Creativity and ICT

FET Consultation Workshop

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1. Introduction

The Future and Emerging Technologies (FET) scheme fosters frontier research that opens up new avenues across the full breadth of future information technologies. FET acts as a pathfinder, promoting the exploration of radically new ideas and trends for future research and innovation. It also aims at providing sustained support to emerging areas that require fundamental research to be carried out over a long period. The core of FET's mission is to go beyond the conventional boundaries of ICT and venture into uncharted areas, often inspired by and in close collaboration with other scientific disciplines.

In preparation for the 2013 Work Programme, FET has launched a consultation process involving interactions with researchers in order to identify new challenges and opportunities for the future. One such Consultation was on Creativity and ICT. This was organised as a one-day workshop in Brussels on 28 November 2011. Around 15 invited researchers attended, each of whom was asked to make a short presentation based on a pre-prepared position paper.

FET has funded certain projects linked to creativity, but as yet has no Proactive Initiative on the topic. Such an initiative could serve to look for radical breakthroughs, exploit fresh synergies and enhance cross-pollination and convergence between the wide range of scientific disciplines involved.

Examples of questions that could be at the core of such an initiative are:

- How does the brain enable creativity, and how could this lead to new technologies for enhancing and supporting creativity in areas ranging from arts to industrial innovations?
- How does individual creativity relate to group creativity, and how does the creativity of groups of people develop in computer-mediated environments (e.g., the internet)?
- What are key challenges in the area of artificial creativity?

The Workshop was organised as an open debate about challenges and the above questions merely provided starting points for the discussion.

2. Context: The Nature of Creativity

Creativity is a distinguishing human attribute. Being creative is a key part of modern life, contributes to our wellbeing, and is an inherently social activity.

There are many definitions of creativity, one being that it is **“the ability to generate ideas and artefacts that are new, surprising, and valuable”**[1]. ‘New’ always means psychologically new – to the individual concerned; sometimes it also means historically new, to the whole human experience. ‘Valuable’ can have many different meanings, according to different domains and judged by different social groups, and is essentially a value judgement.

Scientifically, creativity is an ill-defined concept and research is scattered across a broad range of disciplines and research fields. The issue is being addressed from many perspectives, ranging from cognitive and computational models which help us to understand the mechanics of human creativity through to practical approaches to increasing creativity[2]. Similarly, there are many studies of

1 Presentation of M. Boden

2 See presentation of N. Bryan-Kinns for literature references

creative practice, creative processes, and collaborative creativity which help us to understand the social and inter-personal nature of being creative.

One schema that has become broadly accepted – and was cited by several Workshop participants – is that by Boden who has **observed three ways in which creativity is realised**. The first, *combinatorial creativity*, produces unfamiliar combinations of ideas. Analogy is an example. The second, *exploratory creativity*, is based on some well-defined space of thinking. The space is explored, looking both for previously unreached places and to understand its potential and limits. *Transformational creativity*, the third form, is when the space itself is transformed by altering some of its dimensions. So, ideas are generated that could not be generated before the transformation.

Creativity researchers have tended to consider only the first of these – unusual combinations of familiar ideas. The latter two, based on structured conceptual spaces, or thinking styles, in the mind have received less attention. They involve a grammar (or rules) drawn from one's own or another culture and exploring and testing the limits of this grammar to see how far it can be pushed. This leads to ideas that could not have been generated before; however, they are not entirely new, because the transformed space always bears a more or less recognizable similarity to its untransformed predecessor. At the extremes, it may result in a restructuring of the conceptual space itself and so becomes transformational.

The Wallas stage model was also considered a useful reference[3]. This distinguishes three stages in the creative process: preparation, incubation and illumination. The latter is the 'ah-ha' or 'eureka' moment, but research shows this seldom happens spontaneously and in fact the true moment of insight occurs long before. It is even possible to backtrack a person's thoughts during the period in which they were incubating the idea. Thus, 'intuition' should be thought of as an area of enquiry for creative acts rather than as an explanation: it is a question, not an answer. We have to probe what is going on beneath, which means understanding how the brain sub-consciously evaluates potential solutions prior to the moment of insight. Also, it should be remembered that artists tend to romanticise the eureka moment, leading to an exaggerated view of the creative process.

