Computational Creativity in Slovenia

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Keywords: computational creativity, bisociative reasoning, computational creativity platform

Received: November 6, 2017

Computational Creativity is a field of Artificial Intelligence that addresses processes that would be deemed creative if performed by a human. The field has been very active since 1999, and is now an established research field with its own International Conference on Computational Creativity (ICCC) conference series founded in 2010. This paper briefly surveys the field of Computational Creativity (CC) that is based on the analysis of ICCC conference papers, followed by a more detailed presentation of projects and selected contributions of Slovenian researchers to the field.

Povzetek: Računalniška ustvarjalnost je področje umetne inteligence, ki obravnava procese, ki bi jih ocenili kot kreativne, če bi jih izvajal človek. Področje računalniške ustvarjalnosti se je razmahnilo po letu 1999, kot veja znanosti pa se je uveljavilo leta 2010 z ustanovitvijo serije letnih konferenc z imenom International Conference on Computational Creativity (ICCC). V članku podamo kratek pregled področja računalniške ustvarjalnosti, ki temelji na analizi ICCC konferenčnih člankov, posebno pozornost pa namenimo predstavitvi projektov in izbranih dosežkov slovenskih raziskovalcev.

1 Introduction

As a sub-field of Artificial Intelligence (AI) research, *Computational Creativity*[1] (CC) is concerned with machines that exhibit behaviours that might reasonably be deemed creative [49; 11]. Slovenian researchers have made important contributions to CC. This paper aims to provide an objective snapshot of the field of computational creativity as a whole, and to give a brief summary of the particular contribution of Slovenian researchers to it.

In the next section, we summarise an analysis of the research field, that we conducted in 2016, using it to structure a brief introduction to the field for unfamiliar readers. We then summarise the contributions of Slovenian researchers to CC.

2 Domain understanding

We here summarise the results of a study of the research field of Computational Creativity [36], which was based on the analysis of papers published in the Proceedings of the International Conference on Computational Creativity (ICCC)[2]. The aim of the study was to objectively identify areas of interest in this research field. Here, we use its conclusions to motivate our subsequent outline of CC research.

In the previous study, Pollak et al. [36] used semi-automatic topic ontology generation tool OntoGen [16] to explore the texts of the complete conference proceedings of the International Conference on Computational Creativity to date. This allowed them to make an objective, explainable bottom-up analysis of the field.

The input to the OntoGen tool are documents, which are texts of individual articles from the proceedings. After manual text cleaning and removal of the papers' reference sections, OntoGen performs stemming and stop word removal, followed by the construction of Bag-of-Words (BoW) feature vector representations of documents, where the features are weighted by the TF·IDF heuristic [41] and used for clustering. The user may explore the results, and identify hierarchies of significant terms and clusters of documents. The keywords are identified by OntoGen in two ways: *descriptive* keywords are extracted from document centroid vectors, while *distinctive* keywords are extracted from the SVM classification model distinguishing the documents in the given topic (document cluster) from the documents neighbouring clusters [16]. Other functionalities used were expert's manual moving of documents between clusters to reduce inappropriate paper categorisation and active learning of selected concepts/categories.

Several outputs were presented by Pollak et al. [36], including understanding of the field of Computational Creativity based on its topics, which is also of interest to this study.

A final corpus-based categorisation of the field of com-

[1] http://computationalcreativity.net
[2] http://computationalcreativity.net/home/conferences/

