Creativity Support System for cake design

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Abstract

In this paper, a new formulation of Creativity is presented in the context of Creativity Support Systems. This formulation is based on the central ideas of the theory of Boden. It redefines some concepts such as *appropriateness* and *relevance* in order to allow the implementation of a support system for creative people. The approach is based on the conceptual space proposed by Boden and formalized by other authors. The presented formulation is applied to a real case in which a new chocolate cake with fruit is design. Data collected from a Spanish chocolate chef has been used to validate the proposed system. Experimental results show that the formulation presented is not only useful for understanding how the creative mechanisms of design works, but also facilitates its implementation in real cases to support creativity processes.

1. Introduction

Creativity Support Systems (CSS) can be defined as systems capable of enhancing human creativity without necessarily being creative themselves. They can act as a creative collaborator with scientists, designers, artists and engineers. CSS consists of applying technology to assist humans in *thinking outside the box* and expanding their exploration boundaries generating ideas that have never been imagined before [1].

Creativity can be found in almost all human activities, not only in artistic activities such as paintings, sculpture, music, literature or architecture, but also in engineering, software development, scientific discoveries and others. Creativity is assumed to be closely related to the rational decision-making process. In the literature, decision-making processes are normally considered to be composed by four steps: *Framing the decision*, *generating alternatives*, *evaluating the alternatives* and *choosing and implementing the chosen alternative*. Creativity is mainly associated to the second step: generation of alternatives. Alternatives are normally generated by reviewing processes that were used in the past or were used in different frameworks with subtly common aspects. The skills of creative people are on the one hand to find these apparently different frameworks with common characteristics and, on the other hand, to evaluate the alternatives taking into account the relation between frameworks.

CSS has a potential role in the food industry. Today, a significant portion of a food services or manufacturers' business is focused on generating new ingredient combinations and finding new flavors that will be a commercial success. This research will allow chefs and other food professionals to be more creative and to shorten the time to bring a new flavor to market by helping them in the development process.

In this paper, a new formulation of the central ideas of the well-established theory of Boden about creativity is presented. This new formulation redefines some terms and also reviews the formal mechanisms of exploratory and transformational creativity based on a conceptual space proposed by Boden and formalized by others authors in a way that facilitates the implementation of these mechanisms. To illustrate this formulation, a computational system is developed and tested in the support process of a creative chocolate designer. The study has been conducted jointly with the chocolate chef Oriol Balaguer team (*http://www.oriolbalaguer.com*). Oriol Balaguer is one of the Spanish most awarded pastry chef who is actively involved in the research and development of new products.

The remaining of the paper is organized as follows: first, a literature review on computational creativity is conducted. In the third section, the proposed CSS methodology is presented. A real case example where the methodology proposed is applied is given in section four and, finally, in the last section conclusions and future work are discussed.

2. Computational creativity: State of the art

Creativity should be regarded as one of the highest-level cognitive functions of the human mind. It is a phenomenon whereby something new and valuable is produced such as an idea, a problem solution, a marketing strategy, a literary work, a painting, a musical composition or a new cookery recipe. Authors have diverged in the precise definition of creativity beyond these two features: originality (new) and appropriateness (valuable).

One of the few attempts to address the problem of creative behavior and its relation with Artificial Intelligence was done by Margaret Boden [3][4]. She aimed to study creativity processes from a philosophical viewpoint focusing on understanding human creativity rather than trying to create a creative machine.

Boden distinguishes between creativity that is novel merely to the agent that produces it and creativity that is recognized as novel by the society. The first is usually known as P-creativity (or "psychological creativity") and the second is known as H-creativity (or "historical creativity").

The most important contribution of Boden study is the introduction of the idea of conceptual space composed by partial or complete concepts. She conceives the process of creativity as the location and identification of a concept in this conceptual space. The creative process can be performed by exploring or transforming this conceptual space. If the conceptual space is defined through a set of rules, whenever these rules are satisfied, the creative process can be thought as finding new and satisfactory elements of this space. This is the kind of creativity which Boden calls exploratory creativity. If the rules defining the conceptual space can be changed, then the process is called transformational creativity.

