AN APPROACH TO MULTI-AGENT VISUAL COMPOSITION WITH MIXED STYLES

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Abstract: Applications of computer systems that mix Art, Science and Engineeering have appeared as a result of the evolution of information technologies in the last three decades. Frequently, they involve the use of Artificial Intelligence techniques and they have appeared in the fields of music, literary arts and, more recently, visual arts. This article proposes a computational system based on creative intelligent agents that, by making use of the shape grammar formalism, can support visual composition synthesis activities. In this system, each agent gives its creative contribution through a style of its own. Different modes of agent contribution can be put into perspective like, for instance, cooperative or non-cooperative modes, the resulting composition emerging from these contributions.

1 INTRODUCTION

We can say that the degree of evolution of the human species can be measured by the degree of sophistication of the technology it uses, as well as by the degree of social organisation. There has always been a relationship among technology evolution, human evolution and human societies evolution. The importance of information technologies has been increasing progressively. Presently they impact in every area of society, not only in engineering or management, just to cite the most evident cases, but, and more recently, in art too.

Of course that any form of art involves always some kind of technology. To produce his work, the painter uses tools like brushes, dyes, canvas, for instance, as well as certain techniques to work with these tools. But, in this era of information and computers, the mix of techonology and art is becoming more and more common, not just at the level of execution, but also at the level the creative process. The contribution of Artificial Intelligence, an area of computer science born in the 1950s (Rich 1991, Russell 2003), has been significant for this.

This article makes a very brief revision of the application of computer systems to the artistic creative field, next centers around the visual arts, then introduces the theme of shape grammars, and finally it proposes a system based on creative agents to support the visual composition activity.

2 ART, COMPUTERS AND ARTIFICIAL INTELLIGENCE

There has been, in the last three decades, an increasing use of information technologies in the musical arts. Due to the digital technology of computers it is nowadays possible to store, analyse, modify and synthesize with an accuracy higher than that of the human ear system, and even generate musical compositions. It was in the musical arts that information technologies have penetrated more rapidly, perhaps due to the facts that music is of a more quantitative nature, was more theoretically mature and the needs of memory and processing capacity aren't excessive (at least when compared to those of visual arts). With the progression of Artificial Intelligence and the appearance of the knowledge based systems, in particular expert systems, new methods of musical composition have appeared. The process of composition now involves an interaction between the composer and the computer system in which the composer generates, and concentrates on, the original ideas for a composition, and has support from the computer system that was programmed with knowledge about the composition process (Kurzweil 1990, Miranda 2001).

In the literary arts computers are presently very useful. For instance, text processors are indispensable software nowadays and together with them, there are also a set of software tools like

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spelling correctors, grammar correctors, style correctors, and dictionaries, thesaurus and other kinds of linguistic data bases. In particular, in the field of natural language processing, Artificial Intelligence has had an important role (Winograd 1983, Allen 1987), in understanding (analysis) as well as in generation (synthesis). Automatic translation, data base interfaces in natural language and other kinds of systems involving dialogue, story understanding and generation and poetry generation, are some examples of the rich contribution of Artifical Intelligence.

In the visual arts, due to a slower evolution of hardware, in particular respecting to graphic capabilities (limited graphic resolution of output devices), only more recently (when compared to the musical and literary arts) the use of information technologies has become more attractive. From the decade of 1990 on we could watch a progression in the investigation, with its products migrating progressivelly to software tools to support the creative activity of designers, architects and graphical artists in general. The computer supported visual arts methods of creation vary from free hand drawing by using the computer screen as it were paper or canvas, to the most complex image processing involving the generation of shadows, surfaces, shapes, colors, and the execution of translation, rotation, scaling repetition and distortion operations on shapes. Mixing with the cognitive aspects, in the field of the creative process, mathematical processes and Artificial Intelligence techniques like fractals, chaos theory, genetic algorithms, rule based systems and artificial life (Kurzweil 1990), the latter related to the idea of agents of Distributed Artificial Intelligence (Ferber 1999), have been used. Some of these techniques, namely artificial life, have migrated to the animation and cinema field. As examples of the application of these methods to the visual arts we can point the works of the painter Harold Cohen, with his AARON program (Cohen 1999), and of Leonel Moura with his system of painter robots, that were both participants in an recent art exposition in Lisbon (Bioart 2005).

