figure 3, genetic operations (recombination and mutation) are performed at the genotype level. In order to produce colour images we resort to a special kind of terminal that returns a different random value depending on the colour channel – Red, Green or Blue – being processed.

NEvAr thus follows an iterative process: as the population number increases the average quality of the images also tends to increase, giving rise to new, interesting, and potentially creative and beautiful images (at least in the eye of the person conducting the program). Figures 4 and 5 give some examples of images generated with NEvAr.

One of the misconceptions about evolutionary art tools is that the generation capabilities of a system are deeply connected with the used primitives. Our experience with NEvAr shows that this is wrong. What is necessary, however, is a set of “basic” primitives that can be combined in a powerful way.

From an artistic point of view, we consider NEvAr to be a tool with great potential. The generation of an idea results from an evolutionary process and from the interaction between the artist and the tool. Thus, the use of NEvAr implies a change to the artistic and creative process. But in spite of this, the artworks obey the aesthetic and artistic principles of the artist, who guides the process by providing fitness values to the produced images.

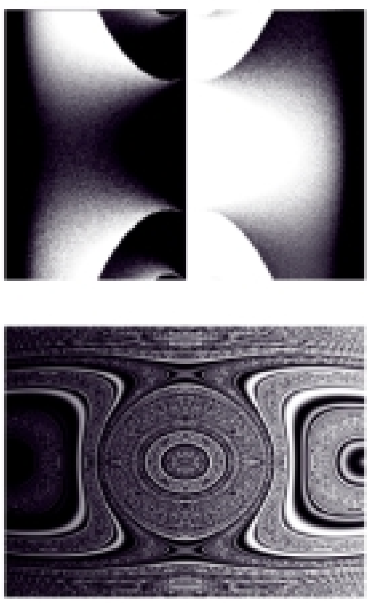

Figure 4: Images evolved by NEvAr under the guidance of its author.

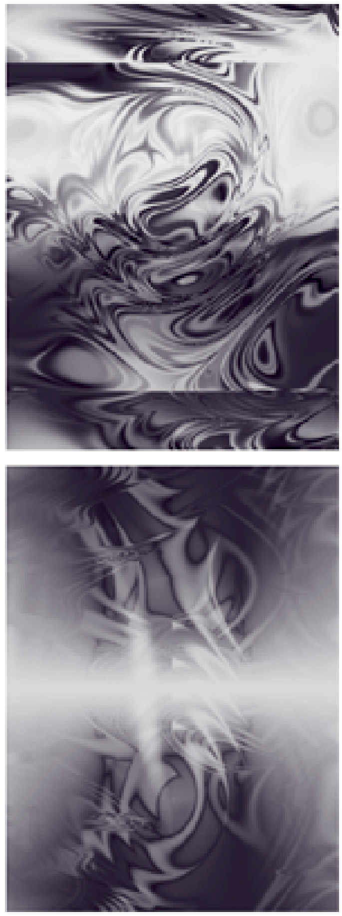

Figure 5: Additional images evolved by NEvAr under the guidance of its author.

Figure 6: The author of NEvAr (F. Penousal Machado) working with the tool.

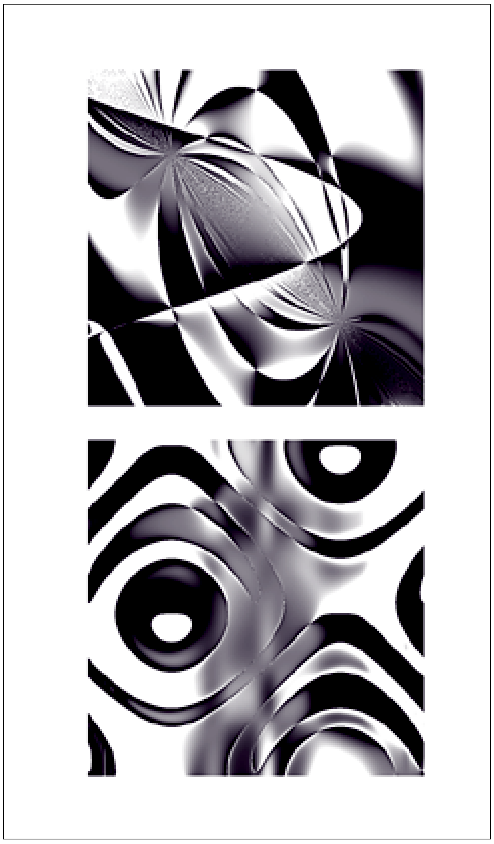

Figure 7: Examples of images evolved by NEvAr without human intervention by making automatic fitness assignment..