Musicians are one community that has been extensively studied. Music research offers a variety of examples of theoretical constructions contributing to the emergence of new areas in science and, more specifically, in mathematics[4]. Mathematical approaches have been applied in music since earliest times (for instance by Euler, whose attempts to map musical space gave birth to graph theory), a tradition that continues through to the present day. In all cases, algebraic and geometrical representations of musical structures and processes are providing a general framework for the creative expression, according to the common assumption that 'creativity results from combination of representations'.

Until now there has been little overlap between those studying mathematical representations of music (the maths/music community) and those studying mental representations and processes (cognitive musicologists). **Cross-fertilisation** between the two would open the way to discussion on the place of formal mathematics in the cognitive processes involved in the creative act, and hence a mutual contribution to the fields of ICT and creativity. In addition, it will be important to **focus also on other modalities** that are less well studied, such as literature and food.

3 Presentation of D. Bierman

4 Presentation of M. Andreatta

In music and other domains **'virtuosos' are lauded for their creativity** and even genius. However, it may be that a virtuoso – someone who is very good in their field – is simply a manifestation of the '10 thousand hours principle': maybe creativity is not so elusive after all and just the result of hard training[5]. Virtuosity has been little studied up to now and could benefit creativity studies as it involves concrete performance tasks that are usually quantifiable and measurable[6].

This raises the question: exactly how rare or special is creativity? What can we do to democratise creativity so that it is available to everyone? Individual creativity depends on **deep knowledge in the relevant field**, typically built up over many years of study and work[7]. It involves not just problem solving but problem seeking: the more you know the more you can identify a 'good problem' and ask the sensible questions. Thus, formulation and reformulation of knowledge is fundamental to human creativity. Such personal knowledge lays the groundwork for any sudden 'flash of inspiration' which may result.

Knowledge and culture can be thought of as a series of ever-expanding boxes. Thinking 'outside the box' is not enough, you also have to build bridges in thinking so as to move people from their current position to a new position. Over time, the whole knowledge/cultural space itself expands by growing out and encompassing all of the bridges built to new ideas. Because creativity is so intimately founded on human knowledge, it will be enriched by stronger technological support of knowledge processes.

Creativity can also be **a collaborative process**[8]. Groups of people can collaborate in creative work, becoming more productive together than any of them would be alone, or all of them would be separately. Connecting groups of people together effectively can stimulate more creativity, because they become more motivated to satisfy human needs and the needs themselves become more visible. Aspects of so-called 'co-creation' include co-definition of issues, co-design of potential solutions, co-decision on issues and options that may arise, and co-production. Social sciences have stressed the importance of rituals of participation (such as networking, familiarity, group dynamics) in building the trust necessary for creativity to blossom in group environments.

Some participants, however, cautioned against too great an emphasis on collaborative aspects. They argued that we have to understand creativity in the individual case before broadening to the social case, which would add yet another level of complexity. Creativity – according to this view – is a product of human minds, so we have to understand the individual context before being able to write programmes and build systems. The contrary view was that social creativity is interesting and important in itself because by studying social interactions we can map creative processes more explicitly. In a sense, co-creation could be thought of as a hybrid system.

5 Presentation of F. Pachet

6 True 'geniuses' maybe a special case. There is some evidence that such highly creative people have extreme personalities and tend to be hugely selfish. They tend to operate more or less permanently in transformational creativity that breaks boundaries, for instance by borrowing an utterly different space from a foreign culture without attempting to combine it with one's own culture.

7 Presentation of D. Moffat.

8 Presentations of N. Bryan-Kinns, D. Moffat, A. Nandi, O. Stock

3 Motivations and Challenges

3.1 What is Computational Creativity?

Computational creativity, as a field, aims towards computer systems which are capable of human-like behaviour in creative contexts, at all levels[9]. It constitutes a new, more open way to view intelligent behaviour, beyond the classical problem-solving perspective of artificial intelligence (AI). In computational creativity, the paradigm revolves around problem seeking rather than problem solving, and there is no assumption of a given 'correct' answer. This is expected to lead, ultimately, to more human-like computer systems.

