CreEx: A Framework for Creativity in Cooperative Problem Solving

Adriana S. Vivacqua[1] and Jano M. de Souza[1,2]

[1] Computer Science Department, Graduate School of Engineering (COPPE)
[2] Computer Science Department, Institute of Mathematics (DCC/IM)
UFRJ - Federal University of Rio de Janeiro
Rio de Janeiro, BRAZIL
{avivacqua, jano}@cos.ufrj.br

Abstract. Creativity has become an important factor in recent years, as companies need to be able to quickly adapt to take advantage of new opportunities and handle fast paced changes in their environment. Creativity theorists have proposed models to explain creative thought that go beyond the individual to encompass social aspects of creativity. However, most existing research concerns an individual and doesn't address group aspects of creativity: interactions between team members that lead to innovative solutions for problems and new ideas. We are interested in computer support for collaborative creativity in problem solving. In this paper, we present CreEx, a framework to foster group creativity. By creating appropriate environments for the exploration of problems and discussion of ideas, we hope to enable users not only to generate novel solutions and capture decisions made, but also to learn about each other's domains and think differently.

1 Introduction

In recent years, fast paced changes have created a volatile environment, in which companies must function. Technological, political and economical changes have generated a need for flexibility, and companies must be able to adapt to survive. The problems companies must face have also become more complex, and can often only be handled by groups of individuals. These groups are frequently interdisciplinary in nature, which often means communication problems, since individuals will have different views of the problem at hand and different opinions on how to go about solving it. In an attempt to address these problems, companies have started to look for creative individuals and to create environments conducive to creativity.

Even though much research has been undertaken in creativity theory, most of it deals with individual creativity: how individuals interact with society, knowledge domains and experts on the field to produce a creative piece of work. We are interested in another aspect, one that hasn't been as explored thus far: group creativity and the in-group interactions that lead to creative results. Nowadays, much significant work is no longer undertaken by a lone creator, but by groups of individuals cooperating on a problem. The result of their interactions is a creative piece of work, and several members contribute to the construction of this shared artifact. While it may be the case that one member had a "creative breakthrough" and practically solved the problem by him or herself, this breakthrough occurred in a group context, possibly as a result of previous interactions between group members.

These interactions, the timing and knowledge involved, group dynamics and characteristics of individual members are the focus of our research. Supporting the collaborative creative process is our overall goal. In this paper, we present CreEx, a framework for creativity in cooperative problem solving. In the next section, we introduce some background work, followed by our framework in section 3 and in section 4 we wrap up with a discussion.

2 Background

In this section, we present some theories upon which we have based our work, a selection of the work most relevant to ours. It is important to note that we are most concerned with creative problem solving, for it has some constraining goals and objectives and more often involves groups of people than artistic expression (which also interests us, but isn't the focus of our research).

2.1 Creativity Theories

Although several different definitions exist, many authors define creativity as the process that leads to the production of an artifact that is both innovative and useful [1,2]. This definition involves a product (the artifact) and an assessment (of its usefulness), two important elements in problem solving. Several theories that attempt to explain the creative process exist, but we are especially interested in the ones that deal with the social aspects of creativity.

According to Csikszentmihalyi [3], creativity is produced by a system of three interacting elements: the individual, the domain and the field. The *domain* establishes shared symbols and rules; the *individuals* work within a domain to create something new and the *field* is a set of experts that judges these contributions to determine whether or not they are creative and deserve to be incorporated in the domain (effectively changing it). This is a cyclic process, through which knowledge is continually built on previous knowledge, with the best ideas being absorbed into the domain and the bad ones being discarded, in a process similar to the evolutionary.

Inspired by Csikszentmihalyi's system model of creativity, Shneiderman [4] proposed GENEX, a framework for the generation of excellence. According to him, the creative process is a four stage cycle: collect (gathering information from diverse sources); relate (consulting with individuals who may be able to furnish useful insights); create (experimenting with possibilities, trying to generate new solutions); donate (disseminating results to the community). A person can move from one stage to another as needed. This process should be supported by creativity support systems.

2.2 Problem Solving

Most problems faced by companies nowadays aren't easily tractable and demand unique, innovative solutions. These problems are often poorly defined and open-ended, having more that one possible solution and no clear stopping point. Therefore, the problem solving process stops when the group runs out of resources. Solving these so-called wicked problems is an iterative and exploratory process, where designers experiment with different paths [5], learning about the problem while devising a solution. The process is one of defining the problem as well as solving it.