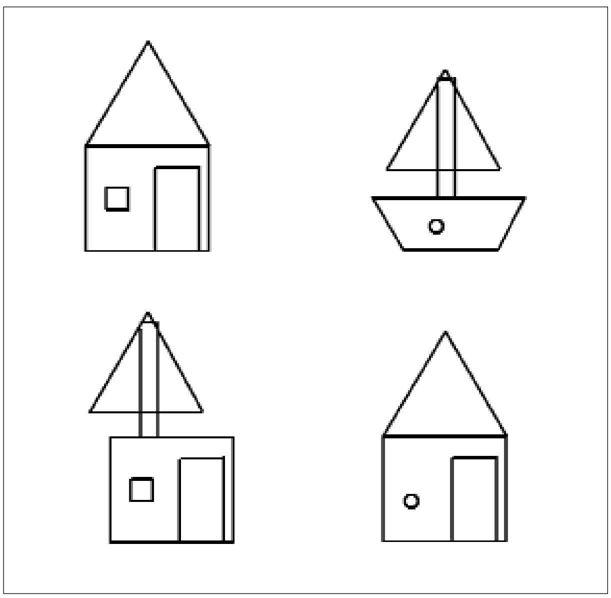

Figure 8: At the top, house domain and boat domain instances. At the bottom, two examples of blends generated by Dr. Divago.

Although NEvAr was originally intended as a tool to help people be creative, we are currently studying ways of giving autonomy to the program by automating the fitness assignment. Our initial idea was to train a neural network and use it to automate this task. But we now feel that full automation is not attainable in the short term, and our current idea is to use neural networks (as well as other techniques) as a filter that eliminates undesirable individuals. Figure 7 shows two images generated by NEvAr without any kind of human intervention.

Further thoughts

If there is one single ultimate goal in computational creativity research, it is undoubtedly t-creativity, for it subsumes the ability to reason at the meta-level, to change the world, and to create new ideas. Pursuing it may seem like a quest for the Holy Grail, yet researching t-creativity forces us to focus on issues that we believe can move us forward to points such as cross-domain transfer processes like *analogy*, *metaphor* and *conceptual blending*.

These cognitive devices motivate the *Dr. Divago* project, a framework for the generation of new concepts in a multi-domain environment. It uses structure-matching procedures to find candidate mappings for blending parts of (apparently) distant spaces. For example, blending the domains "*house*" and "*boat*" (as suggested in Goguen (1999)), Dr. Divago concludes that "*the hatch is the window of the boat*" or "*the mast is the roof of the house*". A drawing module based on logo language coding of elements produced examples such as the ones shown in Figure 8.

Conceptual blending allows for the exploration and creation of an alternate, blended domain (e.g. "*house-boat*"), and therefore makes leaps to unexpected, potentially creative solutions. In Wiggins' terms, this corresponds to a transformation of the conceptual space by changing the set of rules R. And in this sense, t-creativity is theoretically achievable.

Footnote

1 See also Wiggins' article on pp 7 – 11 of this issue.

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Relevant URLs

Creative Systems Group web page:
http://creative-systems.dei.uc.pt

SICOM project page:
http://creative-systems.dei.uc.pt/SICOM.html

IM-Recide project page:
http://eden.dei.uc.pt/~pgomes/imrecide/intro.html

NEvAr project page:
http://creative-systems.dei.uc.pt/NEvAr.html

CREATOR project page:
http://eden.dei.uc.pt/~pgomes/creator/creator.htm

ReBuilder project page:
http://www.rebuilder.com

Dr. Divago project page:
http://creative-systems.dei.uc.pt/DrDivago.html

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