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Antonis Koukourikos
Pythagoras Karampiperis
Vangelis Karkaletsis

National Centre for Scientific Research "Demokritos", Greece

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CREATIVE STORIES: MODELLING THE PRINCIPAL COMPONENTS OF HUMAN CREATIVITY OVER TEXTS IN A STORYTELLING GAME

Antonis Koukourikos, Pythagoras Karampiperis & Vangelis Karkaletsis

Abstract: *The process of effectively applying techniques for fostering creativity in educational settings is – by nature – multifaceted and not straightforward, as it pertains to several fields such as cognitive theory and psychology. Furthermore, the quantification of the impact of different activities on creativity is a challenging and not yet thoroughly investigated task. In this paper, we present the process of applying the Semantic Lateral Thinking technique for fostering creativity in Creative Stories, a digital storytelling game, via the introduction of the appropriate stimuli in the game's flow. Furthermore, we present a formalization for a person's creativity as a derivative of his/her creations within the game, by transitioning from traditional computational creativity metrics over the produced stories to a space that adheres to the core principles of creativity as perceived by humans.*

Keywords: Digital educational games, creativity metrics, semantic lateral thinking

Introduction

Human creativity is a multifaceted, vague concept, combining undisclosed or paradoxical characteristics. As a general notion, creativity adheres to the ability to move beyond traditional and established patterns and associations, by transforming them to new ideas and concepts or using them in innovative, unprecedented contexts and settings (Zhu, Xu, & Khot, 2009). "Human-creativity is something of a mystery, not to say a paradox", states Boden in her book *The Creative Mind* (Boden, 2004), when introducing us to the 'what' and 'how' of creativity. Apart from unveiling the mystery of human creativity, i.e. the ability to come up with ideas or artefacts that are new, surprising, and valuable, she also discusses how computers can help us understand it.

Along with such philosophical approaches, research results from neuroscience should also be considered in the process of revealing / understanding the human creative process. Such an example is the work of (Limb & Braun, 2008), who examine how the human mind perceives complex auditory stimuli e.g. music. In this case, they look at the brains of improvising musicians and study what parts of the brain are involved in the kind of deep creativity that happens when a musician is really in the groove. Their research has deep implications for the understanding of creativity of all kinds. In (Nachmanovitch, 1990), an improvisational violinist, computer artist and educator, in his book *Free play* states that creativity arises from bricolage, from working with whatever odd assortment of funny-shaped materials we have at hand, including our odd assortment of funny-shaped selves.

In the process of involving machines in the creative work, (Lubart, 2005) includes the case of Human-Computer cooperation during idea production and proposes a creative thinking strategy, which relies on random or semi-random search mechanisms to generate novel, unconventional ideas. The role of machines in this case is to implement random searches that challenge humans in the process of selecting/ generating new/ innovative ideas and perhaps turning them into creative products. In this context, the Semantic Lateral Thinking theory is particularly well-suited to establish the cooperative framework,

by implementing automated components that adhere to the theory and applying them to a suitable educational medium, such as open-ended digital games. In this paper, we discuss on the core characteristics of the Semantic Lateral Thinking theory, describe its application in a digital storytelling educational game and present metrics that help us quantify the impact of the overall process on fostering the creativity of the participating players.

The paper is structured as follows: Section 2 discusses some of the techniques proposed by the Semantic Lateral Thinking theoretical framework for fostering creativity. Section 3 briefly presents the application of those Semantic Lateral Thinking techniques in storytelling activities via the usage of appropriate computational tools. Section 4 showcases Creative Stories, a storytelling game that incorporates tools for introducing these tools in a gamified environment. Section 5 presents the scoring mechanism incorporated in the Creative Stories game, intended on quantifying the perceived creativity within the game. We conclude and indicate our future steps in Section 6.

Semantic lateral thinking (SLT) techniques

The term Lateral Thinking was invented by (De Bono, Lateral Thinking; Creativity Step by Step, 1970). It adheres to the tendency of self-organizing systems, such as the human brain, to form and move across asymmetric patterns. Tools and processes supporting lateral thinking aim to assist that "lateral" movement, providing the means to escape from a local optimum in a thinking process towards a more global optimum.

Semantic Lateral Thinking (SLT) involves the use of different conceptual Po (De Bono, PO: A device for Successful Thinking) (DeBono, 1990), a tool or an operator meant to provoke and dislocate from habitual patterns and forms, as well as disassociate established connections. Several techniques can support SLT e.g. Random Stimulus, and/or Re-conceptualization.

The main principle of the Random Stimulus technique is the introduction of a foreign conceptual element with the purpose of disrupting preconceived notions and habitual patterns of thought. The human actor is thus enforced to integrate/ exploit the foreign element in the production of a solution/ idea, and bring together disparate domains.

Randomness is the main guarantor of foreignness and, hence, of stimulation of creativity. Foreignness in this context has two main dimensions: (a) It is important that the human actor feels that he/ she has to somehow integrate/ exploit an element which is introduced completely from without, whose introduction is in no way under his/ her control. In some ways an intruder has to be re-conceptualized as a friendly aid; and (b) the new element should, at least initially, be as unconnected as possible to the subject/ type/ structure of the problem. By doing so, we someway ensure that no unconscious/ unobserved pre-established analogies, preferences and connections creep in the selection of the stimulus. After the presentation of the problem, one is asked to use creatively in the reasoning process the random stimulus provided.

Re-conceptualization involves the use of already established solutions and ideas in new environments. One is encouraged to exploit the potential of familiarity in the production of novel ideas. The familiar features of the established solution/ idea will re-inscribe themselves on the unfamiliar environment or appear in a new light.

