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Emergence in collaborative computer-aided design

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Abstract

This paper introduces the concept of opportunistic design collaboration based on an unstructured mixture of task and result sharing. One foundational requirement of opportunistic design collaboration when using a graphic representation medium is emergence. A system architecture to support opportunistic design collaboration based on emergence is proposed.

1 Introduction

Computational support for design dates back to the early days of computers. Already in the 1950's various programs were being developed and used for the analysis of designs. In the ensuing forty years two major streams of design support developed. The first is an outgrowth of this early work and has resulted in a very wide array of tools to aid designers in their analysis of designs. The second is concerned with the graphical visualisation of designs in two and three dimensions and, more recently, over time. Over the last decade we have begun to see the development of tools to aid in the synthesis phase of designing. The development of these tools has been spurred on through the increasingly widespread use of artificial intelligence approaches.

The prevailing paradigm within which all this computational support has been developed has been that of a single designer largely working by himself/herself on a networked work station. The network here provides access to other computational resources and provides a means of sending and receiving information from others on the design team. However, today design is so complex that very rarely does a design project involve only a single designer. Rather, design nowadays involves not just a design team in which various aspects of the design are allocated to individual designers but each of the various aspects of the design is worked on by a team of designers. This involves a new paradigm in which designers need to collaborate with each other using a computational medium.

Within this collaborative design paradigm two basic information transfer approaches can be delineated. These two approaches represent significant differences in the basis adopted for any development. In the first approach the members of a design team execute tasks and when those tasks are completed make their results available to the other members of the team, ie. asynchronous approach. In the second approach the members of the design team work on the same task together, i.e. asynchronous approach. Whilst the first approach maps well on the distributed artificial intelligence approach of task sharing the second does not map well onto result sharing. The synchronous approach is modelled on a team where two or more designers work on the same task choosing to contribute opportunistically.

2 Opportunistic Design Collaboration

Opportunistic design collaboration involves a mixture of task and result sharing. However, one of its distinguishing feature is not that, rather it is concerned with allowing more than one interpretation of a particular representation of a design description. In this paper we will restrict ourselves to a consideration of only graphical representations of design descriptions. The concept of different interpretations of a particular representation is called emergence.

Emergence occurs when a property that was not explicitly represented or intended in a design description is found and made explicit. There are three views of emergence: computational emergence; thermodynamic emergence; and emergence relative to a model (Cariani 1992). Computational emergence is the view that novel behaviours can emerge as a result of local computational interactions (Forrest 1991; Langton 1989). This is one of the approaches to artificial life. Thermodynamic emergence is the view that thermodynamic theory may be used to describe how new, stable behaviours and structures nay arise at loci removed from known equilibrium. Emergence relative to a model sees emergence as a deviation of the structure or behaviour of a system from an observer's model of it. It is this latter model of emergence which we wish to use as one basis of opportunistic design collaboration.

Figure 1 shows an example of visual emergence. Designer A uses the single visual form shown in Figure 1(a) and locates seven copies of it as shown in Figure 1(b). Designer B, however, does not see seven copies of the original form, rather designer B sees two overlapping squares created by those seven copies. In an opportunistic collaborative design environment designer A and designer B are sharing the same electronic whiteboard and design B now wants both of them to work with the overlapping squares for a while. How can this be achieved.

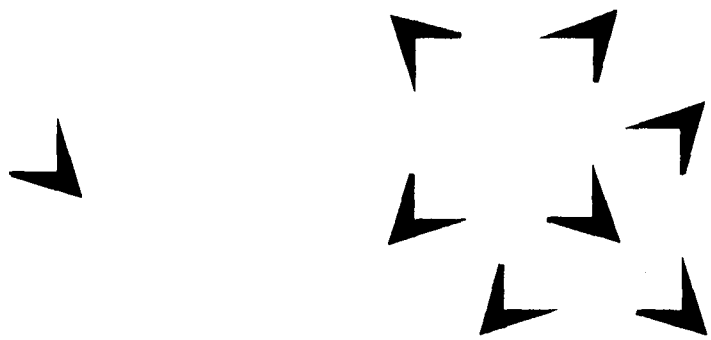

Figure 1. (a) Simple visual form; (b) seven copies of the single form in particular locations such that a number of visual forms emerge.