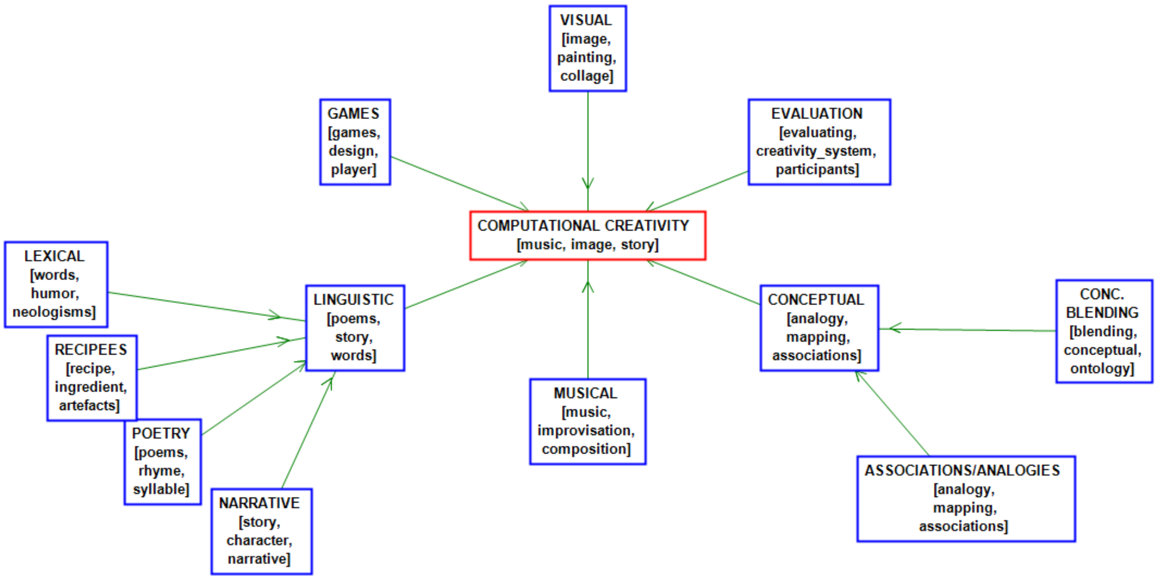


Figure 1: Semi-automatically generated conceptualization of the CC domain, with CC concept naming and sub-concept creation.

putational creativity is presented in Figure 1. The main sub-domains of computational creativity identified by our method were: Musical, Visual, Linguistic creativity, Games and creativity, Conceptual creativity as well as newly created category of Evaluation. For several domains, subcategories were detected also at lower levels, including Narratives, Poetry, Recipes and Lexical creativity as subdomains of Linguistic creativity. Each category can be further characterised through descriptive keywords listed in Table 1, as extracted from cluster centroid vectors.

3 Brief review of computational creativity

We now present a brief overview of Computational Creativity, as represented by the domains identified by Pollak et al. [36]. We have added in an additional category, *scientific creativity*, on the grounds that important work in this area was performed prior to the inception of the ICCC conference, and was therefore not represented in the conferences.

In this position paper we do not present a detailed review of the field but explain the key issues and cite some successful exemplars of CC research. A recurring general theme of ICCC is the attempt to better understand what is meant by term “creativity.” Early on, it was recognised that we must move away from Romantic notions of “great” creativity, if we are to make progress. So ICCC is interested in *creative process* more than *creative output*, and there is no acceptance of the notion of “inspiration”, understood as mystical intervention by some agency extrinsic to the creator. Of course, in a paper such as this, one cannot discuss process without reference to outputs, without being interminably dull. For this reason, we include examples where possible.

Boden [1, 2] first formally raised the question of creativity in AI, but there have been significant precursors of CC field in several domains that are also mentioned here.

3.1 Visual creativity

Most work on visual creativity is conceptualised in terms of painting or drawing. In this domain, there tends to be a focus on painting technique and on the objects produced.

The clear forerunner of CC in this domain was Harold Cohen, a successful artist in his own right, who built a robot painter, AARON[3], programmed in a rule-based style. Its development began in the 1970s, with developments right up to the artist’s death in 2016 [26; 2]. Cohen viewed AARON as a part of his art, and therefore did not always disclose the methods used to make it work, though he did write several papers on some aspects of the system [e.g., 7; 6; 5]. Figure 2(a) shows a well-known painting by AARON.

Simon Colton’s *The Painting Fool*[4] deconstructs painting from subject composition (for example, collage based on stories from The Guardian newspaper) right down to brush stroke [9]. Figure 2(b) shows an example.

DARCI[5] [27], unusually, is multi-modal and can explain itself: it combines image processing with language comprehension, so as to focus the system on the extraction and generation of meaning. DARCI produced the image in Fi-

[3] www.aaronshome.come
[4] http://www.thepaintingfool.com
[5] http://darci.cs.byu.edu

Table 1: Categories and keywords of the first layer of the semi-automatically constructed CC ontology.

Category	Automatically extracted keywords
Musical	music, chord, improvisation, melodies, harmonize, composition, accompaniment, pitch, emotions, beat
Visual	image, painting, darci, artifacts, collage, adjectives, associations, rendered, colored, artists
Linguistic	story, poems, actions, character, words, agents, narrative, artefacts, poetry, evaluating
Games	games, design, player, games_design, angelina, agents, code, jam, filter, gameplay
Conceptual	analogy, blending, mapping, conceptual, objective, associations, team, graphs, concepts, domain
Evaluation	music, poems, improvisation, evaluating, interactive, poetry, creativity system, musician, participants, behavioural
Comp. creativity	music, image, story, games, agents, words, actions, poems, character, blending

gure 2(c), explaining it as follows (there is not space here for the intermediate images): "I looked at this picture, [an elephant walking across a verdant African plain] and it reminded me of this image that I've seen before, [a standing stone] which is a picture of a stone. The picture also seemed gloomy and brooding. So I created this initial sketch, [black and white graphic drawing] and then rendered it in a style related to stone, gloomy, and brooding, which resulted in this image. [intermediate image] It turned out more like a bucket or a cauldron, and it seems creepy, but I'm happy with it."

