An AI based framework for collaborative design

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Abstract:

Design has increasingly become a collaborative endeavour carried out by several individuals with diverse kind of expertise .The individuals may occupy institutional roles in interaction with each other. Design problems are multifaceted, solving them require the contribution of several individuals, and the general approach has been to break design tasks into units which represents individual tasks and are intrinsically co-operative.
Research in Artificial intelligence and especially intelligent agents may assist in collaborative design. Agents contain knowledge about the players, tasks, and applications.
This paper commences by discussing group work and its different aspects , researches technological issues relevant to collaboration, and develops an AI based framework for collaborative design.

1. Background:

A common practice in design is the splitting of a task into its components parts, allowing the different participants to address them separately. For instance, a part for an engineer is to calculate the structure of the proposed layout, whereas a facilities manager's part is to devise and measure the space utilisation.

In co-operative settings players do not only share information but also share applications. Earlier work by (Clarke et al 1991) showed how a co-operative dialogue between an individual and an application can be enabled . This was achieved by construction user interfaces which incorporated considerable level of knowledge in relation to the individual and the application. The interface is user conceptualised employing individual's knowledge, individual's tasks, the task domain, and the style of interaction required by the individuals. The interface is extended to support co-operative work for design groups. It will incorporate co-

operative support handlers, that, for example, assist in choosing the best application and the best interaction technique.

2. Group Work

Group work involves a group of individuals working on task to achieve a common goal. Individuals are members of a design and client teams with an overall objective to agree a design. Groups have advantages over individuals performing a task. Collectively, individuals are more likely to include a broader range, and perhaps more appropriate range, of skills and knowledge pertaining to the task. Each person brings to the group his or her experience. Group work involves much of collaboration, co-operation, co-ordination, and communication (Branki et al 1992).

2.1 Collaboration

Collaboration occurs when two or more players may have common, overlapping, or individual goals. The period of working together may involve the development of a design artefact (hence co-operation) or may involve discussions which advance individual goals.
Collaboration does not require continuous co-operation, or continuous communication. Periods of individual work may still be of benefit to the collaborative efforts.
Other aspects of collaboration include closer collaboration, that is the physical proximity which a highly accurate predicator for collaboration; focus activity which refers to occasions when individuals plan to work closely on a shared task.
Collaboration also demands that individuals share, exchange and maintain information for four reasons (Olsen 1989) ; tasks decomposition, gathering relevant expertise, pooling of different expertise and building shared goals. For a design based group activity, several tasks bear deadlines and their allocation to group members to take them on is necessary; and also because:
. different tasks require a specialised expertise, different design specialists are assembled to handle different aspects of the problem.
. individual members have limited perspectives or opinions on problems. By convening groups a larger set of ideas, wisdom, and judgement can be pooled. They are more likely to agree to a decision or a plan if they have participated in or just observed the process that led to it. Newcomers to a group work can be exposed to learn a range of perspectives by observing and/or participating in group working on problems.

2.2 Co-operation

Co-operation is best described as those periods of collaboration where participants are developing an artefact.
Co-operation brings a synergy that can realise particular benefits. Fruitful interchange between human is based upon achieving such synergy. The hypothesis is to make a computer truly co-operate which might bring similar benefits and one of the key requirement is that "if a co-operative machine is to be fully developed it must support the interactive updating of the shared knowledge base (Clarke et al 1993).

Co-operation is not a fixed pattern of behaviour, but it is changing, adaptive process directed to future results. Not all tasks will enable co-operative behaviour to be realised. For instance, tasks which require a single correct answer (i.e. mathematical problems) tend to provide little scope for co-operation. However, a situation where more than one alternative is sought provide a problem solving environment which favours co-operative behaviour. Empirical evidence to support this position has been provided by two experiments. Firstly, it has been confirmed that the superiority of the group over the individual will be highest for tasks which afford a wide range of possible solutions (Thorndike 1938). It has also been found that pairs were superior to individuals when working on problems requiring some originality or insight, but not on more routine arithmetic problems (Husband 1940) .
Co-operation, with its agreed common goals and behavioural norms, provide a secure environment for making imaginative leaps. The potential advantages of co-operative behaviour within the design process have been indicated by several researchers. In 'creative thinking' face to face group members "spark off" ideas against each other by an assembled effect so that finally the quality of ideas is higher than the individual could have achieved (Broadbent 1973).