3 Emergence in Collaborative Computer-Aided Design

Emergence plays an important role in designing and particularly in collaborative design but is not yet supported in collaborative computer-aided design. Emergence allows for new views of existing situations to be introduced and thus becomes a way of changing the direction or focus of a design.

More formally, emergence allows for new instances of the schema under consideration which were not previously represented to be found. For example, consider Figure 2. the two triangles labelled T1 and T2 have been drawn, triangle labelled T3 is a third

triangle which was not drawn but emerges. It is a new instance of the triangle schema and can now be used in the continuation of the design.

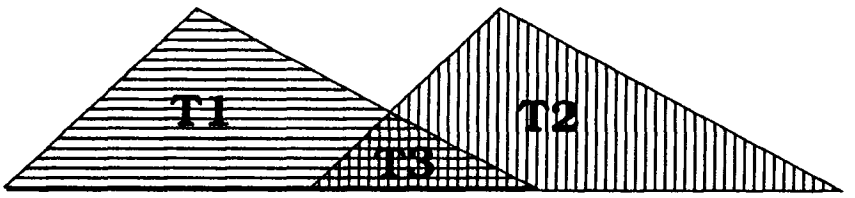

Figure 2. The two triangles T1 and T2 are drawn whilst the triangle T3 emerges as a new instance of a triangle.

Emergence also allows for new schemas to emerge, schemas which were not in the original representations. For example, consider Figure 3 which shows a form produced and represented as a sixteen-sided form from a schema of a sixteen-sided form. Figure 4 shows two squares which emerge from the form in Figure 3. These squares are based on a new schema discovered using a data-driven or feature-driven search process (Gero and Yan 1993).

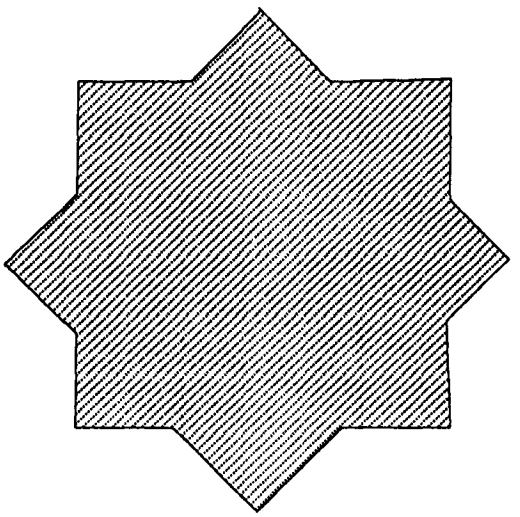

Figure 3. A sixteen-sided form produced using a schema of a sixteen-sided form.

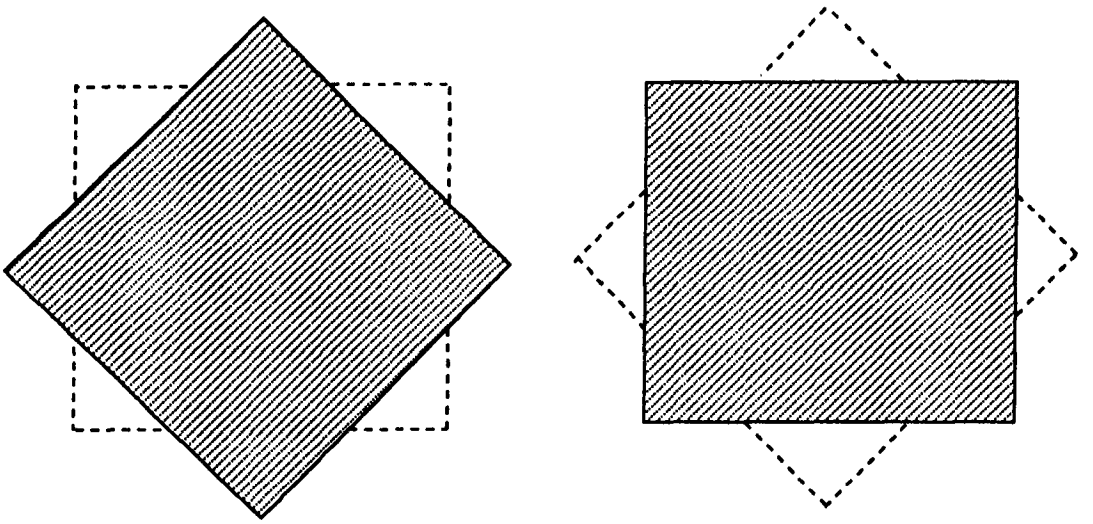

Figure 4. Two four-sided forms which emerge from the sixteen-sided form shown in Figure 3, but which have a different schema to the original form.