3.2 Creative game design

Computational creativity has many applications in games, perhaps most obviously in the area of game level generation, where the landscape and structure of a game are created live. However, probably the most unexpected and interesting example of CC in games is *Yavalath*[6] [3], ranked in the top 100 board games ever invented by the BoardGameGeek website. It is highly novel in that the board is hexagonal.

Another success has been *Angelina*[7] [12], a long term project aiming for completely computational creativity of digital games.

3.3 Linguistic creativity

Creativity in language covers a broad area, including poetry and story-telling. Two systems that demonstrate different approaches are MEXICA [31] and Propper [17]. MEXICA uses a general creative method, the Engagement-Reflection model, to model a two-phase, cyclic approach to creativity. Propper takes a contrasting approach, using heuristics from literary theory [38] to guide exploratory creativity. A third successful approach is that of Tony Veale [46]. Veale's lab specialises in the development of elegant methods of extracting data from lingustic corpora, and then using that data for creative text generation, often in TwitterBots—see `@MetaphorMagnet` [e.g., 47].

[6] `http://www.cameronius.com/games/yavalath/`
[7] `http://www.gamesbyangelina.org`

3.4 Musical creativity

Musical creativity had important precursors too. David Cope's EMI [13; 50] produced many compositions, but none of the reports on the work made it clear what the system actually did, and how much was due to its author. A clearer early contribution, with full scientific reporting, was by [14], which produced musical harmony in the style of J. S. Bach. This is a remarkable contribution, and still stands today as an excellent piece of work; its fault is that its harmonisations sound *too much* like Bach—the system does not reflect on its overall balance, but applies Bachian compositional tricks everywhere.

Perhaps the first attempt at automated composition really to situate itself in CC was the work of [28]. Melodies were generated from a learned model of style, and evaluated in detail by expert musicians [29].

François Pachet's team has produced the most thorough CC music systems to date, working from chords and melodies right through to studio production [40].

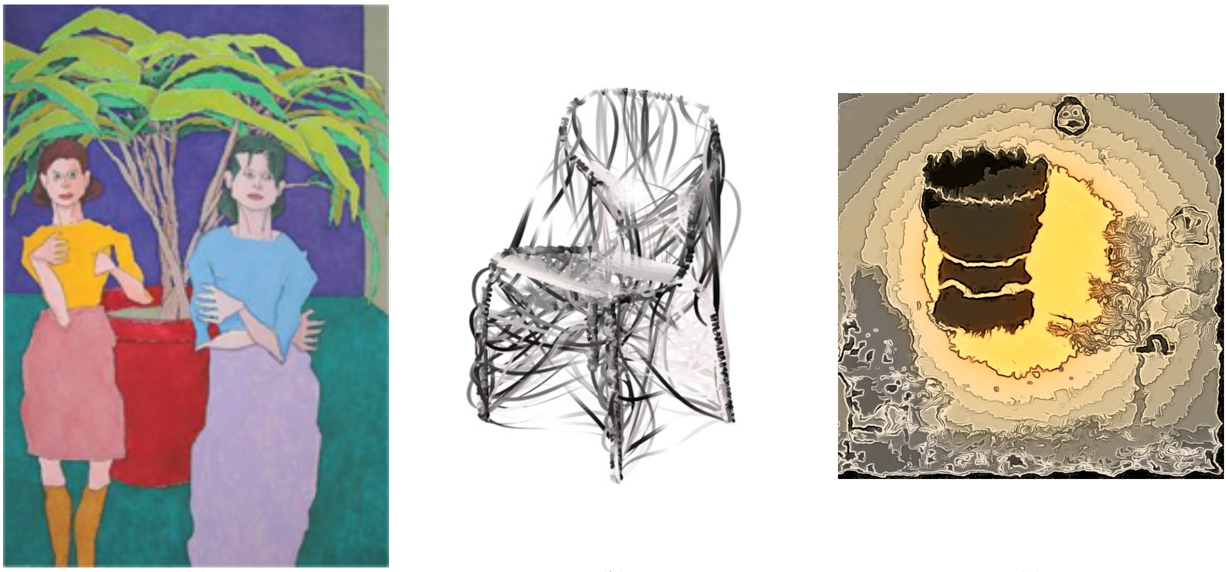
3.5 Scientific creativity

It is often forgotten that human creativity is evident in science and engineering, as well as in the arts and humanities. One of the earliest successes in CC was the HR system of Colton [8]. This was an exploratory creativity system, which invented new integer sequences with properties that mathematicians find interesting; 17 of the sequences it dicovered were novel and interesting enough to be included in the Journal of Integer Sequences, which records these structures and acts as an encyclopedia of them. It also made conjectures about some of these sequences that were subsequently proven correct.