Some problems are naturally interdisciplinary and require teams of experts from different domains to address it. The introduction of other individuals increases the potential for confusion and miscommunication, especially when these come from different backgrounds and disciplines. The number and diversity of individuals involved in the problem solving process is an additional complication, since it can make communication harder and fragment the group [6].

However, many complex problems can only be handled by pooling together resources from a number of different disciplines. Nissani [7] argues that forming interdisciplinary groups to handle complex problems leads to more creative solutions, as outsiders bring fresh insight and methodology to the problem at hand. Along similar lines, Fischer [8] suggests that, in interdisciplinary teams, the ignorance of one person in relation to another's field of expertise stimulated creativity. This "symmetry of ignorance" leads to discussions and explanations of concepts and points of view, which in turn leads to the generation of new ideas.

This is in general agreement with creativity research that points towards external stimuli as a factor for creativity. Santanen and colleagues [9] have proposed a model to explain how individuals reach creative solutions: knowledge is mapped in a person's mind as a network of concept frames, and creativity stems from the combination of unrelated (or distant) frames. Their model maps causal relations between certain factors such as cognitive load or external stimuli and the production of creative solutions to problems. Their experiments have ascertained that external stimuli contribute to more creative solutions: bringing up different concepts led to the generation of novel ideas and links between frames.

3 CreEx Framework

Creative work involves a certain amount of pre-existing domain knowledge and its transformation into new knowledge [11]. The combination of concepts from different domains allows problem-solvers to think in non-conventional ways.

There are two levels of interaction that should be addressed by a system attempting to support cooperative creative problem solving: extra-group and intra-group. Most creativity research has concerned itself with individual creativity and the relations of the individual with the external world (knowledge and experts). When studying a group of individuals, their in-group interactions (with shared knowledge and each other) are as important as those with the external world.

3.1 Handling the Problem

Many researchers recognize that, in problem solving, creativity stems from the way one looks at the problem, and that defining the problem is as important as finding its solution [3]. This is especially true of wicked problems, which are ill defined and open to interpretation.

When studying their methods, Cross [10] noted that designers not only work with domain rules, keeping track of basic principles that govern the domain and the application (such as physical laws and functionality), but also tend to introduce new constraints or characteristics they believe the solution should have, effectively reducing their search space while looking for a solution. This, in fact is a common way of dealing with poorly defined problems: one makes assumptions or introduces new characteristics or constraints, in an attempt to make the problem tractable. Through this process, the problem evolves into a solution. On the other hand, there is also a danger to lose oneself on speculation, never reaching a solution, or to lose track of the new characteristics introduced and the consequences of their introduction.

With this in mind, we are changing our working paradigm from *solving* a problem to *exploring* a problem, redefining and shaping its solution in the process. We believe it is important for a team to work with a shared representation to help guide the process and make sure all participants are on level ground regarding assumptions about the problem space and characteristics the solution should/must have.

Our problem model was created so that a team of individuals can explore and define the problem space as they work, keeping track of assumptions, constraints and features. This problem model has a set of basic interrelated elements:

- Problem: initial problem description, serves as root for graphs that represent the problem space. Includes a description of the problem and goals.
- Sub-problems: breakdowns of the bigger problem, are also problems and include goals, characteristics, etc.
- Characteristics: features the solution should have. May be determined by the client (a requirement), group (a feature the group has agreed upon), individual (a suggestion an individual has made) or domain (a constraint inherent to the domain, for instance the laws of gravity). They may be mandatory (must be addressed for the problem to be solved) or optional.
- Assumptions: assumptions individuals base their work on when designing a solution. These may lead to certain characteristics or constraints that will have to be addressed.
- Questions: questions may be raised by an individual when working alone or by the group, and they may be resolved with the client or by the group. These sometimes lead to decisions or new characteristics or constraints.
- Decisions: decisions made regarding the solution, usually generated after an evaluation process (formal or informal). These are defining elements of the solution statement, and may have implications that translate into new characteristics the solution will need to have.

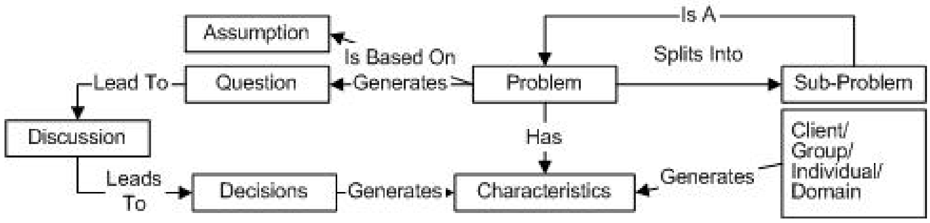

Fig. 1. Problem Model

Problem solvers work on this model (shown in Figure 1), adding new constraints or features and expanding it as they go. They may attach additional resources to the model, such as explanation nodes, files or contacts that may help the understanding of the problem and its evolution. This model can also serve as a basis for discussion with other stakeholders (such as clients or external consultants), who can use it as a basis for understanding what is being discussed and more quickly establish common ground with team members. It is important to note that a user can also work alone. Each individual can work privately on the representation, exploring alternatives and them present them to the group for discussion.

