Towards a Case-Based Model for Creative Processes

Paulo Gomes[1], **Carlos Bento**[2], **Pedro Gago**[3] and **Ernesto Costa**[4]

Abstract. This paper describes a case-based model for creative processes. We defend that searching spaces of cases increasingly away from the problem specification increases the chance of generating more creative solutions. This search within spaces of cases growingly distant from the initial problem implies the need for specific retrieval and adaptation operators.

Within our approach we define four spaces for creative reasoning and describe the retrieval and adaptation operators associated with them.

These processes are implemented in IM-RECIDE (IMaginative REasoning with Cases Imperfectly Described and Explained) a Creative extension of RECIDE. We show an example of IM-RECIDE at work on a configuration task.

Keywords : AI and creativity; Case-Based Reasoning; Design and Configuration;

1 Introduction

Creativity remains an insufficiently understood achievement of human intelligence and no complete theories exist about it. Ashwin Ram [6] defends that creativity is the result of mechanisms which are on a continuum with those used in ordinary thinking. He views creativity as an extraordinary outcome originated in the application of ordinary mechanisms, improved and applied with conscious (strategic) control.

Creative design is a task in which some work has been done towards a computational model for creativity. Linda Wills and Janet Kolodner [5] consider three tasks in creative design: enumeration of several alternative solutions; re-description and elaboration of problem specifications; and evaluation of proposed solutions.

Research in case-based reasoning (CBR) produced extensive knowledge on how to reuse solutions to old problems. Some systems, which perform splitting and merging operations on previous cases for generation of a new solution work in a way that can be considered creative [2, 3, 4].

In this paper we describe a CBR approach for creative processes. We view creativity as a result of reasoning on spaces of cases increasingly further away from the target problem. Each case comprises a problem description, a solution description, and causal links between problem and solution. These links, seen as case explanations [1, 2], take an important role in the determination of the space in which each case is considered.

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Within our framework the spaces of cases determine sets of episodes which have properties in common with the target problem. We define each space in terms of the characteristics that the cases within it share with the target problem.

We describe the reasoning operators associated with each space in terms of how they search for the cases useful for generation of a new solution and the way they generate new cases.

This model for creative reasoning is implemented in IM-RECIDE a creative case-based shell derived from RECIDE [1, 2, 3]. We present its working cycle and show an example in a configuration task.

2 Spaces for Creative Reasoning

From our point of view, creative processes involve exploration of increasingly large spaces of knowledge. Within our approach, generation of creative artifacts is supported on chunks of knowledge representing past experiences. As mentioned before, we consider four spaces for creative reasoning(see Figure 1).

The first space (space I) consists in remembering a previous experience similar to the new situation. Within this space the reasoning process is trivial, it provides solutions to the target problem which are the solutions for the cases in this space.

The second space (space II) comprises episodes which match the structure of the new problem. Reasoning in this space involves using a past experience for derivation of a new solution. In this process the solution is generated by modification of a previous experience in order to fit the new situation. This involves a process of extrapolating the old solution.

In space three (space III), cases with parts potentially useful for generation of the new solution are considered. In this space a more elaborated reasoning process is performed. Reasoning in this space involves splitting and merging parts of old experiences for generation of the new solution.

The fourth space (space IV) comprises experiences with some components in common with the new problem. These experiences are weakly related with the new situation. In this way derivation of a solution from them is a process more complex then the one performed on the other spaces.

Traversing the spectrum of creative processes, from space I to space IV, involves considering experiences for generation of a new solution less and less similar to the new problem. This has two consequences. One is that the artifacts which result from spaces closer to space IV are, in general, more creative (far away from what would be expected as a solution for the new problem). A second consequence is that artifacts that result from spaces with a higher number (see figure 1) are more likely to be bizarre in the sense that useless artifacts are likely to be produced.

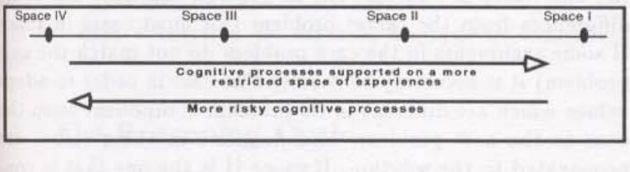

Figure 1. Spectrum of creative processes.

3 A Computational Model for Creative Processes

In this section we describe how cases are represented in the RECIDE family of systems, namely in IM-RECIDE. We present how spaces are delimited and the reasoning processes which take place within IM-RECIDE.