The core distinctive characteristics of the SLT theory –randomness, introduction of external stimuli and re-consideration of an idea in a new environment- constitute digital educational games as a highly relevant platform for implementing and testing the effectiveness of the theory on fostering human creativity. The rest of the paper presents the application of the aforementioned SLT techniques in a storytelling game, via the usage of relevant computational tools, and showcases the proposed foundation for measuring its effectiveness on the attempt to foster creativity.

Incorporating semantic lateral thinking in storytelling activities

In this section, we briefly present a set of computational tools that transparently support Semantic Lateral Thinking techniques. These tools are focused on textual information, that is, the provided elements are words or phrases that act as the random / external stimulus for the humans involved in the activity. The underlying semantics and contexts of these words, are to be analyzed and lead to alternate paths of thought, thus fostering out-of-the-box, creative thinking.

Thinking Seeds Generator

The Thinking Seeds Generator provides a textual stimulus, having a varying semantic distance from its input. The produced word, as it is semantically distant from the initial state, is meant to act as an initiative to think out-of-the-box, re-contextualize ideas or be led to examine other perspectives of a problem / situation.

The input of the Thinking Seeds Generator is a seed phrase and a difficulty degree, which denotes the semantic distance between the random words that will be returned and the initial phrase. In this context, the semantic distance of two terms is the number of edges in the WordNet (Fellbaum, 1998) synset graph that must be traversed in order to reach to a synset starting from another- specific- synset.

The initial word to be used for the process is determined depending on the size of the textual input. When the input is a single word or a phrase up to three words, the input is processed as it is. In the case of larger texts, the service discovers the dominant terms within the text as follows:

1. Stopwords are removed from the text;
2. The remaining words are stemmed, and hashed with respect to their stem;
3. The three (3) most frequent stems are considered as dominant and the words having these stems are considered the dominant words within the text;
4. One of the dominant words is selected randomly as the seed to be used.

Following the process of determining the seed word, the service traverses the WordNet graph according to the following methodology:

1. Retrieve the WordNet synsets to which the seed word belongs;
2. Start from the synset containing the most words;
3. Select the word in the selected synset that belongs to the most synsets;
4. Repeat the first two steps for the selected word until the number of steps is equal to the set difficulty;
5. Select all the words belonging to the last visited synset.
6. Randomly pick one of the words belonging to this synset.

Webminer

The Web Miner is used to provide a summary of web content that is related to an input text segment of variable size. The summary is expressed as a tag cloud structure, i.e. the service returns a set of dominant words found in the examined web content, along with their frequency of appearance.

The input of the service is a word or short phrase, and an indicator that specifies if the service should only handle content safe for children. The service invokes a Search Engine wrapper and retrieves the HTML content of the first 50 results returned by the search engine. The content is cleaned using the boilerpipe library (Boilerpipe, 2016) in order to obtain the textual content of these pages. The stopwords present are removed and the

remaining content is stemmed –using the Snowball stemmer (Snowball, 2016) - and hashed in order to calculate the TF-IDF value for each distinct stem.

For each distinct stem, the most frequent form (with respect to its raw number of occurrences) is chosen to build a structure that encapsulates the {stem form, weighted frequency} pairs for the entire content.

Cloud of thoughts

The Cloud of Thoughts service provides a summary of a text segment, by examining the dominant words / short phrases found within the segment and returning them as a tag cloud structure. Its aim is to identify and present the major ideas present in the text, giving to the user a synopsis of others' thoughts that can lead him / her to change thinking perspectives, guiding his thought in a different path.

The service is invoked with the text to be summarized as its input. After the removal of stopwords, it calculates the logarithmically scaled term frequency as shown above. Finally, a structure that encapsulates the {dominant stem form, term frequency} pairs is returned.

Competitive thinking spaces

The Competitive Thinking Spaces service relies on the premise that a text segment may contain different aspects / points of view and the user can focus on a specific one to proceed with a line of thought. Thus, the service analyses a text fragment and identifies different groupings of the concepts included in the fragment, returning them to the caller.

In order to determine the thinking spaces, the service operates on a text segment provided as input. It discards stopwords and then clusters the obtained word set. If the produced clusters exceed a specified number (e.g. 4), the service reduces the clusters to this number, using the distances between the clusters. It finally returns to the calling agent a structure that encapsulates the clusters and the words / phrases belonging to each cluster.

Assistive computational tools

The assistive computational tools do not fall in the aforementioned categories and are not directly used by Creative Stories. Rather, they are necessary for providing the functionality of the other Semantic Reasoning Computational tool. The assistive computational tools include:

- The Search Engine Wrapper: it is used to obtain online information related to a subject defined by the tutor.
- The Text Clustering Service: it uses Hierarchical clustering to create clusters of these terms that provide indications of the major themes of discussion around the specific topics

The Creative Stories game

This section provides an example on the usage of the described computational tools in the context of Creative Stories, a storytelling game that uses the various tools in a gamified environment. We first present the setup phase for a Creative Stories game session. We proceed to demonstrate the execution of a Creative Stories game session and present the usage of the computational tools within the game.

Creative Stories session setup

The teacher defines the groups that will participate in the Creative Stories game session. He/ She defines the number of groups that will participate in the game session.

The next step is to define the parameters of the actual game that will be used for the game session. The teacher defines the story's theme, the range of difficulty for the input from the computational tools, and the way that the difficulty will progress during the game. Finally, the teacher can select the type of input from computational tools that will be used within the game. The Creative Input option will activate the Thinking Seed Generator and the Web Miner, while the Competitive Thinking Spaces option will activate the eponymous computational tool. In both game playing settings, the Cloud of Thought is used by the participating groups.