However, from Boden's study, it is not clear how the rules give rise to a particular conceptual space and, therefore, what is the true difference between exploring the space and transforming it. In order to clarify and to formalize the creative process, G. A. Wigging [5] presented several papers in which emphasized the notion of search as the central mechanism for exploratory creativity and the notion of meta-level search related to transformational creativity. Wiggings proposes to define a universe of possibilities U which is a superset of the conceptual space. The universe is a multidimensional space, whose dimensions are capable of representing all possible concepts which are relevant to the domain in which we wish to be creative. For transformational creativity to be meaningful, all conceptual spaces are required to be subsets of U.

Wiggings conceives exploratory creativity as a search of concepts in a specific conceptual space. The process involves three set of rules that can be denoted as acceptability, appropriateness and strategy. The first set of rules is associated to the conceptual space membership. Moreover, acceptability is related to the style. On the other hand, appropriateness rules are related to the value of the concept. Valuable concepts may become successful regardless of being acceptable according to the rules associated to the acceptability. This second set of rules that defines the value of a concept is much difficult to define because it depends on cultural and aesthetic aspects, specific context, personal mood, etc. It is important to remark that, in this context, appropriate means suitable to the task, but above all original and surprising. Finally, there exist a third set of rules associated to the search strategy. For instance, some people prefer to work "top-down", others "bottom-up", others rely on ad-hoc methodologies, using informed or uninformed heuristics and even at random. Wiggings points out that by separating acceptability and strategy rules, situations where different designers, each with a personal way of finding new ideas, are working within the same style can be described (a shared notion of acceptability).

From Wiggins perspective, the interaction of these three sets of rules (acceptability, appropriateness and strategy) leads to the exploratory creativity process. However, although working within three invariant sets of rules may produce interesting results, a higher form of creativity can result from making changes of these rules (transformational creativity). In other words, on the one hand, exploratory creativity consists of finding a concept in a specific conceptual space, following a specific strategy and assessing it using a specific appropriateness set of rules. On the other hand, transformational creativity consists of the same process than exploratory creativity but changing the conceptual space, the search strategy or the appropriateness assessment.

Besides Wiggings work, there have been other formalizations of specific aspects of the computational creative process [6][7][8]. Although these formalizations are very helpful in clarifying the nature of creative computation and have enabled some applications in diverse domains including graphic design, creative language, video game design and visual arts [9], the details of most of them are unspecified and the concepts they include are not easy to implement. The current paper starts from the central ideas of Boden and Wiggings and redefines the formal mechanisms of exploratory and transformational creativity in a way which facilitates the implementation of these mechanisms.

3. The proposed CSS

As in Wiggins theory, let's start by considering a universal set of all concepts, $\mathcal{U}$. The idea is that $\mathcal{U}$ is universal enough to contain concepts for every type of artifacts that might ever be conceived. In addition, we define a framework F, as the object $F=\{C, a(), r()\}$ where $C\subset \mathcal{U}$ is the *H-conceptual space* (or "historical conceptual space") formed by all concepts related to the framework F, and $a()$ and $r()$ are maps from $\mathcal{U}$ to R. $a()$ is the *appropriateness* and $r()$ is the *relevance*. The first map is related to the success of considering this concept while the second one is an objective measure of the relation of the concept with the framework. The relevance is the result of the experts' activities. A naïve relevance measure might be a 0/1 value (1 if $x\in C$ and 0 otherwise) but it is possible to consider more complex measures containing more information about the relation between the concept and the framework. The underlying idea is that, although evaluating the appropriateness requires some kind of talent or expertise, relevance evaluation can be performed by means of an objective analysis of other problems in the framework. Thus a concept with high relevance in a framework does not necessarily have high appropriateness. In fact, an original concept always has low relevance in the considered framework.