3.1 Case Representation

In our approach a case is represented by a triple $< P, S, R >$ (see Figure 2) with P and S, respectively, sets of facts representing a past problem and a solution, and R a set of rules representing a causal justification for the solution to the past problem. Facts are represented by PROLOG structures comprising a functor and n arguments, with n equal or greater than zero. The causal justification is in the form of a set of explanations. An explanation is a proof tree that links facts in the problem with a fact in the solution. We consider three kinds of imperfections in explanations: (1) incomplete set of explanations; (2) partial explanations; (3) broken explanations [1, 2, 3].

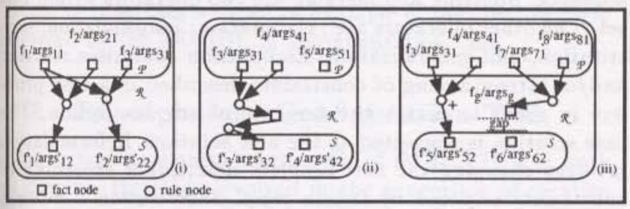

Figure 2. A case with (i) a complete set of explanations; (ii) an incomplete set of explanations; (iii) a partial and a broken explanation.

In a case with an incomplete set of explanations some facts in the solution are not explained and hence are not the conclusion for any proof tree (e.g., Cases ii and iii , in Figure 2. Facts $f'_4/args'_{42}$ and $f'_6/args'_{62}$ in the case solutions are not leaves of a proof tree). A partial explanation is one whose proof tree omits some branches. This means that one or more steps in the proof tree apply a rule for which the conditions are necessary but not sufficient. Rule nodes representing these rules are labeled by "+" (e.g., In Figure 2, case iii, the proof tree on the left). A broken explanation is one in which there is a gap between the proof tree and the case solution (e.g., In Figure 2, case iii, the proof tree on the right).

Four types of case pieces are considered for splitting and merging of cases (see Figure 3): strong, weak, undetermined, and unexplained.

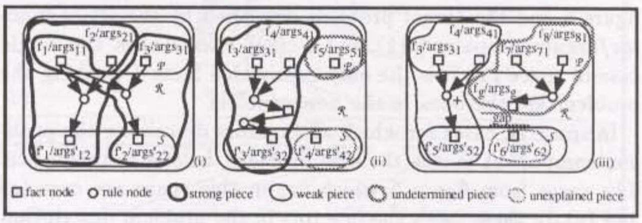

Figure 3. Types of case pieces.

A strong piece contains a complete explanation and the facts which are the premises and conclusion of it (e.g. In Figure 3, the pieces in case i). A partial explanation, its premises and conclusion outline a weak piece (e.g. In Figure 3, case iii, the case piece on its left). A fact in a case problem that is not premise of any explanation or a set of facts premise of a broken explanation plus the explanation, define an undetermined case piece (e.g. In Figure 3, case ii, the piece composed by the single fact $f_5/args_{51}$ and the piece in case iii on top right). Facts in a case solution that are not conclusion of any explanation are unexplained pieces (e.g. In Figure 3, single facts $f'_4/args'_{42}$ and $f'_6/args'_{62}$, respectively, in cases ii and iii are two unexplained pieces). Case pieces establish the way in which cases can be split and merged.

The case library also comprises failure cases. There are two kinds of failure cases: unsplitable and unmergeable. Unsplitable cases represent constraints on splitting operations and unmergeable cases represent constraints on merging operations. The syntax for failure cases is the same as the one used for successful cases. Figure 4 shows an unsplitable case and a unmergeable case. Case i represents that when fact $f_1/args_{11}$ and fact $f_2/args_{21}$ occur in a case origin of a new case they must appear together in the problem description of the new episode. Case ii represents an unmergeable case. It describes that if fact $f_4/args_{41}$ is part of the problem description then fact $f'_3/args'_{31}$ can not be part of the solution description. The role of failure cases in the generation of new cases is extensively described in [2].

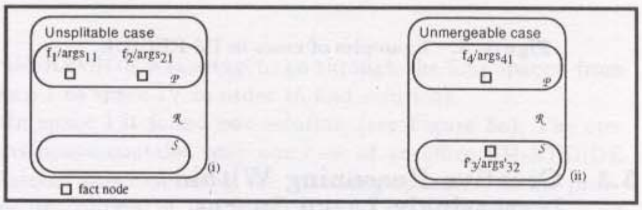

Figure 4. Examples of failure cases. (i) An unsplitable case and (ii) An unmergeable case.

3.2 Spaces of Cases

Here we describe how the four creative spaces are delimited and present some syntactic examples.