Another successful project in scientific creativity was funded by the EU FP7 programme: BISON studied the application of *bisociative reasoning* [20] to medical text analysis (see Section 4.1).

3.6 Concept creation

Concept creation arises as a separate category in the objective analysis because it is central to all creative domains.



(a) (b) (c)

Figure 2: Three computationally created images. (a) *Untitled* from AARON's middle period output. (b) The Painting Fool's *Uneasy*. (c) DARCI's *Always Be A Gloomy Cauldron, Even in Creepy Stone*.

There are too many approaches to survey here; however, a recurring theme is conceptual blending [44], which has been carried forward with some success. An example is the *Divago* system [30], a computational model that uses conceptual blending. The key idea here is somewhat similar to Koestler's *bisociation* [20]: new concepts are created from combinations of features of existing and/or imagined ones. A recent EU FP7 project, ConCreTe, focused on Concept Creation Technology (see Section 4.3).

3.7 Creative systems evaluation

Evaluation is a particularly difficult problem in comptuational creativity, which attracts commensurate attention in the literature. There are two distinct ways that computationally creative systems involve evaluation: first, in the conventional scientific sense, where the correctness and value of work is assessed; and, second, in the sense of *reflection* within the system, that allows it to make intelligent creative decisions. Quite often, but certainly not always, these two aims coincide.

The value of a creative act is a function of four aspects [51]: Context, Observer, Creator and Artefact, forming the acronym COCA. But this does not give detail of how creativity might actually be assessed. Ritchie [39] gives a detailed set of criteria that can be used to assess the creativity of a computer program, which have been used in several projects. Jordanous [e.g., 18] and van der Velde et al. [e.g, 45] have made substantial contributions in this area.

4 Computational creativity in Slovenia

To the best of our knowledge, the only Computational Creativity research in Slovenia has been performed by the members of Department of Knowledge Technologies at Jožef Stefan Institute (JSI) in Ljubljana. Most of the research, including the work summarised in Section 2, has taken place within three distinct EU-funded projects and the PROSECCO networking action, all supported by the European FP7 funding programme. We summarise this work, with a special focus on Slovenian contributions.

4.1 Bisociation networks for creative information discovery (BISON)

BISON[8] was a research project from the field of scientific creativity, which deals with the bisociation-based scientific knowledge discovery. Arthur Koestler [20] argued that the essence of creativity lies in "perceiving of a situation or idea … in two self-consistent but habitually incompatible frames of reference", and introduced the expression *bisociation* to characterise this creative act. The key vision of the BISON project was to develop a fundamentally new ICT paradigm for bisociative information discovery. JSI's main contributions were related to scientific literature mining aimed at creatively forming new hypotheses based on yet uncovered relations between knowledge from different, relatively isolated fields of specialization. We developed CrossBee[9], a literature-based discovery support tool [19], where different elementary and ensemble heuristics

[8] `http://cordis.europa.eu/project/rcn/86374_en.html`

[9] `http://crossbee.ijs.si/`

are implemented for bisociative bridging term (b-term) discovery. The heuristics are defined as functions that numerically evaluate the term quality by assigning it a bisociation score (measuring the potential that a term is actually a b-term). Other methodologies developed for cross-domain literature based discovery focus on exploration of outlier documents [34; 42]. JSI's methods were tested on standard datasets (e.g., migraine-magnesium studied in early research by [43], but also actually led to new hypotheses in understanding autism [23] and Alzheimer's disease [4].

4.2 The What-If Machine (WHIM)

The WHIM project was concerned with the automated generation, understanding and evaluation of fictional ideas. Fictional ideas are propositions of situations that are unrealistic or commonly considered as unplausible, such as: "What if there was a little fish who couldn't swim?" which are a central part of various creative works and products. Artificial production of What-if ideas is creative work that is inherently hard to automate, but there are now some generators available (e.g., [22]). In the generation process, there is usually a trade-off between a template driven process (with a relatively narrow covering of the fictional ideation space) or more open and autonomous generative process (producing more interesting and valuable ideas, but larger amount of lower quality results).