2.3 Communication

A major feature of group work is the need to communicate. Communication concerns the transfer of information between collaborators. Reference to an act of communication is made to an event involving the choice of an available medium for the transfer of information. Design is a communicative activity in which individuals are called upon to decipher one another's world. For instance, the early synthesising of concept solutions may take place in the context of "decipherisation" within a design team (Schon 1983). And when individuals are in a communicative and co-operative situation they may become aware of the social needs and effective utilisation of the resources at their disposal.
Communication can also be two fold. The initial one focuses on , for instance, the client(s) building upon the contents of a brief, elaborating upon the description and the constraints for the benefits of the designer(s). The client(s) is the major source of information. In the final one, the designer(s) will submit completed design for approval and criticism. The designer(s) and the client(s) will consider the design options and successive designs will be refined until a solution becomes acceptable.

2.4 Co-ordination

Co-ordination refers to the necessity in ordering the passage of information amongst collaborators, due to the reliance of one upon the process performed by another.
Co-ordination is also seen as a body of principals about how activity can be co-ordinated, that is, how group members can work together harmoniously. Co-ordination may have four components : goals (i.e. design proposals), activities (i.e. designing, ordering, construction), actors (i.e. design and client teams), inter-dependencies of action in order to achieve goals (Malone et al 1990).

3. Technological Support to Collaborative Design: Research Issues

3.1 Computer-Supported Co-operative Work (CSCW)

CSCW is an endeavour to understand the nature and requirements of co-operative work with the objective of designing computer-based technologies for co-operative work settings (Bannon et al 1989).
CSCW is probably a novel idea in supporting co-operative work for design groups. The emphasis is to understand co-operative work as a distinct form of a work, and to support it with the appropriate technology.
CSCW research has taken two views for the development of shared applications to facilitate co-operative work. The first one is the " purpose built" applications such as generic tools for sharing (Crowley et al, 1990). The second view is the clean separation between application and window system functionality. This is possible with the facility offered by modern window systems. Window systems have been extended by adding "pseudo-servers" between the existing workstation software (servers) and the applications (clients) (Lawers et al, 1990)
In sum, CSCW is a research field involved in exploring a wide range of issues concerning co-operative work arrangements and its support via information technology. Studies in areas such as Computer-Aided Design, Computer-Integrated Manufacturing (CIM), Computer-Aided Software Engineering (CASE),etc., are all relevant to the CSCW field to the extend that they study the use of computers to support co-operative work in different domains.
Within CSCW technology, shared window systems allow the provision of multi-user interfaces to existing applications without modification to the application. However, they are based on the assumption that multi-user interfaces can be modelled as a collection of multiple single interfaces. Shared window systems do not allow for different roles, experience, and preferences among group members. They are strictly WYSIWIS (What-You-See-Is-What-I-See) the information presented to one user is exactly the same as to the other.

3.2 Multimedia in a Human-Computer Dialogue

In communicating design intentions, or information is conveyed in more than one form. Designers use different types of media which are essential in the reasoning process and are related in common use. With integrated office packages, a number of designers see advantages in being provided with the ability to move between different media. So for example, it is advantageous for a user to halt an animation, 'cut' a still frame, 'paste' in some text, and forward the whole to some other user, who might then choose to perform some geometrical operation such as changing the perspective. Alternatively, the message can consist of an animated sequence, which the recipient might choose to replay selectively.
Multimedia can be viewed from two perspectives: the technological and the user-centred. The former concentrates on when to use media and in what combination to achieve the maximum effect (McCartney 1990). The latter focuses on the possibilities offered by the technology to the user.
One of the current areas of research in multimedia, is finding the appropriateness of different media, maintaining its consistency, and resolving media conflict, (Alty et al 1991) explores some of these areas. Knowledge based techniques have also been applied to multimedia such

as work on relating different media, adaptive interfaces with the explicit representation and use of the real-world expertise, dialogue-like interaction, personalisation and design for usability (especially for non-expert).
Another aspect of multimedia is integration of different media because translation between them is not always possible. A system that provides integration allows change in one media to be reflected in the other one. One type of output can serve both as input and output. For instance changes in a residential map by means of a new housing development results in a revision to a graph, hence predicting for example population growth and new transport demands. In another example, maps could easily be extracted from images by means illustrating roads, existing development, and projecting new ones.
Multimedia integration system requires a strategy for providing easy and powerful access to information of all types of media. It does not change the differences between media by making them accessible to all users with equal ease. Such system needs an interface management system that is consistent, flexible, and could smooth the transition between different media: the "seamless" integration of media. Multimedia integration system was proposed by (Branki et al 1992b) to use existing design applications.
A knowledge base approach to media integration would probably result in an intelligent media system providing sensible default options, by incorporating knowledge about the most appropriate media for various situations.
Considerations of multimedia are difficult with reference to links between media and hypermedia inevitably becomes a consideration. One of the main advantages of hypermedia over multimedia databases is that the technology allows a user to browse a complex database without the need to return to the index level and formulate a retrieval query every time a new piece of information is sought.
Current hypermedial systems do have a number of limitations with the most significant being that the links which a user pursues are typically specified in advance by some script writer. There is desirable need for a more dynamic interface. This facility ultimately requires that the system creates and/or destroys links at run-time , either in response to some utility which is invoked by the user, or by performing knowledge-based inferencing.