Space I comprises the cases for which all functor/arguments pairs, describing the problem component, match the new problem. As an example consider the case library represented in figure 5 and the target problem described by the set of functor/argument pairs [a(1), b(1), c(2)]. Case (a) is the single case in space I as it is the only case which facts describing the problem are the ones in the new problem.

In space II, cases for which all functors describing the problem component match the new problem, belong to this space. The cases from figure 5 which are in this space are case (a) and (e). In these cases the functors in the problem description are the same functors that describe the new problem.

Space III contains the cases with, at least one strong or weak piece (see section 3.1) with all functor/arguments pairs matching the target problem. In the example in figure 5 space III comprises cases (a), (b), and (d). In case (a) the case pieces comprising explanations $a(1) \wedge b(1) \rightarrow x$ and $c(2) \rightarrow y$ are the ones responsible for considering this case. The case piece in case (b) responsible for its inclusion in space III is $a(1) \wedge b(1) \rightarrow +w$. Case (d) is also in space III due to case piece $b(1) \rightarrow +r$.

Space IV gathers all cases which contain at least one strong or weak piece with at least one functor/arguments pair matching the target problem. The cases in figure 5 which are included in space IV are (a), (b), (d), and (e). As an example, case (e) is included because its case piece $a(1) \wedge b(3) \wedge c(2) \rightarrow t$ shares a(1) and c(2) pairs with the new problem. This means that there is a chance that fact t in case (e) belongs also to the solution for the new problem.

In the next subsection we describe the reasoning mechanisms used in each space.

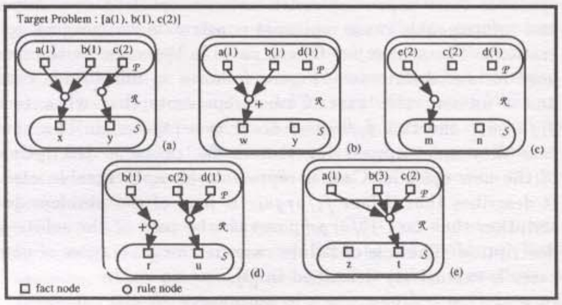

Figure 5. Examples of cases in IM-RECIDE.

3.3 Creative Reasoning Within Increasingly Large Spaces

Here we describe how case retrieval and adaptation are performed within each space. We give also some examples of case reuse.

When a case is selected from space I its solution is the one for the target problem. Considering again the example in figure 5 the solution [x, y] for case (a) is the solution for the new problem [a(1), b(1), c(2)].

In space II the case most similar to the new problem is the one which is selected. As, in general, this case has some differences from the target problem (for most cases in space II some arguments in the case problem do not match the new problem) it is necessary to modify this case in order to adapt values which are different in its problem component from the ones in the new problem. Modifications in these values are propagated to the solution. If space II is the one that is considered, one possible solution for the target problem in the example is [z, t'] (see figure 5). This solution comes from case (e) by a process of propagation of the changes in its arguments.

In space III a new solution is created by splitting and merging cases (this is the process performed in RECIDE). It is an iterative process. IM-RECIDE starts selecting the most similar case from the set of episodes which have some differences to the new problem. Then it splits the case in pieces according to section 3.1, selecting the pieces that match part of the target problem. These pieces are then merged and form a new case. If the problem description in the new case has some discrepancies from the target problem then other cases are selected to eliminate these discrepancies. Pieces from these cases which are relevant for the new case are merged for generation of a new solution. Splitting and merging takes place in space III in the generation of solution [w, y] for the target problem in Figure 5 from cases (a) and (b). From case (a) piece $c(2) \rightarrow y$ is used, while case (b) contributs with piece $a(1) \wedge b(1) \rightarrow +w$. This solution is an alternative solution. Case (b) is first selected and split in three pieces. Only the piece containing the explanation is used, then IM-RECIDE looks for cases with the fact c(2) and it selects case (a), splitting the case in two pieces and selecting the one with fact c(2).

In space IV generation of new solutions results from the application of a set of operators. These operators are applied in sequence. Splitting and merging are two operators within this set. The other operators are : elaboration; reformulation; substitution; and generalization. Elaboration comprises relaxing and/or strengthening of constraints described in a case problem in order to match the target problem description. The case solution is suggested as the new solution. Reformulation involves changing the new problem description according to constraints imposed by failure cases. Substitution comprises replacing a functor/arguments pair in the past case in order to make it similar to the new problem. The solution which results from this substitution is given as the one for the new problem. Generalization involves considering values initially not considered in the problem description of a past case, and assuming the case solution remains unchanged. Four possible solutions were created in space IV: [r, v], [z, t], [w, v], and [w, t]. Substitution was used on case (d) to generate solution [r, v]. Generalization was applied to case (e) to create solution [z, t]. Generation of solutions [w, v] and [w, t] involved a more complex process, in which more than one operator was used. Solution [w, v] was created by first splitting and merging case (b) and (d) and then relaxing some constraints by elaboration of the new case. The solution [w, t] was generated by splitting and merging cases (b) and (e) and then using generalization in the new case.