3 THE GRAMMARS OF SHAPE

Shape grammars were introduced in the 1970s by Stiny and Gips (Stiny 1972). They are similar in principles to the grammars used in the area of Artificial Intelligence in natural language understanding and generation (Allen 1987), with the difference of being based not on symbols, but on shapes (points, lines, two-dimensional and three-dimensional geometric shapes) as well as, by extension, also other parameters like dimensions, colors, *etc.*.

A shape grammar is composed by a basic vocabulary of shapes, an initial shape and a finite set of rules that specify how shapes can be generated from other preexistent shapes, similarly to the lexicon, the initial symbol and the grammar rules of a language used in a natural language processing system. The rules of a shape grammar specify how, in a composition in progress, shape existing in the composition can be replaced by new shapes.

Each rule has a left side, pre-condition, or antecedent, and a right side, action, or consequent. The left side specifies the pattern for which the rule is applicable and the right side the respective pattern for substitution. Briefly, a rule is applicable if there is a similarity transformation (*i.e.*, an isometry or a transformation of scale) leading to a match of the shape of the left side of the rule with a shape existing in the composition. Rules are applied in a forward manner (from antecedent to consequent), like in the production/rule-based *forward-chaining* systems of Artificial Intelligence, which perform a kind of forward inference. When applied, a rule replaces the shape(s) matched in the composition with the shapes in its right side. Symbolically, we can express a rule in the following schematic form:

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<shape(s)-to-match> =>
   <shape(s)-for-substitution>
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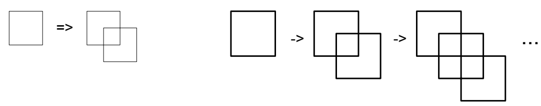
Special markers (labels) that aren't part of the composition can be used for rule application control and application termination condition specification.



a) rule b) resulting composition

Figure 1: Shape grammar example.

For instance, in Figure 1 we show a shape grammar with only one rule, as well an example of a possible result from the repeated rule application.

Even a simple shape grammar like this can show some emergence behavior. This feature depends on the degree of detail and hierarchy accomodated by the internal computational representation used for the geometric shapes in the system (which influences the ability to consider and process certain shapes as non-atomic ones, and to recognise shapes in the composition that weren't explicitly included in it).

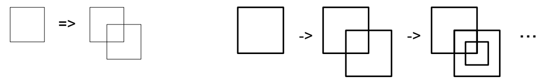


Figure 2: Shape grammar example.

For instance, in Figure 2, we show possible results with the same shape grammar of Figure 1 with a system able to recognise emergent shapes.

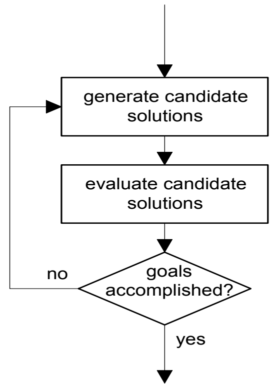


Figure 3: Solution generation for a design problem.

Shape grammars with various rules allow for a greater diversity of alternative compositions. The process of finding a solution for a design problem can be seen as a search process which generates candidate solutions for the problem. This process takes place in the search space of alternative possible compositions resulting from the application of the rules of the shape grammar (Mitchell 1998). In its most basic form, this is an iterative generate-and-test search process that, in each iteration, produces a possible solution and evaluates it, testing if the goals of the design problem were attained. In Figure 3 we represent the basic structure of this process.