In the proposed CSS, it is assumed that an expert *i* on a given framework $F_o = \{C_0, a_0(), r_0()\}$ knows value $a_o(x)$ for some subset C^i_0 of C_0, but values $a_o(y)$ for those concepts $y \notin C^i_0$ are unknown by the expert. Following Boden, we call C^i_0 the *psychological* or *P-conceptual space*, that is, the concept space associated to the framework F_o and to the expert *i*. At the same time, the expert does not necessarily know $a_i(x)$ for another framework F_i. Thus, it is considered that expertise of the expert is only guaranteed in a single framework.

In this model, we consider that function *a*() depends on the framework but not on the expert. The difference between experts of the same framework is related to the different P-conceptual spaces, all them subsets of the H-conceptual space. In addition, the activity of an expert is not only to evaluate concepts but specially selecting them following some selection strategy. Once a new concept is selected and applied by the expert, if this does not belong to the P-conceptual space, the expert can obtain the value of *a*() and hence, the P-conceptual space and/or the H-conceptual space is extended to include this new concept.

Let us consider a set of different frameworks $F_1, F_2, \ldots, F_m$. If $x \in \mathcal{U}$ is a concept, we can consider the *relevance vector* of *x* respect to the set of frameworks $F_1, F_2, \ldots, F_m$ as $\Phi(x)=(r_1(x), r_2(x), \ldots, r_m(x))$. This vector describes the membership relation of *x* to the set of frameworks $F_1, F_2, \ldots, F_m$. If $x \notin C_i$, then $r_i(x)=0$. Following Boden notation, if the expert only explores the conceptual space C^i_0, the task is just exploratory creativity. If the expert explores beyond C^i_0 by extending it, transformational creativity is then performed. The utility of CSS relies on proposing new concepts $y \in \mathcal{U}$, $y \notin C^i_0$ to the expert from the relevance information of these concepts with respect to frameworks different to the one initially considered and from the relation among all these frameworks.

The system that we consider is able to propose new concepts $y \in \mathcal{U}$, $y \notin C^i_0$ with likely high $a_0(y)$. In order to predict how valuable a new concept *y* is, i.e $a_0(y)$, our hypothesis is that no obvious relations between different frameworks exist, therefore the *appropriateness* $a_0(y)$ and the *relevance vector* $\Phi(y)$ are closely related. In this sense, it is considered that concepts with similar relevance vectors on the current framework should have similar appropriateness function. This hypothesis could not be true for a small set of frameworks but seems to be true for larger ones.

Given the relation between appropriateness and relevance, our CSS will use the set C^i_0, or a subset of it, as a training set in a learning system in order to extract the relation between appropriateness in F_0 and the *relevance vector* in a set of frameworks $F_1, F_2, \ldots, F_m$. Once trained, we only have to feed the CSS with other concepts and the system will propose those concepts with expected high appropriateness.

We propose in this study an illustrative example to validate our formulation and hypothesis. The example will highlight the relation between the appropriateness in a given framework with the relevance of the concept respect other apparently distinct frameworks.

4. Experimental framework: designing a new chocolate cake with fruits

To illustrate the implementation of the ideas presented in the previous section, let us consider the following creative problem: creating a new chocolate cake by combining dark chocolate with a fruit to obtain a highly accepted product. The expert that has to create the new chocolate cake has a large experience in combining chocolate with many different ingredients –cheese, liqueurs, olive oil, nuts and, of course, fruits. Due to his experience, he knows whether several combinations of specific types of chocolates and fruits are suitable or not but, of course, he does not know how well chocolate combines with all existing fruits. Thus, a CSS is going to be developed according to the methodology presented in the previous section in order to assist the expert in creating suitable new combination.