In scientific terms, a range of computational systems can be envisaged, from **hybrid human-computer systems** that are intended to support or assist human creativity (human-in-the-loop), to **autonomous computer systems** that perform tasks that would be thought of as creative if performed by a human ('human-free creativity').

The first approach can be considered as **machine-empowered creativity**[10], using machines not to emulate human creativity but to support and enhance it. Machines would be relied on for the kind of operations where they are better suited than humans, while keeping the human in the loop. This requires a general picture of the creative process and how technology could be brought to bear. Potential examples include:

- Identifying novelty, for instance by storing previous instantiations of a desired artefact and validating candidate solutions against them;
- Quality metrics for artefacts based on formal requirements;
- Machine support for traditional inspiration techniques (e.g. striking combinations of elements based on random selection);
- Machine support for the identification or establishment of analogies between problem statements;
- Protocols and interaction schema for applying such mechanisms in collaboration with real users.

The second approach – **human-free creativity** – would be more revolutionary, in scientific terms, challenging many of the assumptions held by current researchers[11]. For instance, it would show that 'creative behaviour' does not necessarily mean human-like creative behaviour; and that contributions could be made by pure computational systems as well as by hybrid systems. Arguably, a focus on creativity theory not grounded in ICT would risk only incremental breakthroughs while leaving little scope for fundamental contributions to computer science. Computers do many things better than humans (recognising patterns, analysing massive datasets, etc.) because they work in different ways. We need to find ways to engineer software that can take on some of the responsibilities in arts and science projects and by ignoring autonomous systems we would be missing an opportunity to alter the nature of creativity.

9 Presentation of G. Wiggins
10 Presentation of P. Gervás
11 Presentation of S. Colton

3.2 Challenges in Computational Creativity

A FET Proactive Initiative on Computational Creativity should aim to embed computational creativity mechanisms in existing systems – both hybrid and autonomous – and apply them for widespread use in areas with high economic and social impacts.

Participants identified a wide range of approaches, techniques, models and systems that could help people be creative in different ways. A non-exhaustive list included[12]:

- mathematical modelling of creativity – describing the creation of new knowledge or new solutions to problems mathematically;
- computers helping in the creative process – for instance, by inducing divergence that supports human creativity;
- computers measuring human creative performance – focusing on the moment of insight and the incubation phase in the creative process;
- computers helping to train creativity – using biofeedback techniques to train sub-processes based on a validated neurological model of creativity;
- implementing creativity in ICT – based on mathematical and computational techniques and models, possibly inspired by cognitive, biological, neurological, and evolutionary processes;
- automatic creative discovery of abstract concepts;
- automatic creation of future-oriented concepts, messages and artefacts;
- semi-automatic collaborative human-computer creation;
- automatic appreciation and evaluation of creative production.

Interesting possibilities arise in **externalising/augmenting human knowledge** so that it can be structured, valued and shared. The aim here would be to build software systems that act as thinking partners (or electronic sounding boards) that support scientists (or other communities) to plan their work, identify problems to solve, formulate hypotheses, and design experiments to test them[13]. The thinking partner could adapt to the user's own thinking, capturing tentative thoughts and retaining them to supplement the human long-term memory, and stimulating creativity by identifying areas of uncertainty and other problems. In addition, intuitive visualisation and navigation techniques would allow domain experts to surf through the knowledge network, identify problems to solve, and add in new conclusions to grow the network. It should be possible to connect multiple thinking partners together, so that their users collaborate simply by sharing their externalised thoughts.