In IM-RECIDE only the solutions that do not violate failure cases are output for external evaluation. In this way, some of the solutions mentioned above may not be presented to the user.

In the next subsection we describe a complete reasoning cycle.

3.4 The Reasoning Cycle

The reasoning cycle comprises three steps: initialization; problem solving; and validation.

In the initialization step the system decides on the cognitive risks it wants to face in the generation of a new solution. This means the construction of a list of spaces which will be used for reasoning and deciding in which order they will be explored. Working on more risky spaces (in particular space four) may result in more creative, but also more bizarre solutions. It involves also higher computational complexity. In the current version of IM-RECIDE it is the user who decides the order for exploration of the creative spaces.

In the problem solving phase the reasoning operators are applied on a creative space for generation of new solutions. If no solution is constructed within a specific space, the system switches to the next space from the list that was created during the initialization phase. When a solution cannot be generated, and there are no more spaces to search for, the user is asked to give a solution for the problem.

After a solution has been produced it has to be validated. In a first round it is internally validated by failure cases. As reported before, these failure cases represent constraints in the generation of a new solution. If any failure case is triggered by the new solution, then the solution is rejected.

If a solution passes the internal validation, the user is asked to accept or rejected the new case. If she/he rejects the new solution the user is asked to explain this rejection in terms of failure cases. After this the process returns to the problem solving step.

In the next section we give an example of the creative cycle performed by IM-RECIDE in a configuration task.

4 An Example in a Configuration Task

In this section we present an example of IM-RECIDE at work and describe the steps involved in the generation of creative solutions.

4.1 The Domain

IM-RECIDE is used for placement of equipment and furniture in a room.

A problem comprises: a set of equipment to place in a room (ex.: the room must have a coffee machine), the location of windows and doors (ex.: a window on the left side of the South wall), room functionalities (ex.: phoning, reading, meeting, etc.), and room type (ex.: office, kitchen).

A solution describes the objects and its location in a room in order to fulfill the problem specifications.

For simplicity of the example bellow we consider a square room with a window and a door (see Figure 6a). A room comprises nine regions as represented in figure 5a. The room is oriented North. Walls are named as East wall, West wall, North wall, and South wall. To specify positions within a wall we have three wall regions : left, middle, and right. Figure 6b represents the case in figure 6a.

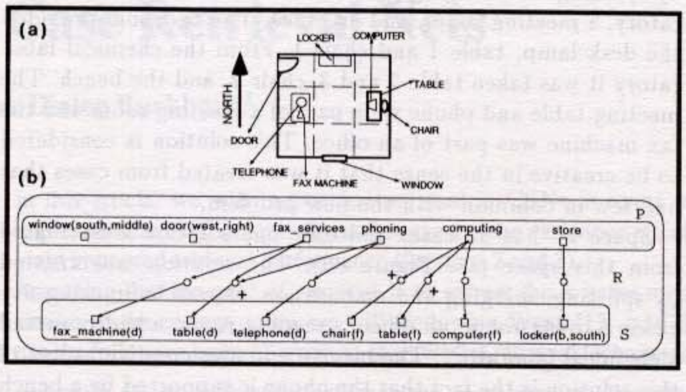

Figure 6. Plan for a room and its representation within IM-RECIDE.

4.2 Generation of Creative Artifacts

In this subsection we describe the new cases generated by IM-RECIDE for the problem represented in figure 7. The goal is to come up with a configuration for objects in a room with a door in the middle region of the North wall, and a window in the middle region of the East wall (see room configuration in figure 7). The room must be able to allow to send faxes, phone, meet, read and write activities (see room functionalities in figure 7). The current case library comprises 42 successful cases, 32 unsplitable cases and 85 unmergeable cases.

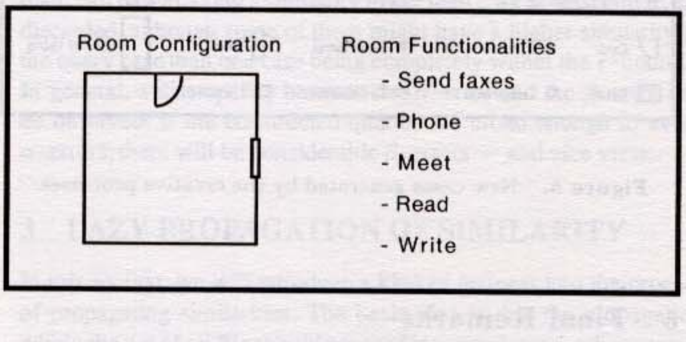

Figure 7. A target problem.