In our case, since we constrained the problem to combine fruit and dark chocolate, the universe $\mathcal{U}$ is formed by all fruits. The P-conceptual space C^i_0, which consists in all fruits that the expert knows whether they blends in well or not with dark chocolate, is just a subset of $\mathcal{U}$. Moreover, the expert is able to assign a value $a_0(x)$ for all $x \in C^i_0$, which is represented as a qualitative value (very bad, bad,…, good and very good). The objective of our CSS consists in suggesting other fruits $y \in \mathcal{U}$, $y \notin C^i_0$, with a high predicted value function $a_0(y)$, i.e. they are valuable to the expert.

Following the proposed CSS methodology, we can learn the value *a*() of a fruit respect to the dark chocolate (framework F_0) through the way it is related to other frameworks. In this example we are considering only frameworks related with recipes and ingredients, but other alternatives could also be considered. For obtaining the relevance value with respect to a framework we have made use of a large recipe databases and we counted the number of recipes containing both the fruit and the term associated to the framework.

Although the combination of fruits and dark chocolate could have nothing to do with the combination of fruits and rice, for instance, according to our assumption, given a fruit that has high value of a_0 and has similar relevance vector than another unknown fruit, this unknown fruit could be considered as a good option for extending the search.

4.1 Data collection

In order to validate our method, we used the data provided by the chocolate chef Oriol Balaguer who assessed, according to his expertise, the combinations of 28 different fruits respect to their suitability to combine with dark chocolate [10]. In addition we have considered 14 frameworks aside from the main framework (dark chocolate). All considered frameworks consisted in ingredients used in cooking, but not necessarily in pastry making. In this implementation of the CSS, we are not focusing on the frameworks selection problem. Instead, we think that the ad-hoc selection for this example is enough for illustrating how the formulation presented can be implemented and we leave framework selection as a near future work.

In order to obtain the relevance vector for each fruit we used the online database of recipes *www.allrecipes.com*. Table 1 depicts the list of the 28 fruits and 14 frameworks. The last column of this table shows the qualitative assessment provided by the expert following the labels in table 2. Values of table 1 are obtained by searching both terms simultaneously (fruit and framework). This value represents the number of recipes of the database containing both terms.

We can think that this list of 28 fruits constitutes the conceptual space and the CSS can learn the relation between the relevance vector of these fruits with respect to the 14 frameworks and the assessment provided by the expert. Once this relation is captured the CSS can obtain the relevance vector of other fruits respect to this set of frameworks. It calculates the predicted value a_0 for these new fruits and proposed those which have high predicted a_0.

Table 2. Labels and linguistic meaning in the fruit assessment by the expert.

Labels	**Linguistic labels**
1	It does not combine at all
2	It does not combine well
3	Combines well
4	Combines very well
5	It is an excellent combination

4.2 CSS training and results

Our proposal is based on the existing relation between the appropriateness of a concept with respect to a framework and the relevance vector of this concept with respect to a set of other frameworks. To validate this, we used data from Table 1 for obtaining this relation and assessing its significance. This validation is performed twice by using, on the one hand, the complete range of expert's valuation shown in Table 2 and, on the other hand, using just a binary valuation (suitable or not suitable) that simplifies expert's assessment. We used a multiclass and a two-class support vector machines (SVM) and we validated it by means of a leave one out cross-validation process. If the SVM can correctly estimate the appropriateness of a fruit from the relevance vector, it can be used to propose new fruits with high predicted appropriateness.