3.3 Intelligent Front-Ends (IFE)

In co-operative settings individuals do not only share information but also share applications. An important issue is the construction of user interfaces which incorporates a considerable level of knowledge in relation to the user(s) and the application(s). By doing so, a co-operative dialogue can be enabled. Such interface is defined as one which helps users overcome their incomplete understanding of the computer system and, in this support, employs knowledge of the user, the user's tasks, the task domain and the style of interaction required by the users (Sharrat 1991). For example a shared drawing application would require a WYSIWIS mode of interaction, whereas a spreadsheet needs a command of interaction which would enable users to view the same data in different format. The issue here is to consider the types of shared information that are cognitively familiar to users. The intention is not to modify existing applications which carries the risk of negating their power and flexibility but to extend their functionality by constructing other components.

To achieve these goals, an Intelligent Front-End(IFE) was conceived as an intricate synthesis of human-computer techniques, knowledge manipulation, data model manipulation, user handling and the user interface to the possible application. In essence, the IFE is a generalised software environment which defines the mapping from any user's conceptual model of a domain to the data and control requirements of any targeted application .The IFE is extended to support co-operative work for design groups. The system incorporates intelligent support, i.e. co-operative support handlers that, for example, present the information in a different variety of media.

3.4 Co-operative Support Handlers:

Co-operative support handlers are components of the IFE and incorporate knowledge about the individuals and the applications. They participate fully, or partially, in a design session where individuals co-operate and communicate via individual workstations. Their roles may be of different forms:

. they assist the individuals in carrying out tasks; they simply aid the individuals in decomposing the tasks into one or more sub-tasks;

. they create from the information supplied by the individuals(s) and the support handlers, the description required by the application;

. they orchestrate an application against the selected task and feeds it with its required information;

. they initiate a design session, acknowledge latecomers;

. they solve the questions on design session such as who has control of the application;

. they have knowledge of different individuals profiles and responds in the appropriate manner to ensure that the design session is tailored to their profiles;

. they present information in different types of media; they are responsible for choosing the best representation to the individuals and interact with them in a way that may be different to the way they interact with applications;

. they support criticism of the shared information (representation) of design; such actions stimulate and improve reflection;

. they provide support in conflict resolutions (when conflicts are detected) by explaining the course of actions; the resolutions do not have to be based on design principles; they assist in generating alternative answers that might contradict those principles and provide a basis for reasoning about them that might be used in another situation; the main issue here is that design has a uniqueness of being conflictual and uncertain.

4. Framework for Collaborative Design

The framework takes into consideration the use of existing software applications in design. Two reasons influenced such a decision. Firstly, it is not realistic to take into consideration the effort and cost spent in most current software systems. Secondly, while there are many situations where application designed from the outset to take multi-user interaction into account, it is also appropriate the case that providing the design groups, with only these, means those groups will be deprived access to many of their pre-existing tools.

In remote working, there are different levels for what is being shared. Design groups may :

. share the same view of the same application such as a shared drawing surface
. share the same application and the same information but it may be presented in a different media
. share the same data, but manipulated by different applications and hence have a different view of the same data

(Figure 1) illustrates a framework for shared applications. The dialogue handler is responsible, at the user end, for sharing. The framework needs to know the information presented at each workstation. It enables, and facilitates user preferences.

The main intention is to develop an architecture for media usage in a collaborative design system in what (Greenberg1991) calls personalisable groupware. An architecture whose behaviour can be tailored to match the needs of group participation, (i.e. each member of a group may observe a different behaviour) and the particular needs of the group as a whole (i.e. each group may observe a different collective behaviour).

Greenberg illustrates the first point, by an example of two architects (one senior, one junior) in a real time meeting consulting a client over blueprints displayed over a shared computer-aided design (CAD) package. Depending upon personal needs and tastes, each participant may require a slightly or even completely different style of interface. The senior architect may have complete access to the control of the CAD package, while the apprentice architect may only be able to observe the drawing. The CAD-ware client may still be able to gesture and sketch around the existing drawing through a very simple graphics pencil. Illustrating, the second point, about group differences, the same groupware may be used by a group of contractors to implement the blueprint. In this case, the contractors may only be able to illustrate that part of the drawing that they are responsible for, perhaps to indicate deviations they had taken from the design.