3.2 Mapping Interactions

Problem solvers should be able to map their discussion and decision making process, generating a history of interaction. Dialog mapping [5] is an interesting approach, for it allows individuals to interact by mapping their thoughts, questions and responses, generating a graph that helps them visualize the argumentative process leading to decisions. We are inclined to use such an approach as well: any of the elements described above could serve as a root for a new discussion thread, which would explain and capture the decision making process, possibly leading to the introduction of new elements in the problem model.

In our framework, the team works together refining and exploring the problem as they move towards a solution. Discussion elements originate in the problem model, and may also cause the generation of new characteristics for the problem. This shared representation guides the group in their solution attempts, and the mapped dialogs serve as basis for reflection and explanation of previous decisions

3.3 Managing Knowledge

A lot of knowledge is involved in creative work. From shared domain knowledge to individual, extraneous knowledge that can generate insights, it should be managed and saved as it becomes relevant to the problem-solving context. Thus, part of our work involves capitalizing on individual differences to generate more creative ideas. This means selecting individuals with distinct backgrounds and having them utilize this knowledge when working on the problem. We created a simple user model that maps a user to his or her interests and resources (which may be files or contacts). The following elements are involved: the user, resources (may be files or contacts) and knowledge areas the users are interested in and resources refer to.

User models are initially built through text mining of individual's documents, emails and contact lists and clustering these into specific knowledge areas. Based on this information, it becomes possible to select appropriate individuals to serve as external consultants in the project and breaking an individual's frame of mind through the presentation of external information (which could potentially lead to new insights). The selection of these individuals is based not only on the domain knowledge they possess, but also on their range of external knowledge.

As mentioned before, creative sparks come from the introduction of external knowledge into the problem domain [9]. This could be achieved by displaying documents from different domains, to have the user switch context for a brief period of time and look at the problem under a different light. This is what we call *context bridging*: searching for relations in other contexts and bringing them into focus, thus forcing a different outlook on the problem. Initially, this will be accomplished through the use of WordNet, looking for words applicable in more than one domain the user knows and following links between words to get to external information that is somehow linked to the domain.

To manage this knowledge we have envisioned shared and private knowledge bases, containing the group's and each individual's knowledge. Agents are used for information retrieval, looking for relevant information as members work on the problem. So as not to breach privacy, these agents work only within the limits of the knowledge bases: agents mining private knowledge bases can only present their suggestions to the owner of the knowledge base, never to the group. It is then up to the user to decide whether this information should be shared with the group or not. It is important to note that it is the users, who have an understanding of the knowledge and its relation the problem, who introduce new knowledge into the process. It is also likely that group members will need to engage in an explanatory process, so all understand the relevance of a piece of knowledge to the problem. This externalization process helps others understand a different point of view and each individual better structure his or her thoughts.

During the creative process, especially when it is constrained by having to produce a solution in a timely manner, there are two very distinct moments: there is a moment of *divergence*, opening up new alleys and experimenting new solutions; and there is a moment of *convergence*, closing down on the best solutions, making decisions, criticizing and choosing options. Initially, it is important not to discard every idea, but to keep an open mind, allowing the exploration of new ideas. However, as time goes on (and deadlines approach), it becomes important to focus and decide on one particular path, generating a solution to the problem. This means that available resources (such as time, money or individual availability) must be managed carefully. These resources should be determined at the beginning of a project and the system watches them as the process goes on. The system should warn the group of approaching deadlines so that members can focus on evaluating options and finding a solution. Additionally, the system could suggest a line of thought (based, for instance, on how much work has gone into it) for the problem solvers to work with. It can also remind the group which constraints of the problem have been met and which haven't, so that problem solvers can focus on open ends.

5 Discussion and Further Work

We have envisioned an environment to support creativity, with support for the following activities: idea generation and management, branching from one idea to the next or generating new ideas and saving alternatives; exploration, discussion, extension and study of each idea; evaluation, analysis and critique of ideas and proposed solutions; decision-making on the final solution.