A system for the execution of this search process must have a generation component (which is the shape grammar), a test component (which filters the acceptable solutions) and, additionally, a control strategy (rules for determining which way the system will follow next). This control strategy can be more than a simple depth-first or breadth-first search and include heuristics to make the search process an informed one, causing the system to give priority to the best alternatives. Such a system could include specific design knowledge in any of those three components. In terms of interaction with the user, different configurations are possible: in one extreme all functionalities are carried on by a user, in the other extreme all the process would be automatic.

The use of shape grammars has been exploited in applications in different design problems, in the context of syntesis (generation) and analysis (interpretation) of visual compositions and also as means to the description and the representation of styles, including for didactic purposes and also other specific applications, for instance in architectural drawings (Gips 1999, Tapia 1999, Knight 2000, Mitchell 1998).

A style is a way of someone doing something (Simon 1971) and shows up when that someone chooses an alternative or a process for generating a solution. In the field of design, a style is a king of design knowledge which is a characteristic of a product, or a set of products, of design, and is recognisable through the presence of some visual elements like shape, color, relative position, texture, dimension, orientation (Dondis 1973, Bonsiepe 1983, Wong 1993), as well as certain ways of combining those elements. Visual compositions can be generated automatically according to specific styles. Each style is implemented by the set of rules of the shape grammar specific to the style.

4 AGENTS, STYLES AND AGENTS WITH STYLE

The Intelligent Agents technology has been applied to complex problems involving intelligence and interaction among agents, human included, namely in the field of the Internet and in animation in cinema. It is an intelligent systems technology from the area of Artificial Intelligence that proposes a problem solving approach where the problem solving effort is distributed to a group of intelligent agents (Weiss 1999, Ferber 1999). In this context, an agent is defined as an entity situated in an environment, that perceives the environment, and acts in the environment. Not rarely, an agent based system is composed by a certain number of agents, *i.e.*, it is a multi-agent system, each with a certain level of intelligence and a certain level of communication capabilities. In terms of problem solving, the idea behind a multi-agent system is to approach the solution of problems that an isolated agent wouldn't be able to solve.

Respecting to the complexity of the internal architecture, we can classify agents in cognitve and reactive agents. Cognitive agents tipically have an architecture containing internal representation mechanism that allow them to maintain an up-to-date model of their environment and of themselves, to reason about the environment and about the results of its own actions in the environment. This kind of agents is the most sophisticated, autonomous and intelligent, and they have capabilities to maintain goals and plan their actions in order to be able to attain those goals. In general, multi-agent systems with cognitive agents are composed by a small number of agents and the activity in the system comes more from the cognitive activity of the agents than from the interaction amongst them. Communication can be very sophisticated and is usually based on message passing, and may inlcude standardised protocols. Agent activity coordination mechanisms can vary and can go from a total cooperation among agents to antagonistic forms involving competition and negotiation.

Reactive agents have a very simple architecture. They don't have any internal representation and reasoning mechanisms (and thus, they can't have goals, and they aren't able to plan their actions) and its behavior is based on stimulus-response patterns. In general, multi-agent systems based on reactive agents are composed by a great number of agents and the activity of the system stems more from the interaction amongst them. Communication is very primitive, and is carried through signal exchange or by operating and recognising changes in the environment.

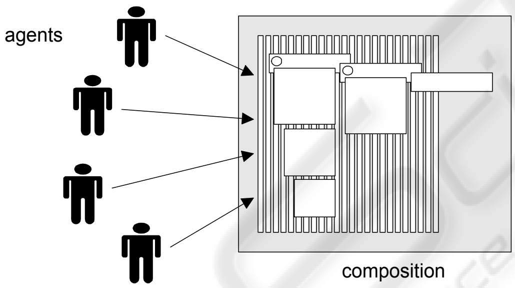


Figure 4: A system for multi-agent generation of visual composition.