After the teacher has setup the described parameters, the game session can be activated and the students can enroll as members of their group and play the game.

Creative Stories conceptual design

After enrolling in the game session, the players are presented with a multi-panel environment from which they can provide their input, observe the activity of the other groups and get feedback from the computational tools. The central panel presents the story fragments created so far by the group (Group 2 in the example) and contains the input field for writing and submitting a new story fragment, along with an indication for the points that will be added for the specific fragment, as they are calculated by the relevant computational tool (analyzed in section 5 of the paper). In the right-side panel, the players can see the progress of the other teams participating in the game session, along with tag clouds that summarize the stories of the other groups and can be used as inspiration and guidance for progressing with the story. These tag clouds are created via the usage of the Cloud of Thoughts tool, called with each group's story as input.

In the left-side panel, the players can observe their current score and use the input from the computational tools for obtaining input to be used within their story. There are two distinct modes of playing the game with respect to the type of automated input that is used, the Creative Input and Competitive Thinking Spaces modes. The next subsections briefly describe the characteristics of each mode.

Creative input. Figure 1 depicts a mock-up of the game screen in the case that the Creative Input option was selected by the teacher. In this mode, the tools used for providing input to the players are (a) the Thinking Seeds Generator and (b) the Web Miner. In (a) the players are called to use the word or phrase provided by the Thinking Seeds Generator in their story fragment. In (b), the players are called to use all the words included in the tag cloud produced by the Web Miner in the story fragment. Each group is free to modify the difficulty (semantic distance) of the provided input and retrieve a different set of thinking seeds and tag clouds by hitting the refresh button.

Competitive Thinking Spaces. Figure 2 showcases the game screen in the case that the Competitive Thinking Spaces mode is active. In this case, the game uses the Competitive Thinking Spaces tool to provide additional input to the players. The input for the tool is the accumulation of the story fragments produced so far by all the participating groups. The groups try to use every word within one thinking space in order to "conquer" the respective space. When this is accomplished, the particular space becomes unavailable for the remaining groups, which have to focus on a different space.

Creativity points awarding

As mentioned in section 4.2, during a Creative Stories session, the participating groups are rewarded with Creative Points, determined by their usage of input from the computational tools, as well as, usage of information from the activities of the other players. The Creative Points are defined as the product of the base Creativity Points

returned by a Creativity Points Computation service and a modifier that depends on the usage of the aforementioned elements.

We use two distinct functions for calculating the Creative Points in Creative Stories, depending on the type of input selected for the specific Creative Stories session.

In the case that the Creative Input option is selected, the Creative Points are given by the following equation:

$$CreativePoints(T) = \left(1 + \prod_{i=1}^{N_T}\left(1 + \frac{difficulty_i}{10}\right) + n + \prod_{i=1}^{N_W}\left(1 + \frac{n * difficulty_i}{10}\right) - 2N_O\right)BasePoints(T)$$

In the equation, N_T is the number of times the player used the Thinking Seeds Generator services, N_W is the number of times the player used the Web Miner services, while N_O denotes the number of words that the player used and appear on the tag cloud created from the other players' stories. n is the number of words included in the tag cloud returned by the Web Miner.

In case the Competitive Thinking Spaces is used as the computational tool input for the game session the equation for the calculation of the assigned Creative Points is the following:

$$CreativePoints(T) = N_{Clusters}BasePoints(T) - \frac{1}{2}N_o$$

where, $N_{Clusters}$ is the number of clusters completed by the specific team, and N_o is the number of words that the team used from the tag clouds summarizing the stories of the other teams.
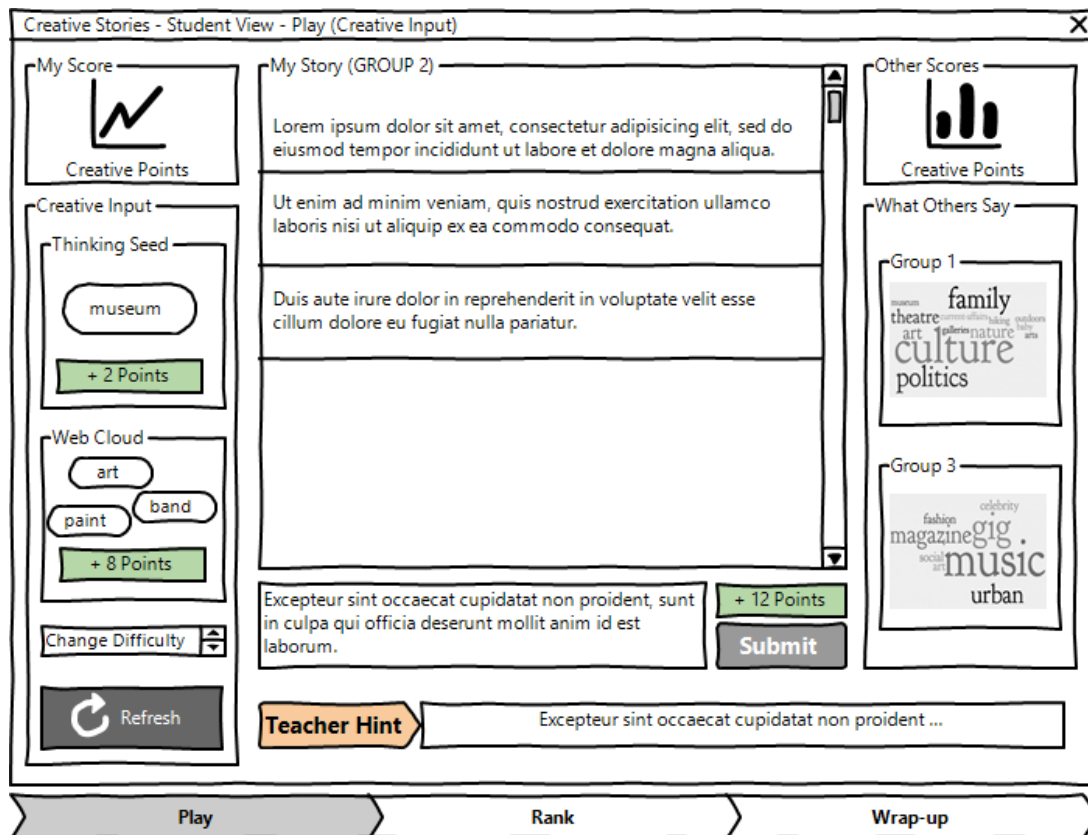