Table 1. List of the some fruits assessed by the expert (last column) and the list of some frameworks considered in this example.

	rice	**chicken**	**vinegar**	**sugar**	**pie**	**caramel**	**bread**	**app**
Apple	331	494	606	2265	586	152	525	**1**
Pear	18	29	49	185	38	17	38	**1**
Quince	0	0	0	7	0	0	0	**2**
Apricot	53	80	51	250	30	6	51	**4**
Peach	26	44	49	374	150	3	53	**3**
Plum	55	119	91	142	18	2	89	**5**
Boysenberry	0	0	0	4	0	0	0	**4**
Blackberry	4	6	15	156	72	5	10	**4**
Strawberry	25	38	95	794	219	8	116	**4**
Bilberry	0	0	0	0	0	0	0	**5**

Parameters of the SVM were tuned by optimizing the geometric mean of sensitivity and specificity because data are imbalanced. In the first case, we employed a multiclass SVM (5 classes) with a Gaussian kernel. The best parameters obtained were C=1000 (regularization cost) and γ= 10000 (Gaussian kernel parameter). Software R and LibSVM library were used to train the datasets and predict accuracy of classifying. The total accuracy obtained is 42.86%. This value means that 42.86% of the times, the predicted value match to the expert assessment. Taking into account that there are 5 classes and the expected accuracy in the case of random values is 100/5=20%, the accuracy value obtained reaffirms our hypothesis. In the second case, pattern labels are changed in order to maximize CSS utility. Instead of labels showed in Table 1, a binary classification is employed in which the first class contains those combinations that are suitable to the expert and the second class those which are not. Patterns corresponding to values 3 and less are considered to the first class and the rest of patterns are considered to belong to the second class. In this case, the best parameters obtained by the tuning process were C=100000 and γ= 0.1. The total accuracy obtained is 85%.

Conclusion and Future work

In this paper we proposed a new formalization of the mechanism of creativity based on the Boden notions of *conceptual space* and *transformational creativity* through a search beyond the boundaries of this conceptual space. This study redefines the formal mechanisms of exploratory and transformational creativity introducing the concepts of framework and relevance of a concept with respect to a framework. The formalization presented has been implemented in a real example conducted with a Spanish chocolate chef.

The obtained CSS was able to propose new unknown fruits that are predicted to combine well with dark chocolate. The validation of the method has been performed using a SVM. The obtained results allow us to conclude that the assumptions on which the method is based are satisfied in this example.

It is important to remark that in this implementation we are not focusing on the frameworks selection problem. This is an important point to study in future work. Also, including both complete and incomplete concepts to the formalization presented will be an interesting topic for research.

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References

[1] C.J. Thornton, How thinking inside the box can become thinking outside the box. *In Proceedings of the 4th international Joint Workshop on Computational Creativity*, (2007).

[2] B. Shneiderman, Creating Creativity: User Interfaces for Supporting Innovation, *ACM Transactions on Computer-Human Interaction* **7**,1 (2000), 114-138.

[3] M.A. Boden, *The Creative Mind: Myths and Mechanism.* Weidenfiel and Nicholson, London, (1990).

[4] M.A. Boden, What is creativity? In M.A.Boden, editor, *Dimensions of Creativity*. MIT Press (1996), 75-118.

[5] G. Wiggins, A preliminary framework for description, analysis and comparison of creative systems. *Knowledge-Based Systems* **19** (2006), 449-458.

[6] G. Ritchie, Some empirical criteria for attributing creativity to a computer program. *Minds and Machines* **17** (1) (2007), 67-69 (2007).

[7] G. Ritchie, A closer look at creativity as search, *In Proccedings of the 3rd International Conference on Computational Creativity* (2012).

[8] J. Charnley, A. Pease and S. Colton. On the Notion of Framing in Computational Creativity, *In Proccedings of the 3rd International Conference on Computational Creativity* (2012).

[9] R. Manurung, G. Ritchie and H. Thompson. Using a genetic algorithms to create meaningful poetic text. *Journal of Experimental & Theoretical Artificial Intelligence* **24**(1), (2012), 43-64.

[10] N. Agell, G. Sánchez, M. Sánchez, F. Ruiz, Group decision-making system based on a qualitative location function. An application to chocolates design, *In Proccedings of the 27th International Workshop on Qualitative Reasoning* (2013).