This environment should not be too restrictive, but should keep tabs on deadlines and prerequisites, to help ensure that the project will come to an end. In such a system, it is important to keep knowledge bases of the problem domain and of external domains (these belong to team members, mapping their knowledge and interests), plus a shared problem representation. Our system framework is composed of individual and shared knowledge bases, plus sets of agents (assistants) to retrieve relevant information as the problem solving process evolves. Users should also be able to work synchronously or asynchronously.

We believe supporting creative work to be an important issue. With our framework, we expect not only to support and foster creative work, but also to study creative dynamics and interactions. We are trying to determine which interactions lead to creative results and what requirements a collective creativity support system should have. The system is undergoing initial implementation of user profiles for tests with rules for the introduction of external consultants and knowledge.

There is much work to be done, models need to be perfected and validated; and issues such as motivation (a key issue for creativity), conflict management and negotiation (to ensure convergence) still haven't been addressed in our framework. Privacy (especially when introducing external information) and authorship will also need to be addressed. Situations such as a person becoming too close to the problem and not being able to objectively evaluate the results should also be addressed. Determining the timing of the system, so that it will foster creativity is important and we have been studying group behaviors to address these different situations.

A few systems have been proposed to support creativity: [11] and [12] present systems that introduce external knowledge into the process, both working at an individual level. Brainstorm [13] enables anonymous submission and criticism of ideas by a group. EDC [8] is an enhanced physical environment for group problem solving, targeted at urban design.

In an inspiring parallel with Jazz music, Kao [14] highlights the interaction between individuals and the need for an appropriate environment for creativity. He points out that, in jazz (as in many other disciplines), there is a balance between cooperation and competition, as musicians try to outdo each other without losing the agreed-upon theme. He points out that there are rules that must be followed and a common language they all speak in order to be able to produce something coherent. The interplay between individual and group efforts creates a new experience each time, with each person contributing to the whole according to his or her own preferences and style. These interactions, where individuals have the freedom to create and add to the group creation, are at the heart of improvisational jazz music and are a source of some great cooperative endeavors. We believe this sort of creative cooperation to be important not only in jazz (or other arts related disciplines), but also in business and educational environments.

Acknowledgements

This work was partially supported by CAPES and CNPq.

References

1. Bonnardel, N.; Creativity in Design Activities: the Role of Analogies in a Constrained Cognitive Environment; Proceedings of Creativity & Cognition, 1999
2. Burleson, W. & Selker, T.; Creativity and Interface; Communications of the ACM, vol 45, n. 10; October 2002
3. Csikszentmihalyi, M. Implications of a Systems Perspective for the Study of Creativity. In Handbook of Creativity, Cambridge University Press, Cambridge, UK, 1999
4. Shneiderman, B. Creating Creativity: User Interfaces for Supporting Innovation; In ACM Transactions on Computer-Human Interaction, vol 7 n.1, March 2000
5. Buckingham Shum, S., MacLean, A., Bellotti, V. and Hammond, N. Graphical Argumentation and Design Cognition. KMI-TR-25, Knowledge Media Institute, UK, 1997.
6. Conklin, J. Wicked Problems and Social Complexity. In Dialogue Mapping: Defragmenting Projects through Shared Understanding. Forthcoming. CogNexus Institute, 2003.
7. Nissani, M. Ten Cheers for Interdisciplinarity: A Case for Interdisciplinary Knowledge and Research. Social Science Journal 34 (2), pg. 201-216, 1997
8. Fischer, G. Symmetry of Ignorance, Social Creativity, and Meta-Design. In Proceedings of Creativity and Cognition, 1999
9. Santanen, E.L., Briggs, R.O. & de Vreede, G. The Impact of Stimulus Diversity on Creative Solution Generation: An Evaluation of the Cognitive Network Model of Creativity. 36th Hawaii International Conf. Systems Sciences (HICSS'03). IEEE Computing, 2003
10. Cross, N. Creative Cognition in Design: Processes of Exceptional Designers. Proc. of Creativity & Cognition 4, Loughborough, UK, 2002.
11. Nakakoji, K., Yamamoto, Y. & Ohira, M. A Framework that Supports Collective Creativity in Design using Visual Images. In Proceedings of the 3rd Conference on Creativity and Cognition (C&C'99), Loughborough, UK 1999.
12. Shibata, H. & Hori, K. A System to Support Long-term Creative Thinking in Daily Life and its Evaluation; In Proceedings of the 4th Conference on Creativity and Cognition (C&C'02), Loughborough, UK, 2002.
13. Stenmark, D. Klang, M. & Olsson, S. A Critical Look at Knowledge Creation. In Proceedings of IRIS22, Jyvaskyla, Finaland, 1999.
14. Kao, J. Jamming: the Art and Discipline of Business Creativity. Harper Collins Publishers, New York, 1997