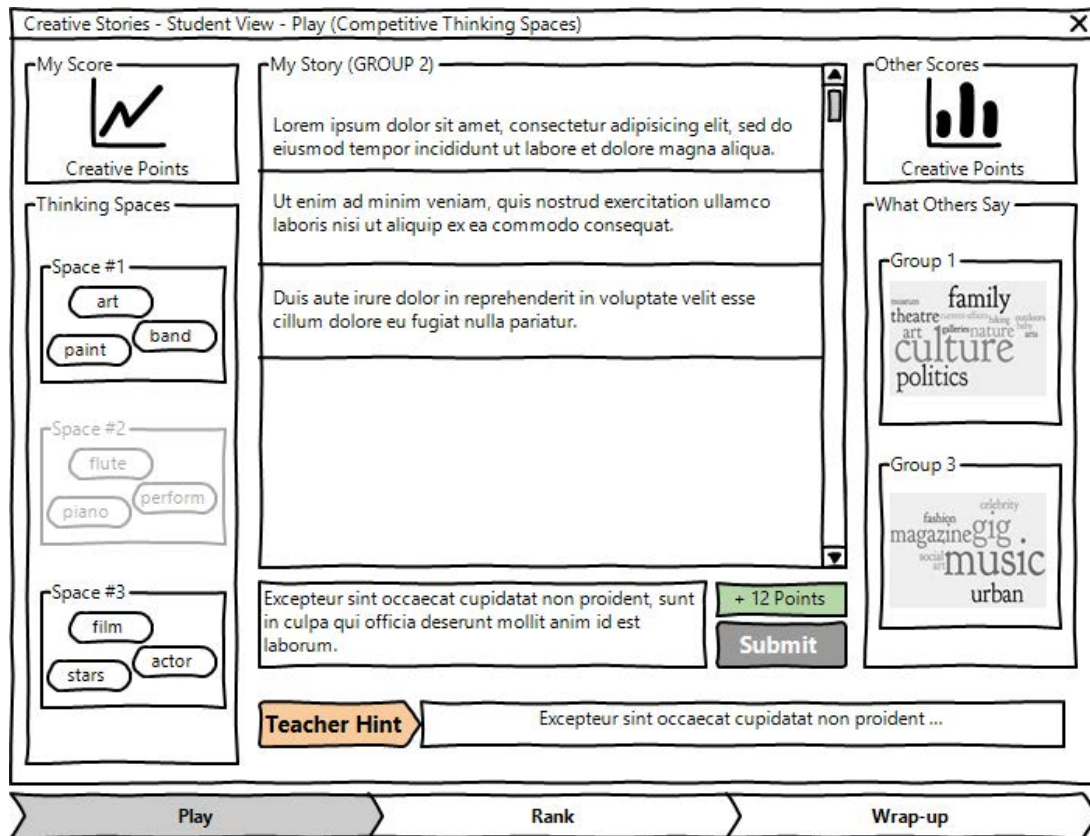Figure 1: Playing *Creative Stories* in the creative input mode

Figure 2: Playing *Creative Stories* with competitive thinking spaces

Creative Stories gameplay

After the user logins to the game, he/she selects the mission that he/she will play and whether he/she will play in single player or multiplayer mode.

At the game initiation, the player is presented with a multi-panel interface where the core game is played. The central panel presents the story created so far by the player and the input field, where the player will write the next segment of his/her story. At the left-side panel, the player is reminded of the central theme of the mission, and he/she can see the time remaining until the completion of the session. Furthermore, he/she is presented with a summary of the content created by the other players participating in the session. In the single player mode, the particular field is de-activated.
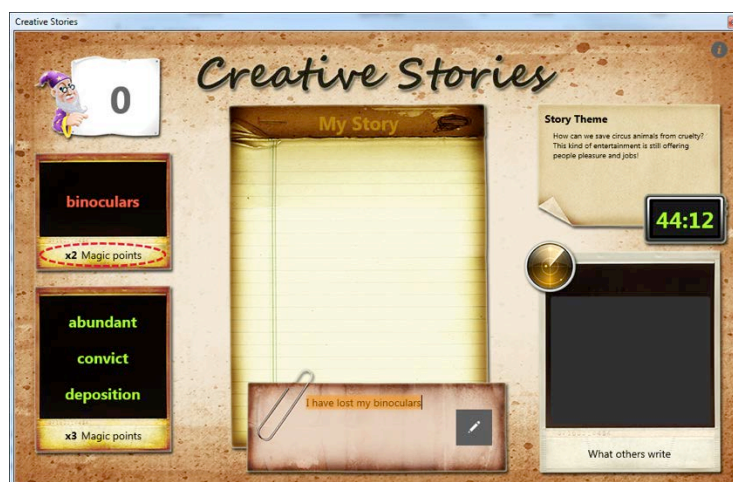

Figure 3: *Creative Stories* interface layout

As the game progresses, the user proceeds to writing his/her story, trying to use the terms suggested by the wizard. The game is finished either when the time allotted has run out, or by user selection, by tapping the game clock.