The field of **computational creativity is inherently multidisciplinary**, relating in particular to software engineering and the cognitive sciences. An understanding of the issues requires study of artificial intelligence (which can be considered the parent discipline), psychology and human behaviour around ICT systems, as well as domain expertise for the creative field concerned. Recent advances in the underlying disciplines now make computational creativity a realistic endeavour[14]:

[12] Presentations of D. Bierman, O. Stock, A. Cardoso
[13] Presentation of D. Moffat
[14] Presentations of M Boden, O. Stock, G. Wiggins

- In AI, progress has been steady and continuous, even though no extraordinary breakthroughs have occurred or are likely to occur;
- In human-computer interaction, there is a better understanding of the relation between human creativity and computer systems;
- Research on collaborative environments has started to provide a basis for approaching creativity as a social process involving humans and machines;
- Cognitive science, and more indirectly cognitive neuroscience are offering incremental understanding of creativity phenomena which may inform the design of computational creativity systems;
- A new contribution is from the field of performative science – deploying science and technology through the performing arts[15]. This emphasizes aspects such as real-time technology, agency, authorship, and multidisciplinary interaction and communication.

Neuroscience has made some valuable advances, for instance it has helped us to understand how combinational creativity works through conceptual associations. But its importance should not be over-emphasized. In the brain, the relationships between conscious and unconscious processing are complex. Even if major breakthroughs are achieved understanding how creativity works in humans will, most likely, be only of limited value in relation to computational creativity.

4 Suggested Approach

Participants were divided over the weight to be given to theory versus applications within a potential research programme. Some considered that theoretical (e.g. philosophical) research must accompany, and even precede, ICT research. Proponents of this view argued that if we do not know what creativity *is,* we cannot hope to know how it works nor how to imitate it in AI terms. Others argued for an empirical approach, checking theories against evidence from systems which in turn should lead to better theories. We need to explore how humans approach creativity and come up with a computational model that can be checked against reality in some way.

One school of thought was that, given the state of current knowledge, breakthroughs in generic computational techniques and models was unlikely and hence research should concentrate on applications instead. This school argued that **we needed to show concretely how machines could outperform humans in demanding creative tasks and to focus on building systems rather than theories.** Research should aim towards systems that provide support services to humans involved in creative tasks (i.e. as a cognitive extension for humans through new forms of intelligence that complement and augment human intelligence)[16]. Proponents advocated a bottom-up approach, whereby creative systems are built using real-world constraints in a variety of domains. Examples could include co-authoring, scenario (re)interpretation, and data exploitation and filtering. Research should also aim towards improving communication with humans, thus facilitating interaction. Examples include use of expressive language and narrative power in human-computer communication.

15 Presentation of A. Mura

16 Presentation of A. Cardoso

The contrary view was that research in creativity would be of much greater value if set in the context of a generalised theory. Experience in other fields (such as complex systems) has shown that research should aim towards generic breakthroughs and theories from the outset, otherwise there is a risk that we end up with a series of highly customised solutions but no useful insights. Such discussions have already been aired within the computational creativity community, but FET could be the right place to force researchers to take a more generic approach. **An FET Proactive Initiative should have a Science of Creativity as its mission,** with individual projects being required to explain and to justify their expected contributions towards a generalised theory. However, unrealistic claims, as were made for AI, must be avoided. It should be clear that the advances being sought are in **a theory of computational creativity**, rather than a general theory of human creativity *per se*.

Other aspects of the methodological approach raised in the discussion included:

- **Balancing observation versus simulation:** In addition to the theory vs application debate, a balance has to be struck between the study of creativity as an observed phenomenon and as a simulated phenomenon[17]. Moreover, this should not be to the exclusion of approaches from other philosophies, including better epistemological and methodological understanding of the nature of human and computer creativity.
- **Benchmarks, ability to perform and testability:** Benchmarking is essential to good science[18]. In a field such as computational creativity, where natural benchmarks are lacking, we have to find ways of enforcing rigour, although the measures need not necessarily be quantitative. Potential benchmarks include experiments, exhibitions, performances and installations, and others should be elaborated. Performances/installations are controversial as they provide no verifiable or lasting output. Similarly, Turing-style tests, which rely on imitation, are not sufficiently rigorous for these purposes. 'Testability' itself is a controversial term and needs to be better defined.
- **Need for real-world testbeds:** Contemporary research emphasizes 'everyday creativity', that is creativity beyond the confines of the lab, office, or gallery, that embraces the everyday and helps us all realise our full creative potential[19]. Invariably, this involves the study of digital social infrastructures (such as social networks) in the collective context. Such settings provide testbeds for understanding, designing and evaluating systems which create and sustain new forms of Everyday Creativity.
- **Multiple evaluation frameworks:** One consequence of the multidisciplinary nature of computational creativity is the need for appropriate evaluation mechanisms that combine trans-disciplinary and domain-specific elements. Aesthetics, epistemology, utility and ethics all provide potential dimensions by which to evaluate computational creative systems[20].