The system we propose in this article is a multi-agent system based on creative Intelligent Agents in which shape grammars are used to support an activity of visual composition. In this system, sketched in Figure 4, each agent (see Figure 5) gives its own creative contribution through a style of its own. A style is represented by a set of rules implementing the shape grammar for the style. Each agent has the set of rules of its own style, and tries to apply them, depending of the present state of the composition. Given a set of these agents, each one with its own style, and given a set of shapes recognisable in the context of those styles each agent will apply the rules of its style, whenever possible, together progressivelly generating a visual composition, or a set of alternative visual compositions.

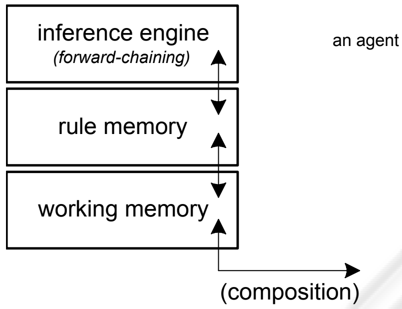
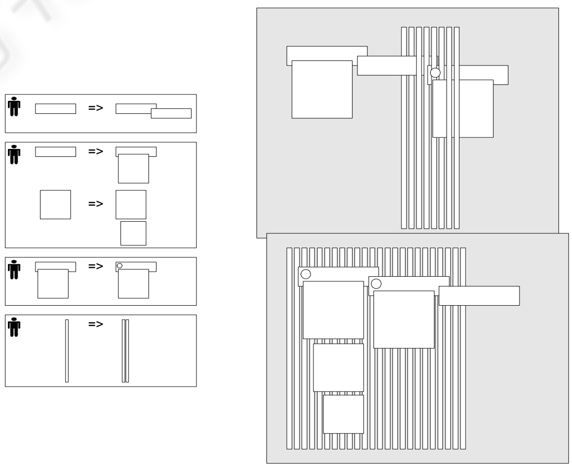


Figure 5: Architecture of an agent of the system depicted in the previous figure (simplified).

As the agents of this system are rule-based they are, essentially, reactive. However, the rules contain knowledge, *i.e.*, problem domain knowledge (styles of visual composition) so, in a certain perspective, the agents can be considered cognitive. The interaction among the agents occurs through changes in their environment, which means the visual composition in progress. Control of the agent activity can involve human external intervention. Several forms of agent activity coordination can be put in perspective, some involving more cooperative agent contributions others more competitive in nature. The resulting composition will emerge from these contributions.



a) agents and grammars b) alternative compositions

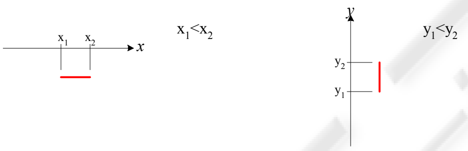
Figure 6: Shape grammar example.

For example, in Figure 6, we represent a set of agents with simple shape grammars and two possible visual composition results, one of them is the result of a less cooperative process (the result of the style application shows an apparent disorder), and the other of a more cooperative one (in this case the result of the style application shows more order).

Possible applications for this kind of system are visual composition generation with mixed styles, free generation or controlled and goal oriented generation (*e.g.*, technical drawing, Web page layout design).

5 WORK IN PROGRESS AND FUTURE WORK

The system we have described is still being conceptualised but there is already some work in progress leading to its realisation. This work in progress includes an embryo of an ontology of a geometric two-dimensional domain, including geometric points and relative position relations between geometric points on the x and on the y direction, line segments and relative position relations between line segments on the x and on the y direction, and rectangular shapes and relative position relations between rectangular shapes on the x and on the y directions in the plane. In the following we very briefly show some aspects of this ontology.