Figure 4: *Creative Stories* mid-session screenshot

After the completion of the game, the players are presented with their performance in terms of the main axes of creativity as described in the present document.

Figure 5: *Creative Stories'* creativity scores

Creative Stories is available as an Android application. It is available for all Android devices running Android 4.2 or newer and having a screen size of at least 7". The Google Play Store link for the app is:

https://play.google.com/store/apps/details?id=com.embarcadero.CreativeStories

Modelling the principal components of human creativity

In order to properly evaluate the impact of the application of the aforementioned lateral thinking techniques – via their incorporation in gamified applications – in creativity, it is

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essential to devise and apply a conceptualization of creativity which will allow the monitoring and evaluation of the user's creativity. Hence, it is important to construct a methodology for associating user in-game activity with a quantifiable creativity measure, so as to encourage him/her towards increasing that measure. Furthermore, it is important to assess that the used measure reflects the human perception for what actually constitutes creative activity and creative creation.

Within the field of Computational Creativity, significant effort has been devoted towards identifying variegating aspects of the creative process and constructing appropriate metrics for determining the degree that an artefact exhibits creativity with respect to these aspects. However, the formalization of a person's creativity (i.e. a creativity user profile) as a derivative of such creations is not straightforward, as it requires a transition to a space reflecting the core principles of creativity as perceived by humans. This becomes a necessity in domains where personalization goes beyond timely and personalized knowledge provision, targeting the encouragement and fostering of creative thinking. Thus, it becomes essential to develop methodologies for modelling creativity to support personalization based on creativity aspects / characteristics of users. The present section describes a user modelling framework for formulating creativity user profiles based on an individual's creations, by transitioning from traditional computational creativity metrics to a space that adheres to the principal components of human creativity. Furthermore, in this section we present the Creativity Profiling Server (CPS), a system implementing the aforementioned user modelling framework for computing and maintaining creativity profiles and showcases the results of experiments over storytelling educational activities.

Background

The usage of computational methods for producing creative artefacts, as well as, unveiling the essence of human creativity and using computers understanding it, is the subject of extensive debate (Lubart, 2005). Additionally, the creativity of a person can be expressed qualitatively by taking into account its origin in psychometric or cognitive aspects of their thinking process (Boden, 2004). Research on this direction has deep implications for the understanding of creativity of all kinds. In any case, while machines can mimic human creativity, or provide the necessary stimuli for encouraging and promoting the production of creative ideas and artefacts, it is not straightforward to assess the exhibited creativity by using automated techniques. Rather, most efforts have been focused on analyzing creativity on different aspects and producing different metrics, based on the nature of the examined artefacts.

Hence, the core assumption for building a user's creativity profile, is that his/her creativity is showcased by his/her creations, named Creativity Exhibits. These exhibits can follow different modalities, corresponding to the aforementioned reasoning patterns, e.g. texts, diagrams/pictures, actions etc.

The calculation of a creativity profile, constitutes the process of (a) measuring the creativity expressed by given creativity artifacts; (b) associating these measurements with dimensions of human creativity corresponding to the given dimension.
For achieving (a), we employ creativity metrics derived from computational creativity and formulate them in accordance to the characteristics of the examined exhibits. A number of different creativity metrics are proposed from the literature on computational creativity (Boden, 2004).

More specifically, Novelty reflects the deviation from existing knowledge/ experience and can be measured as a difference metric between what is already known and the given piece of content. Novelty is a generally accepted dimension of creativity within the area of computational creativity and an essential candidate for measuring elements of creativity within the human-created content when interacting with the machine. It has been used as

a heuristic for driving the generation of novel artefacts in exploratory creativity known as novelty search, an approach to open-ended evolution in artificial life (Lehman & Stanley, Exploiting Open-Endedness to Solve Problems Through the Search for Novelty., 2008). Surprise is another essential characteristic which may be represented as the deviation from the expected (Macedo, 2004). The higher the deviation the higher the perceived surprise. Surprise offers a temporal dimension to unexpectedness (Maher, Brady, & Fisher, 2013). Likewise, impressive artefacts readily exhibit (ease of recognition) significant design effort and may be described via two heuristics, Rarity (rare combination of properties) and Recreational Effort (difficult to achieve) (Lehman & Stanley, Beyond Open-endedness: Quantifying Impressiveness, 2012). These four metrics will be used to construct the creativity profile of a human user, as expressed by the artefacts that this user has constructed alone or as a participating member of a group of users. In the case of Textual Exhibits, examples of such artefacts include a written story, a dialogue and any other textual creation.

In (Karampiperis, Koukourikos, & Panagopoulos, 2014) we present a formulization of the Computational Creativity Metrics for Novelty, Surprise, Rarity and Recreational Effort over textual artefacts, inspired by the observations and concepts presented by (Ritchie, 2007). In the present work, we use these text-based metrics for the core aspects of creativity and examine their conformance with the human perception of what constitutes a creative artefact. We proceed to identify the deviations between these two perspectives (computational metrics and human judgment) and propose a model for transforming the automatic measures to a space that more accurately reflects the human opinion. In this way, the constructed human creativity profiles can be used for providing personalized material / content that is suitable for a specific user or addresses his/her limitations regarding creativity.