17 Presentation of G. Wiggins
18 Presentations of S. Colton, P. Verschure, G. Wiggins
19 Presentation of N. Bryan-Kinns
20 Presentation of O. Stock

5 Target Outcome / Expected Impact

The target outcome of a prospective FET Proactive Initiative on Computational Creativity would include systems, applications, theories and models in both hybrid human-computer and autonomous ICT systems. Such outcomes would draw on targeted research at the intersection of creativity and ICT as well as taking into account developments from other fields. In addition to conventional outputs (scientific papers, workshops, prototypes, etc.), performances and installations should be used as scientific tools to explore the theories and models generated. Benchmarking and the gathering of data to validate and support theory should be a key focus of the research programme.

Other key outcomes of the research programme should include:

- **Contributions in science and knowledge**, including a better understanding of the scientific process, and of the nature of knowledge; and a deeper appreciation of creativity across various domains (science, music, arts). It should also aim towards a scientific theory of human culture that is clear, rigorous, backed by evidence and broadly testable.
- Encouraging **multi-modal approaches** which provide comparisons across different types of creative endeavour;
- A focus on **integration** as a step toward generalised creative systems.

A key expected impact of this research is likely to be **in hybrid systems improving and expanding the creative behaviour of humans.** Software is anticipated that is better able to adapt to people by understanding the intimacy of their thought processes. Although precise outcomes are difficult to predict, it is expected that along the way less ambitious artistic, technological and scientific systems will be developed, such as artificial mathematicians, artificial composers, etc. Indeed, some existing systems have already made contributions to refereed scientific literature.

Examples of **areas with high economic and social impact** which could benefit from embedding computational creativity mechanisms include: engineering design, the digital content industry, including games and entertainment, technology-enhanced learning, and tourism. It will be essential to involve creatives themselves (artists, domain experts) in the research process.

A particularly significant impact would be in **expanding the role of technology in the creative industries**, where value chains are little documented at present[21]. The application of ICT in the content industries has focused largely in expanding the range of technical possibilities available to the human creator, with little effort directed to exploring the role of technology in the creative processes themselves. This would extend the possibilities for small-scale production in the digital content industries, and problem-solving in creative processes in general. Examples include on-the-fly generation of customised content on-demand for consumers, and personalised advertising within dynamic contexts.

Ethical issues may arise here and should be studied; for instance in using ‘persuasive user interfaces’ in advertising to induce the user to behave in a certain way[22].

21 Presentations of P. Gervás, F Peinado, O. Stock
22 Presentation of O. Stock

6 Suitability for ICT and FET / Long-Term Vision

Computational creativity is highly suited to FET funding. The field is emerging, having been around for at least a decade, fundamentally technological but also high risk, in the sense that the gains to be made are extremely challenging and speculative. As yet there is no established roadmap and the limited research activity is fragmented, both geographically and across multiple research communities. Backing by FET would give the field as a whole momentum and send a clear message that the study of creativity in the context of ICT is to be encouraged.

This is clearly a grand challenge and success cannot be guaranteed. However, in scientific terms, the field decomposes into various sub-problems which would be valuable goals in their own right and could be pursued more or less independently.