The Framework is an extension of the IFE system . The IFE includes co-operative group working, that is, users working as a group and using applications to assist them in their task. The intention is developing such framework, is to be able to conceptionalise or personalise it to the needs of individual within the group.

In recent years the development of powerful concurrent computers and other hardware environments has provoked research interest in concurrency and distribution in AI (Fennell et al 1977). A new subfield of AI, called Distributed Artificial Intelligence (DAI) has emerged which concerned with the co-operative solution of problems by a decentralised and loosely coupled collection of agents (Davis et al 1983).. The agents are able to work in parallel, so that the overall completion time may be substantially reduced. The approaches to DAI point to a promising future for real-time systems for co-operative work in which those special requirements will be accommodated. Real-time systems have already been developed which have shown that DAI techniques are potentially of great value to applications in real-time problem solving (Nii 1988).

The types of media communicated within the framework may be static or dynamic in the form of text and/or speech (verbal), graphical images and/or animation (graphical), still pictures and/or video (pictorial), alarms/bleeps and/or music (audio).

As design tasks are complex, information used may be very complex too. The use of multiblackboards helps reduce the information complexity. Such architecture dispatches information over several blackboard architecture, each blackboard contains relatively small amount of information. This makes the system more sufficient. Finally, managing multi-

blackboards is easier than managing a big single one, because the management can be spread over several blackboard handlers (Dai et al 1990) .

4.1 The Blackboard (BB)

A blackboard is a way of organising large amounts of data or knowledge in a manner which allows different agents to act upon the data, almost concurrently. The analogy with a traditional blackboard is very strong in that the method of communication between participants in the problem solving exercise is via the blackboard.
The BB acts as a communication centre for its clients. It stores the information representing the current state of the problem as input by the user or inferred by the support handler. Blackboard clients are divided into two categories: those at the individuals-end (dialogue handler and user support handlers) concerned with extracting from the individuals the input and the target definitions, and those at the back-end concerned with creating the input and instructions to drive the application program(s). The clients within these two categories exchange information by means of separate communication areas on the blackboard termed the individuals and the targets areas. The two classes exchange information by means of the main problem definition area. The main problem definition area contains the definition of both the description of the problem and the specification of the required targets.
Clients can also explicitly ask the blackboard for information or to keep them informed of new information posted to any particular area. This avoids clients having to tell the blackboard and also serves as a mechanism whereby two or more clients can create a blackboard as a communication channel between them. For example, the user dialogue area is used to pass information between the dialogue and the support handler in order to validate input and provide essential feedback.

4.2 Dialogue Handler (DH)

The DH is a communication switch and a protocol converter sitting between a communication media and the blackboard. The DA is responsible for mapping the data generated by the communication media in the format required by the blackboard and conversely, to map the commands emanating from the blackboard to semantically equivalent to the communication media.
It also decides on how best to present the communication media to the individual.

4.3 User Handler (UH)

The UH tracks the individual's progress and ensures the system responds in an appropriate manner. Its function is to set, and, update the appropriate user conceptualisation (individual type and level of expertise). This ensures the subsequent design session is tailored to the individual's skill level and that the appropriate level of guidance and feedback or help can be given by the support during the session.