4 Architectures for Opportunistic Design Collaboration

Computer support for synchronous collaborative design is now being researched (Maher and Saad 1992) and various architectures for multi-user synchronous CAD systems are being developed. Figure 5 shows one such architecture.

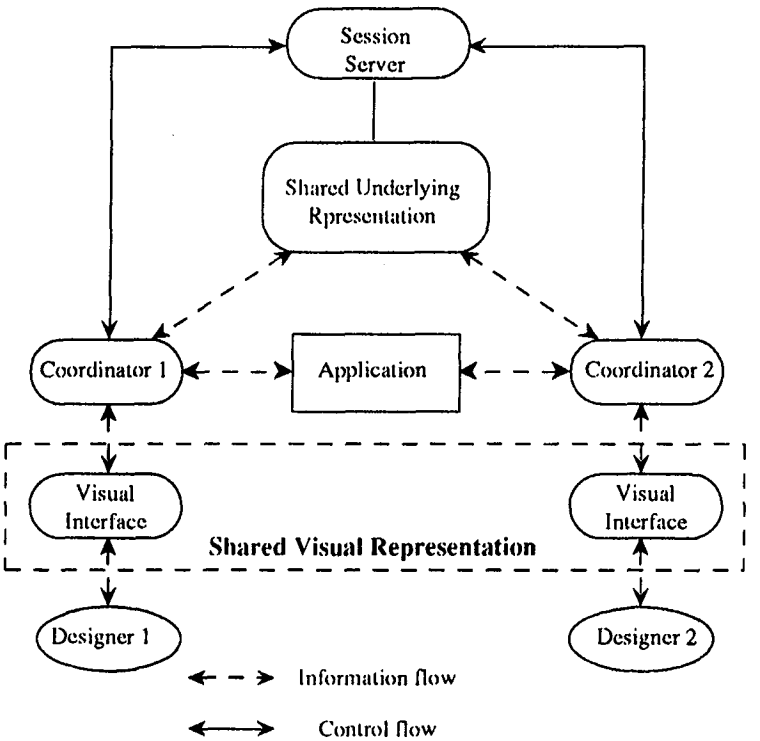

Figure 5. An architecture for a multi-user synchronous CAD system (Maher and Saad 1992)

In this architecture two concepts are introduced: a shared underlying representation and a shared visual representation.

Figure 6 shows an implemented version of the above architecture where the dxf file provides the shared underlying representation and AutoCAD is the CAD system. The underlying representation in this implementation is only accessible through a process in the CAD system.

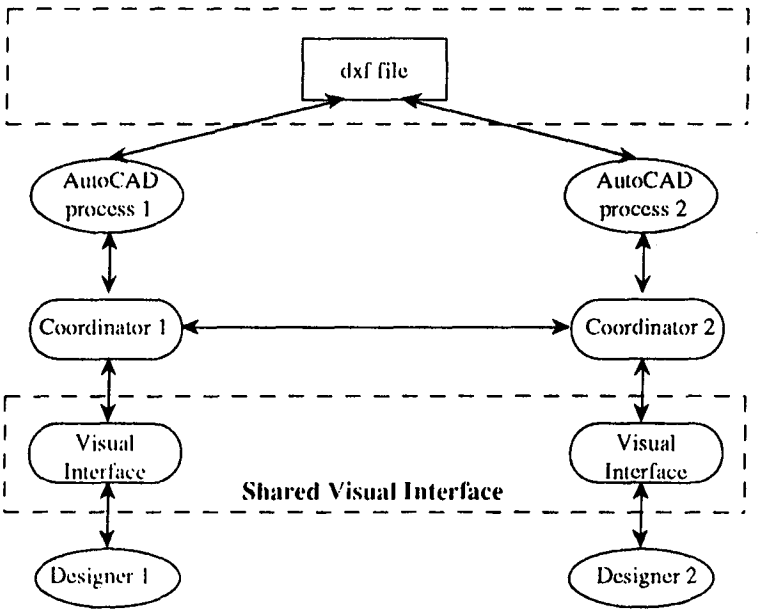

Figure 6. An implemented version of the generic architecture shown in Figure 5 (Maher et al 1993).