IM-RECIDE was setup to go through the four spaces, from space I to space IV in order to find solutions.

In space I it found one solution (see Figure 8a). The creative space contains only one case of an office. IM-RECIDE retrieved this case using the matching operator, as the problem description of the case matched the new problem, and presented the office solution.

Space II was then searched. This space comprises two cases, but only one solution was found (see Figure 8b). This solution was generated by extrapolation of a case representing an office. It was necessary to modify a window in the selected case.

Space III comprises 20 cases and was in the origin of 12 solutions (five bizarre solutions and seven acceptable solutions). One of these solutions is shown in Figure 8c. It was created by splitting and merging parts of a bedroom, a chemical laboratory, a meeting room, and an office. The bedroom provided the desk lamp, table 1 and chair 1. From the chemical laboratory it was taken table 2 and 3, chair 2, and the bench. The meeting table and phone were part of a meeting room and the fax machine was part of an office. This solution is considered to be creative in the sense that it was created from cases that had few in common with the new problem.

Space IV has 32 cases and only one solution was created from this space (see Figure 8d). The solution was created by splitting, merging and elaboration. It was built using five cases: a living room, an office, a reading room, a bedroom and a chemical laboratory. The bizarre and also creative aspect of this solution is the fact that the phone is supported by a bench and the meeting functionality of the room, is achieved by a dinner table. Elaboration was a fundamental operation in the generation of this solution. Through the relaxing of the door and window locations it was possible to find cases with useful parts. It is important to stress that the reason why only one solution was generated in space four deals with the fact that the system does not repeat solutions previously generated in other spaces.

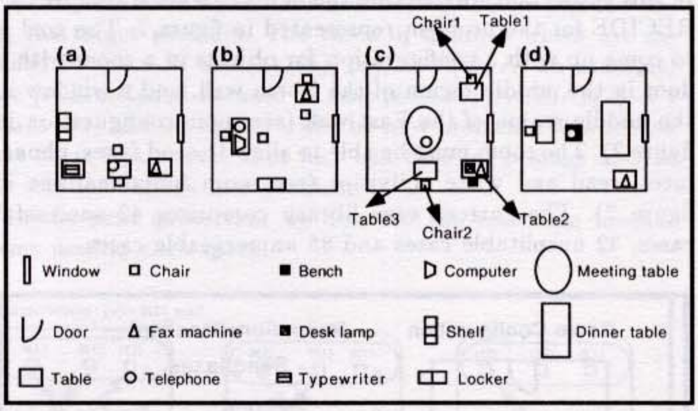

Figure 8. New cases generated by the creative processes.

5 Final Remarks

A first remark relates to our view on creative reasoning. Along the paper it becomes clear that we see creativity as the result of specific reasoning processes and exploration of increasingly large spaces of knowledge (as cases more and more distant from the target problem are considered for reasoning).

The need for reasoning on large spaces of knowledge explains why generation of creative artifacts is a process that is computationally complex. In fact we can characterize a creative process as a successful navigation within an initially very large space of knowledge. We believe that daring to navigate in this space (daring to try quite unpromising chunks of knowledge) and doing this in the right way (applying the successful navigation heuristics) is, in part, what distinguishes creative from "boring" persons and machines. Another prerequisite to be creative is to access diversified knowledge (for instance by traveling, talking with quite different people, having diversified activities, etc...). A third requirement we identify is the need for mechanisms to deal with different representations for the same object (particularly useful when making inter-domain transfer of knowledge).

It also becomes clear that creativity involves risks. Specially the risk of producing bizarre things as it can be exemplified by some results generated within spaces III and IV in the example described in section 4. This puts a great challenge on the process of validation. In particular when criteria for acceptance involves aesthetic or idiosyncratic aspects it is not expected that validation can be an automatic process.

A last remark relates to open issues. We identify three main research directions on this subject. One is the identification of the reasoning processes involved in creativity. We present some of them but it is easy to guess that other ones are important for creative reasoning. A second aspect relates to the development of heuristics for exploration of initially intractable spaces of knowledge as those we have when we want to use these mechanisms in real applications. Conceptualization of those heuristics seems also to be a difficult task for human beings. A third issue is the need to make a deeper study on how to perform validation within creative systems. This is also a complex task. It is well known how in the past outstanding ideas had to wait longtime before they were understood as worth contributions to human kind.

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