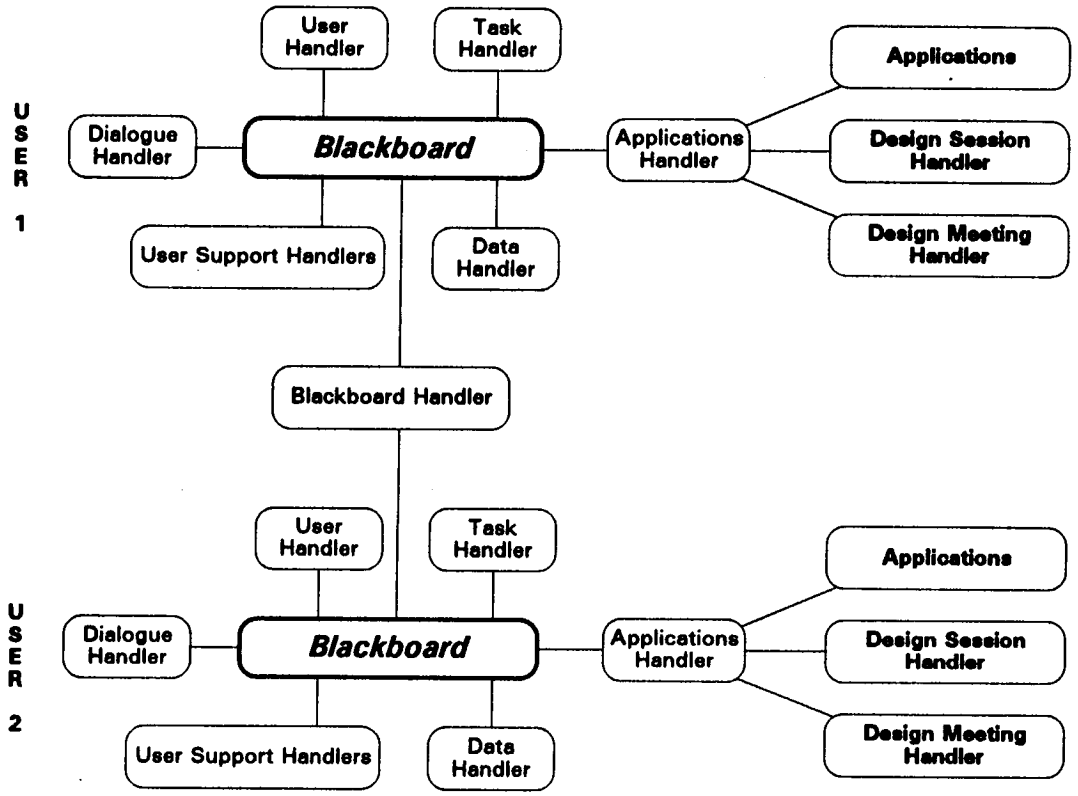

Figure 1. Framework for Collaborative Design

4.4 User Support Handlers (SH)

The USH assist the individuals in carrying out tasks; they simply aid them in decomposing the tasks into one or more subtasks. They are responsible for choosing the best representation to the individuals and interact with them in a way that may be different to the way they interact with applications. They support criticism of the shared information (representation) of design (Branki et al 1993); such actions stimulate and improve reflection. They assist in accessing information, players externalise design ideas and design relies heavily on the ability to recall ideas. The USH aid in associating ideas which is an important part in design thinking. They assist in choosing the best suited application and the best interaction technique. They support the expression of design actions; the expression is useful for a number of tasks such as explanation, learning, and redesign. They provide support in conflict resolutions (when conflicts are detected) by explaining the course of actions; the resolutions do not have to be based on design principles. They assist in generating alternative answers that might contradict those principles and provide a basis for reasoning about them that might be used in another situation (the main issue here is that design has a uniqueness of being conflictual and uncertain). They control the dialogue, collect and validate entries, make whatever inferences are appropriate and store them on the blackboard.

4.5 Data Handler (DH)

The DH creates from the information supplied by the individuals and the SH, the description required by the application (s).

4.6 Task Handler (TH)

The TH chooses the relevant application with which to implement the task.

4.7 Applications Handler (AH)

The AH orchestrates an application program against the selected task and feeds it with its required information.

4.8 Design Session Handler (DSH)

The role of the DSH is to initiate and terminate a session, acknowledge latecomers, support multiple group sessions.

4.9 Design Meeting Handler (DMH)

The DMA resolves the questions on session control policies such as who has control of the application, who likes control, and how it is passed to other individuals.

4.10 Blackboard Handler (BBH)

With groups, Blackboards are coupled in the system and are capable of running concurrently. The multi-blackboard framework is provided for communication channels among blackboards. If a single blackboard is used, within a Design Session, it then may become a bottleneck.
A Support handler may need to exchange information in order to co-operate. The role of the BBH is to convey information from one individual workstation to the other. The passing of information is done via the blackboard. The BBA also performs information transformation required by the user support handlers and applications.
The information presented to one player is either the same as the others or in a different format depending on the individual's choice, as it could be inferred by a user support handler.

5. Summary

Design is not acted upon by one individual but by many more. Individuals interact and their interaction is greater, if not best, in Individuals reasoning processes.
The framework proposed is an extension to other work done on Intelligent Front Ends. The work of Clarke has been influential. The Framework, with its group work functionality, supports the use of existing Computer Aided Building Design applications.
Within the framework individuals are dynamically related because they learn to reinforce the concepts expressed during the interaction. Players also introduces new information, without it

there is a risk of reducing the effectiveness and the creative potential of the relationship. One major research issue is the handler does not have to remain captive of its initial facts and inferences procedures. In this way, it becomes free of its limitations, and improve its performance overtime.

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