In order for opportunistic collaboration based on emergence to be supported two modifications need to be made to these architectures. The first is to allow the designers to see the visual aspects of possible emergent forms. This requires that emergence processes be available at the shared visual representation level. The second, and more fundamental, is to allow for alternate representations at the shared underlying representation level. These alternate representations need to modify the dxf file in Figure 6. Figure 7 shows such an architecture.

5 Emergence Process

Gero and Yan (1992) have proposed a process model of shape emergence based on the concept of 'shape hiding'. Shape hiding makes shapes which were explicitly represented become implicit. Thus, the shapes which go to make up the original or primary form lose their coherence and what is left is only background or unstructured shapes. It is to that background or unstructured representation that emergence processes are applied. Figure 8 shows a process model for shape emergence.

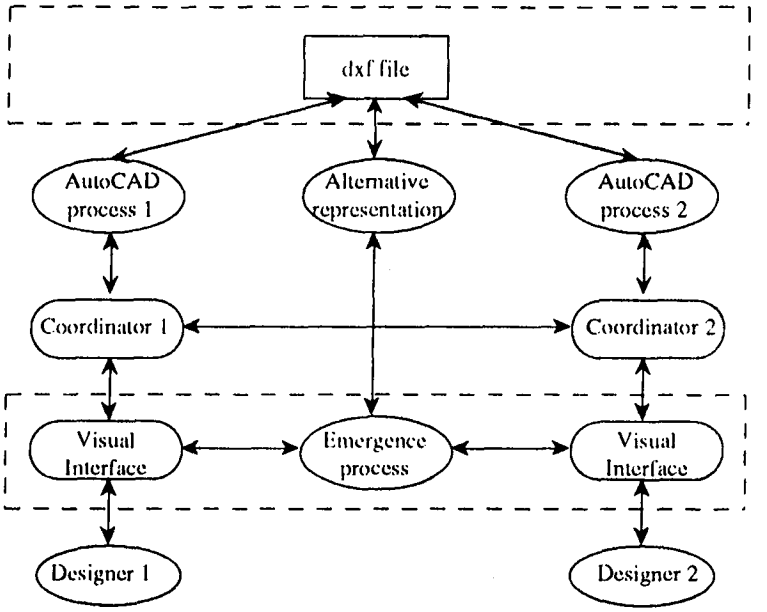

Figure 7. An architecture which allows for opportunistic design collaboration based on emergence (Maher et al 1993).

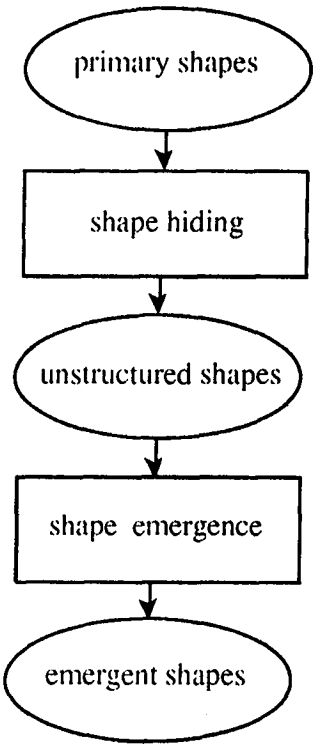

Figure 8. A process model of shape emergence (Gero and Yan 1992)

This model of emergence relies on the use of an alternate representation. A number of such representations have been proposed. The one based on the concept of 'infinite maximal lines' (Gero and Yan 1992) has been developed and implemented in a single user environment.

6 Discussion

A number of approaches can be considered in developing collaborative computer-aided design systems. The approach adopted here is to provide support for a model based on two characteristics of collaborative design - opportunism and emergence. Opportunistic collaboration demands synchronous computational support. This requires that drawing surfaces be shared rather than one be the progenitor of the others or that one be the original drawing surface with the others copies. Emergence requires alternate representations of drawings which allow for the possibility of shape hiding.

Both shared drawings surfaces with a shared underlying representation and emergence systems have been developed. This paper proposes bringing them together to provide a different kind of computational support for collaborative design.

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