The rest of this section is structured as follows: We proceed to examine the correlation of the proposed metrics with the human perception of creativity. Afterwards, we build on these observations to propose a transition model from computational metrics to a two-dimensional orthogonal space which aims to closely reflect the way human beings perceive creativity. We present the experiments for assessing the effectiveness of the proposed model towards this goal, describe the architecture and functionality of the Creativity Profiling Server, a system that incorporates the proposed model and report on the experiments for a preliminary evaluation of the system.

Correlation of computational creativity metrics with the human perception of creativity
As a first step towards understanding the adherence of the proposed metric formulization with the human perception for creativity, we organized and conducted an experimental session based on storytelling activities. The session aimed to provide a preliminary evaluation for the overall approach, in order to acquire sufficient evidence that could justify future conducting of experiments at a larger scale, with a statistically significant participation and with participants bearing characteristics that are more representative of the general population.

For the execution of the experiment, we employed forty (40) human participants, split in ten (10) teams of four (4) members each. All teams were asked to construct a story, on a specified premise, the survival of a village's habitants under a ravaging snow storm. The stories were created incrementally, with twenty (20) fragments produced for each story. Following the completion of the stories, the teams were organized in two groups, each consisting of five teams. Without any interaction between the groups, each team was called to rate the stories of the remaining four teams belonging to their group, using a rank-based 4-star scale (i.e. the best story received 4 stars, the second-best story received 3 stars etc.). In this way, we obtained a ranked list of the five stories in each group. The goal of our experiment was to determine if, using the ranked lists of one of the test groups and

a formalized representation of the computational creativity metrics, we can identify their correlation and examine if the distribution of values for the metrics follow the pattern of human judgment. To this end, we define a constrained optimization problem over functions of the aforementioned metrics, which is described below.

Hence, the obtained results indicate that, while the proposed computational creativity metrics are correlated with the perception of humans for creativity, this correlation is not direct for all metrics. The following section discusses on the implications of these observations and details our approach for using the proposed metrics towards building a dimensional plane that more accurately reflects the human perspective for creativity.

Transferring computational creativity metrics to the human perspective

As stated, each textual artefact can be described by 4 computational creativity metrics, namely, Novelty, Surprise, Rarity and Recreational Effort. Following the formulation of the creativity metrics, therefore, the next hypothesis that was examined was the reduction of the dimensional space for representing creativity as expressed through creative artefacts, in an orthogonal space. In order to effectively conceptualize human creativity, orthogonality is a particularly desirable attribute of the conceptualization space to be used, since it allows the examination of independent variables when trying to analyse and influence / encourage certain creativity aspects. Hence, the first step towards identifying the adherence of the computational creativity metrics with the human perspective is to examine the orthogonality of the proposed metrics formulation. To this end, we ran an experiment for calculating the four basic computational creativity metrics on two datasets derived from distinct and distant domains, and determined whether the four metrics are orthogonal.

The first dataset comprised transcriptions of European Parliament Proceedings (Koehn, 2005). Given the formulation of computational creativity metrics described in (Karampiperis, Koukourikos, & Panagopoulos, 2014), we consider as a "story" the proceedings of a distinct Parliament session and as a fragment the speech of an individual MP within the examined session. The second dataset was derived from a literary work, Stories from Northern Myths, by E.K. Baker, available via the Project Gutenberg collection. In this case, the story is a book chapter and the story fragment is a paragraph within the chapter.

Table 1. Computational metrics correlation: Formal verbal transcriptions

	Novelty	Surprise	Rarity	R. Effort
Novelty	1.00000	0.13393	0.12329	-0.40681
Surprise	0.13393	1.00000	0.26453	-0.43151
Rarity	0.12329	0.26453	1.00000	-0.33499
R. Effort	-0.40681	-0.43151	-0.33499	1.00000

Table 2. Computational metrics correlation: Literary work

	Novelty	Surprise	Rarity	R. Effort
Novelty	1.00000	-0.64243	0.10392	-0.10762
Surprise	-0.64243	1.00000	0.07376	-0.02538
Rarity	0.10392	0.07376	1.00000	-0.03882
R. Effort	-0.10762	-0.02538	-0.03882	1.00000

In total, we examined 50 distinct parliament sessions from the EuroParl dataset and 40 chapters from the storybook. Based on the obtained results, we calculated the correlation between the four computational creativity metrics. Tables 1 and 2 provide the correlation values between the four metrics. It is evident that the computational creativity metrics by themselves are not orthogonal. In order to better approximate the human perception for

creativity, we propose the following abstraction for modelling the examined aspects of creativity to a space more closely resembling human thinking:

- Novelty is the perspective to be held as the one dimension of the dimensional space, as the conducted showed that it has a monotonic incremental relation with the perception of humans on what is creative. Furthermore, it is a generally accepted dimension of creativity (Ritchie, 2007).
- Atypicality, that is, the tendency to deviate from the norm without actually breaking through. In other words, to what extend (without necessarily being novel) the artefact differs from the ordinary (thus being surprising, rare and difficult to construct)

We consider Atypicality as a combination of the Surprise, Rarity and Recreational Effort metrics, each bearing a different weight towards determining Atypicality. These two axes also provide a rough conceptualization of the two major qualitative aspects of creative work: whether the said work is visionary, i.e. it provides a groundbreaking approach on a given field; and whether it is constructive, i.e. it uses in a novel way established techniques and ideas in order to produce a high-quality artefact. As stated, Novelty has an analogous and close to monotonic association with the human judgment for creativity. Therefore, and in order to satisfy our requirement of orthogonality, we consider Novelty as the strictly defined dimension of our space and seek for the formulation of Atypicality that results to a dimension orthogonal to Novelty.