Relevant traditions of work are to be found in AI (including knowledge-based systems, automated reasoning systems, multi-agent systems, and more recently the semantic web, and ontological knowledge bases); in Computational Linguistics; in Cognitive Science and other cognate disciplines (including decision support systems, computer supported argumentation, and group decision making); and in e-Science (visualisation and the sharing of experiment designs and data). None of this is yet developed to the point where it could be applied directly here and support from FET would stimulate the transfer of research results toward the field of creativity.

The field touches on and is complementary to a number of other FET Proactive Initiatives and research topics, including spatial computing, unconventional computing, massively-parallel computing, constraint programming, and brain-inspired ICT.

7 Communities

A multi-disciplinary approach is essential. Relevant communities include:

- Artificial intelligence
- Computer science
- Software engineering
- Neuroscience
- Cognitive science
- Psychology (cognitive, developmental, social, clinical, and evolutionary approaches)
- Linguistics (including computational linguistics) and social sciences
- Creative arts
- Philosophy and the humanities, including musicology and literary criticism.

Computational creativity is a demonstrably new research community. Over the last 10-12 years it has developed its own annual international conference, been given featured status in the magazine of the American Association for Artificial Intelligence. The successful series of Computational Creativity workshops and conferences now attracts around 100 researchers worldwide. Recently, computer science researchers have launched an international autumn school (first held in Porvoo, Finland, November 2011), demonstrating growing interest in computational creativity outside of its own core community[23].

Europe has led this field since its foundation in the late 90s. However, despite a substantial nucleus of European researchers, as yet only the UK has allocated funding to this area (for one research fellowship). The US has recently started to take notice, with specific funding programmes being announced by NSF and a number of scientific meetings organised on the topic in the US.

23 Presentation of G. Wiggins

Annex I : List of Participants

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Annex II: Workshop Terms of Reference

Context

The Future and emerging Technologies (FET) scheme fosters frontier research that opens up new avenues across the full breadth of future information technologies. FET acts as a pathfinder promoting the exploration of radically new ideas and trends for future research and innovation. It also aims at providing sustained support to emerging areas that require fundamental research to be carried out over a long period. The core of FET's mission is to go beyond the conventional boundaries of ICT and venture into uncharted areas, often inspired by and in close collaboration with other scientific disciplines.

In preparation for the 2013 work programme, FET has launched a consultation process involving interactions with researchers in order to identify new challenges and opportunities for the future.

Consultation on Creativity and ICT

Provisional scope:

FET has funded some projects that are linked to creativity, but has never yet had a proactive initiative on the topic. Such a proactive could serve to look for radical breakthroughs, exploit fresh synergies and enhance cross-pollination and convergence between the wide range of scientific disciplines involved.

Examples of questions that could be at the core of such an initiative are:

- how does the brain enable creativity, and how could this lead to new technologies for enhancing and supporting creativity in areas ranging from arts to industrial innovations
- how does individual creativity relate to group creativity and how does the creativity of groups of people develop in a computer mediated environment (e.g., the internet)
- what are key challenges in the area of artificial creativity

The workshop is meant to be an open debate about challenges and the above questions are only meant as starting points for the discussion.

Your task

We therefore invite you to present an analysis of grand challenges and research topics which should be included in the FET work programme to tackle them. Discussions can also include the means to implement the research – i.e. whether the projects should be big or small, or whether networking or coordination between researchers should be fostered.

The brainstorming and discussions will be open and unconstrained and are expected to lead to the emergence of radically new ideas inspired by the cross-fertilisation of different aspects and backgrounds. A rapporteur will write down draft conclusions, which will be subsequently consolidated using participants' feedback.

The consultation is organised as a full day workshop in Brussels (Avenue de Beaulieu 33, 1160 Brussels) on **28 November 2011**. You are invited to submit your ideas on key scientific challenges addressing the Creativity and ICT by **21 November 2011**, using the template provided, and to present them at the meeting within 5 minutes maximum. Please note that we are looking for candidate topics and challenges at the research programme level rather than at the level of single project ideas. After the presentations, the workshop will conclude with a discussion aimed at producing a unified recommendation for a new Proactive Initiative.

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