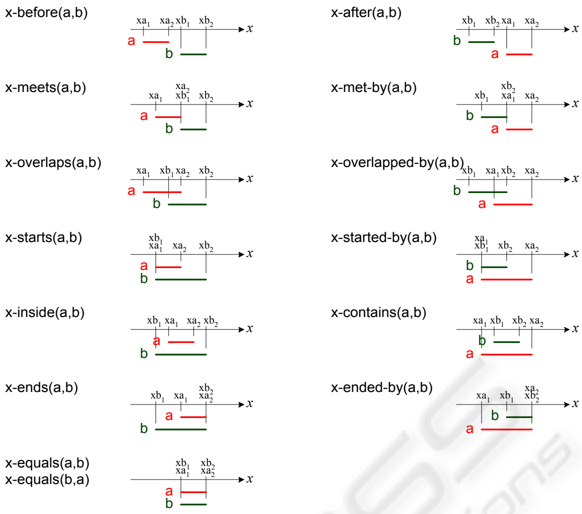


a) horizontally b) verticallly

Figure 7: Relative position relations between two geometric points on the same line.

Starting from the relative position relations between two geometric points on the same line shown in Figure 7, we have built the 13 basic relations between two line segments horizontally (x axis) and vertically (y axis). For reasons of space economy we only show, in Figure 8, the relations for the first case (x axis); for the other case there is an equal number of similar relations but in the vertical direction (y axis). These relative position relations on an axis are inspired by the temporal interval relations of (Allen 1983).

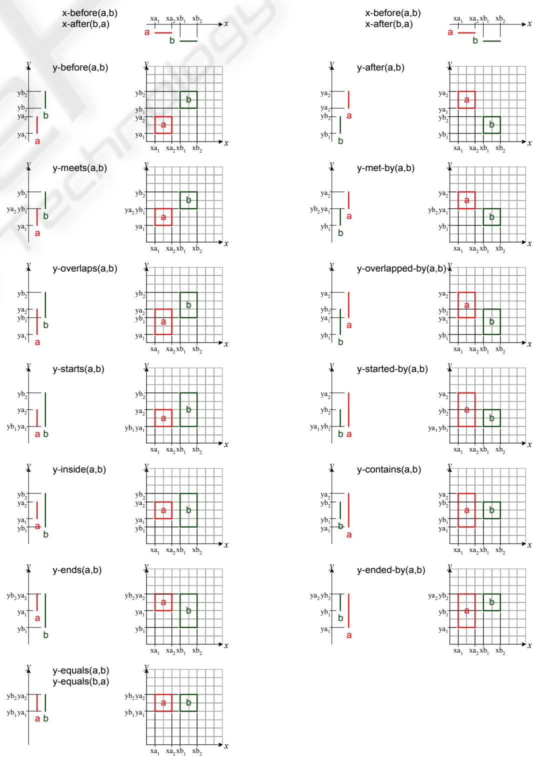
Combining these relations pairwise we can get the relative position relations between rectangular shapes in the two-dimensional plane, in number 169 (13x13).



a) direct relation b) inverse relation

Figure 8: Relative position relations between two line segments horizontally (in the x axis).

For reasons of space economy we only show, in Figure 9, 13 of those relations.



a) direct relation b) inverse relation

Figure 9: Relative position relations between two rectangular shapes in the two-dimensional plane.

A different aspect in the work in progress is a small prototype program, being developed in

Common Lisp, to implement the *forward-chaining* inference engine for experimenting with the set of rules the shape grammar of an agent. We also intend to look for software tools that allow suitable domain knowledge representation and reasoning, preferably implemented in, and with good integration with the symbolic environment of, Common Lisp. Possible candidates are the rule and logic based tools LOOM (LOOM 2005) and LISA (LISA 2005), for instance.

In the near future, more immediate work to be developed has to do with computational geometry (*e.g.*, geometric shape manipulation, including similarity transformations, particularly for recognizing shape patterns in the left side of shape grammar rules). But the most significant aspects to give special attention to are the control mechanisms for rule application, which can be viewed in the intra-agent and in the inter-agent perspectives, the latter involving the coordination of the activity of the agents in the multi-agent system.

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