More specifically, let Atypicality of a text t be the normalized weighted sum of its Surprise, Rarity, and Recreational Effort:

$$A(t) = \frac{w_s Sur(t) + w_r Rar(t) + w_e Eff(t)}{w_s + w_r + w_e}, \text{ with } w_s, w_r, w_e \in [-1,1] \ .$$

We aim to find the weight values that constitute Atypicality orthogonal to Novelty, i.e. those weight values for which Correl(Novelty, Atypicality)= 0. We thus define the following optimization problem:

$$Minimise \sum_{i=1}^{n} (\ Correl(Novelty_i, Atypicality_i) \ )^2, \text{ s.t. } w_s, w_r, w_e \in [-1,1]$$

where n is the number of the combined datasets.

The resulting model defines two orthogonal axes, Novelty and Atypicality, which define the space for measuring and characterizing the observed creativity, as a Euclidean vector, the length of which indicates the quantitative aspect of the creativity exhibited by the artefact, while its direction indicates the tendency for either Novelty (visionary creativity) or Atypicality (constructive creativity). The observed correlation in the case of the formal verbal transcription dataset reached 2.986E-07, while in the case of the literary work dataset the correlation reached 1.436E-07.

The Creativity profiling server
The Creativity Profiling Server (CPS) allows the storage, maintenance and update of creativity profiles of users using creativity exhibits that are produced from applications of the outside world. CPS provides a simple and straightforward API in order to expose its functionalities and to facilitate the communication with the outside world. Through the CPS API, the example application can submit creativity exhibits and receive the corresponding creativity measurements, create group of users and finally receive the creativity profile of a user. The aforementioned functionalities and the internal structure of CPS are depicted in Figure 6.
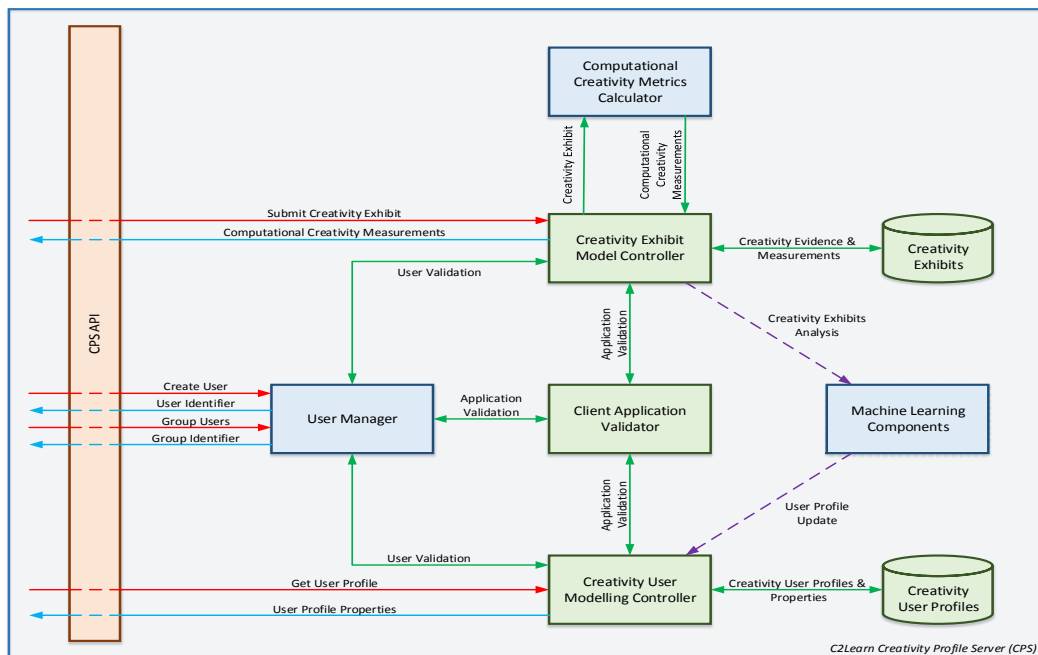
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Figure 6: CPS Architecture

The distinct modules incorporated in the CPS Architecture are the following:

- Client Application Validator: The module is responsible for ensuring that a client request is originated from an application registered to CPS.
- User Manager: This module is responsible for ensuring that client requests contain a valid user profile ID. Also User Manager is responsible for creating and destroying groups by joining and disjoining user profile properties respectively
- Creativity Exhibit Model Controller: This module is responsible for storing, maintaining and updating the creativity exhibits delivered by applications and also forward the creativity exhibits to the Computational Creativity Metrics Calculator: This module is responsible for calculating all the metrics of a creativity exhibit regarding of its type.
- Creativity User Modelling Controller: This module is responsible for storing, maintaining and updating the Profile Properties of each User Profile in CPS. Also this module delivers to client applications the properties of particular user profiles.
- Machine Learning Components: This module is responsible for calculating the value of the Creativity Profile Properties of a given user.

In a typical situation an application creates a user through the CPS API. The CPS API send the request to the User Management. Afterward User Management verifies through the Application Validation module that the application is registered to CPS. Since the application is validated User Management creates a unique user profile id and sends it to the application. Since a user profile is created then the application can submit creativity exhibits of this user. More specifically the application submits the creativity exhibit to the CPS API along with type of the creativity exhibit and the timestamp the creativity exhibit was created. After submission the API sends the creativity exhibit and its type to the Creativity Exhibit Model Controller module. After validating the user and the application through the User Management and the Application Validator respectively, the module sends the creativity exhibit to the Computational Creativity Metrics Calculator module. The Computational Creativity Metrics Calculator returns back the measurements of the creativity exhibit. Afterwards, the Creativity Exhibit Model Controller module stores the

creativity exhibit along with the measurements to the CPS database. Finally, the Creativity Exhibit Model Controller invokes the Machine Learning Components. Machine Learning Components take as input the creativity exhibit and calculate the values of the profile properties of the user. Afterwards the newly calculated values are send to the Creativity User Modelling Controller module, which stores the values to the CPS database.