The What-if Machine was also the inspiration for a real musical show Beyond The Fence, billed as "the world's first computer-generated musical", that performed in London in 2016. In this artistic project—containing the musical and a documentary—several computational creativity research prototypes were combined and used in the artistic process [10].

JSI's main role in the WHIM project was in automated modelling of human evaluations. The main tasks included the design of a large crowd-sourcing data gathering exercise, resulting in more than 10,000 evaluated fictional ideas and next, to build data mining models, which would allow differentiation between the sentences, appreciated by human evaluators as good/creative (regarding their novelty and narrative potential) or bad. We tested also an alternative approach for gathering human evaluations through interaction with the robot Nao [35]. Other contributions of Slovenian researchers to the WHIM project included bisociative generation of fictional ideation [32] and the RoboChair[10] system for enhancing scientific creativity by generating questions regarding decisions made by authors when writing scientific articles [37].

4.3 Concept creation technology (ConCreTe)

The ConCreTe[11] project focused on AI technology for concept construction, identification, and evaluation. ConCreTe addressed several forms of conceptual blending (CB), a basic cognitive mechanism by which two or more mental spaces are integrated to produce new concepts [15]. Optimality principles (OPs), a key element in the CB framework, are responsible for guiding the integration process towards good blends. The role of OPs was studied from the point of view of computational systems [24], as well as within a study of human perception of visual animal blends[12] [25], performed with the aim of better understanding of creative artefacts reception.

The main contribution of JSI to ConCreTe was the ConCreTeFlows platform[13] [48] for collective CC workflows construction. It is a platform built on top of the existing ClowdFlows infrastructure [21], but it is specialised at supporting (primarily text-based) computational creativity tasks, such as conceptual blending and poetry generation. It currently contains more than 35 native widgets for supporting creativity by developers from five different institutions participating in ConCreTe. The asset of a web-based system is that it integrates creative software written in a large variety of programming languages (e.g., components written in Python, C#, Java, PROLOG). An interesting example of multimodal conceptual blending [48] is available as an interactive workflow.[14]

4.4 Other projects and activities

We have described the main projects from the field of CC in which we were actively involved. Other project were closely related to computational creativity. For example, within the EU project MUSE[15], the question of interactive story-telling was addressed. Our main role was the integration of the developed components in the online workflow environment [33].

The PROSECCO[16] networking action had a crucial role in building the European CC community, with a number of events including the organisation of summer schools, code camps, etc. Computational Creativity has became an important research topic in Slovenia. A large number of activities were organised also by Slovenian researchers and held place in Ljubljana, including the 5th edition of the ICCC conference[17], with material available through VideoLectures[18], and the Symposium on Computational Creativity[19]. We have also organised the Computational Creativity art exhibition entitled You/Me/It.[20]

Since 2016, a Computational Creativity course has been offered at the International Postgraduate School Jožef Ste-

[10] http://kt-robochair.ijs.si/
[11] http://www.conceptcreationtechnology.eu
[12] http://animals.janez.me/
[13] http://concreteflows.ijs.si
[14] http://concreteflows.ijs.si/workflow/137/
[15] http://www.muse-project.eu/
[16] http://prosecco-network.eu/
[17] http://procsecco-network.eu
[18] http://videolectures.net/iccc2014_ljubljana/
[19] http://videolectures.net/ktsymposium2013_ljubljana/
[20] http://computationalcreativity.net/iccc2014/you-me-it-art-exhibition/

fan[21].

As CC related outreach activity, a large number of events for children and youth were organised for science promotion by means of a Nao robot, for which the main developer Vid Podpečan received the Slovenian "Prometej znanosti" (Prometheus of Science) science dissemination award.

5 Conclusion

This paper presented a brief review of historic and current activity in Computational Creativity, an exciting and relatively new sub-field of Artificial Intelligence. In particular, we have highlighted contributions from Slovenian researchers.

Computational Creativity is in some sense a final frontier for AI [11], because it pulls the field away from comfortably defined problem-solving activity such as classification, into the areas that are more challenging to formulate. Much of the work in this developing field is focused not so much on "What is the answer?" but rather on "What is the question?", and this makes for exciting prospects for the future, both in Slovenia and elsewhere. In 2008, the Association for Computational Creativity[22] (ACC) was founded to manage the ICCC conferences and support the CC community into the future.

Acknowledgements

We acknowledge the support of the Slovenian Research Agency (core funding no. P2-0103), the European projects Prosecco (grant no. 600653) and ConCreTe (grant nb. 611733). GW is very grateful to the International Postgratuate School Jožef Stefan internationalisation grant for funding a sabbatical visit in Autumn 2017, which enabled his contribution to this paper.

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