Once a user creativity profile is created, then the application can request through the CPS API the User Profile Properties and also the Model which describes the profile. After sending the request to the API, the request is redirected to the Creativity User Modelling Controller module. This module, after validating the user and the application through the User Management and the Application Validator respectively, retrieves from the CPS database the properties for the corresponding user and send them back to the application.

Preliminary CPS evaluation

In order to obtain a preliminary assessment for the effectiveness of the proposed approach, we conducted a two-phase experiment in order to determine (a) the degree to which the selected computational creativity metrics conform to the opinion of experts regarding the creativity exhibited in a textual artefact and (b) the degree to which the proposed model for human creativity reflects the opinion of such experts.

For the purposes of the experiment, we employed twenty students who were asked to produce five stories each under pre-defined topics. For the first stage of the experiment, we sampled the stories produced during the aforementioned story writing session, randomly selecting two stories by each student, and asked five experts to rank them with respect to their creativity, as the latter is perceived by each of these experts. We then compared the ranking results with the ranking derived from the results produced by the CPS. For the second stage of the experiment, we picked the complete set of stories (i.e. five stories) for five of the users and asked from the same five experts to rank these users with respect to their creativity, using as evidence the produced stories. We then compared the expert ranking to the one produced by the CPS.

In order to evaluate the similarity between the rankings of the experts and the rankings of the CPS, for the textual exhibits' and the users' ranks, we employed a metric based on Kendall's Tau, defined by the following equation:

$$Success = \frac{1}{2} + \frac{N_{concordant} - N_{discordant}}{n(n-1)}, \text{ where } N_{concordant}$$

stands for the concordant pairs of ranked exhibits or users,

$$N_{discordant}$$

stands for the discordant pairs when comparing the ordering of the experts and the CPS and *n* is the number of the examined exhibits or the users. We calculated this metric for the series of textual exhibits rankings and the series of participating users' rankings. The following table presents the summary statistics of the two Success metric series we had as an outcome.

Table 3. Correlation coefficient between expert and CPS rankings

	Textual Exhibits	Users
Min Success	0.58	0.56
Average Success	0.74	0.71
Max Success	0.89	0.88

Although the results are promising and indicate a strong connection between the creativity measured by the proposed model and the creativity as perceived by humans, it is important to notice that further and larger-scale experimentation is needed in order to better understand the extent as well as the nature of this connection. The population sample is too small to allow us to generalize the reported findings, and it is expected that the expansion of the experiments to a larger and more diverse set will likely lead to a decrease of the similarity between the modeled and the human perception of creativity.

Conclusions

In this paper, we presented the Semantic Lateral Thinking (SLT) techniques suitable for fostering creativity, which can be used in storytelling educational activities. We defined a set of computational tools facilitating the implementation of the aforementioned techniques in a digital storytelling game. Finally, we demonstrated the mechanics of such a game, Creative Stories, which builds upon the usage of a Creative Scoring mechanism for quantifying the impact of the SLT stimuli within a story.

The paper also showcases our findings towards transitioning from computational creativity metrics associating specific attributes of text artefacts with creativity aspects to a creativity calculation model that better reflects the human perception of creativity. Furthermore, the present manuscript provides a summary of the architectural design and functionality of the Creativity Profiling Server (CPS).

Our future work will focus on examining the correlation between the usage of these stimuli and the creativity as perceived by using traditional creativity metrics. Towards this objective, Creative Stories will be used in real-world educational settings, and the obtained results will be analyzed in order to assess the effectiveness of SLT on fostering creativity via its usage within digital educational games.

Towards the continuation of our research regarding the modeling of human creativity, we aim to examine the effectiveness of the current model in more complex experiments, examining textual exhibits from different domains and modalities (prose, poetry, speech) in order to obtain a more general reflection of the human perception of creativity. Observation over more open-ended experiments will likely lead to further refinements and extensions of the proposed human creativity model.

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Biographical information

Antonis Koukourikos holds a BSc in Computer Science from the University of Crete and is a PhD candidate in the Department of Digital Systems of the University of Piraeus. Currently, he is a member of the Institute of Informatics & Telecommunications (IIT) of the National Center for Scientific Research "Demokritos" (NCSR-D). His main scientific interests are in the areas of Ontology Matching and Evolution, Linked Data Management, and Natural Language Processing.

Contact: kukurik@iit.demokritos.gr

Dr. Pythagoras P. Karampiperis, holds a Diploma and MSc in Electronics and Computer Engineering and an MSc in Operational Research, all from the Technical University of Crete, Greece. He also received a PhD on Adaptive Educational Hypermedia Systems from the Department of Digital Systems, University of Piraeus. Currently, he is the head of Computational Systems & Human Mind Research Unit at the Institute of Informatics Telecommunications (IIT) of the National Center of Scientific Research "Demokritos" (NCSR-D). His main scientific interests are in the areas of Computational Creativity, Machine Learning, Technology-enhanced Learning, and Semantic Web Technologies.

Vangelis Karkaletsis is a Research Director at NCSR "Demokritos", and head of the Software and Knowledge Engineering Laboratory of the Institute of Informatics and Telecommunications. His research interests are in the areas of Language and Knowledge Engineering, as applied to content analysis, natural language interfaces, ontology engineering, personalization.