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Haiyan Fan
Texas A&M University, hfan@mays.tamu.edu

Sanjay Notakar
Thinking Frontiers, sartan1729@yahoo.com

Marshall Scott Poole
Texas A&M University, mspoole@tamu.edu

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Haiyan Fan
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hfan@mays.tamu.edu

Sanjay Notakar
Thinking Frontiers
sartan1729@yahoo.com

Marshall Scott Poole
Texas A&M University
mspoole@tamu.edu

ABSTRACT

Complex design problems require members of project teams go beyond individualistic work to engage in joint activity of generating new insights, new ideas, and new artifacts. Excellence in the design of GUIs requires creative problem solving. It is widely accepted that creative problem solving is most effective when individuals or groups employ a cyclic process of divergence-convergence consisting of three phases. In this paper we propose a collaborative environment for GUI design and evaluation, at the core of which is a process-based Agent Facilitator (AF). The advantage of this AF lies in its 1) focus on process of managing group dynamics rather than the content of the discussion, 2) democratic and non-obtrusive facilitation style, 3) strong feedback mechanism and 4) transparent collaboration and consensus making process. We discuss the system architecture and the implementation of a prototype extending the online chat mechanism. Although our initial effort has focused on the domain of Graphic User Interface (GUI) design, this framework is applicable to other design domains.

Keywords: collaborative design, creative problem solving, GSS, agent facilitator, GUI design,

INTRODUCTION

Complex design problems require members of project teams go beyond individualistic work to engage in joint activity of generating new insights, new ideas, and new artifacts. In the past twenty years, Computer Supported Cooperative Work has been a prolific area in exploring computer-mediated technologies to facilitate design collaborations ranging from software engineering to mechanical engineering and urban planning (Olson, Olson et al. 1993). Extant literature has identified two major categories of technologies in collaborative design. The first one treats design collaboration as argumentation via computer-mediated technology. Through the creation and use of "coordinative artifacts" (Schimidt & Wagner), this approach aims to argument designers' ability to create, to reflect, to reason and to make decisions (Fischer and Reeves 1992) . The second approach is to build collaborative problem solving system to tap into the synergy of human collaboration. These system view the design team as a social unit and support team engagement in the idea generation and decision making process (Patel, D'Cruz et al. 1997; Poltrock, Grudin et al. 2003). Open source software communities have successfully experimented with Web-based, computer-mediated communication in exploiting local knowledge (Scharff 2002).

In this paper we take the second approach mentioned above and present an agent facilitator-based collaborative design GSS framework. We first review the work process of prototypical collaborative design from the perspective of "disciplined creativity". Next, we review agent facilitation technology as a way to effectively mange this creative process. Then we present a process-based model of agent facilitator based on the facilitating heuristics proposed by Poole et al (1998). Although this framework is applicable to different domains, our initial effort has focused on the domain of Graphic User Interface (GUI) design. Due to space limitation, we focus on the conceptual development of the proposed framework, leaving out the discussion on detailed implementation and evaluation of the system for an upcoming work.

COLLABORATIVE DESIGN AS CREATIVE PROBLEM SOLVING

Design is a ubiquitous activity that penetrates all walks of life from the traditional design discipline such as architecture and engineer to any organized joint construction of some kind of artifacts such as documents, Web sites, software, etc. The complexity of design problem requires beyond the capability of any individual and calls for the collaborative effort of a team or community. In software design projects, cross-functional collaboration typically involves multiple minds such as UI designers, programmers, human factor specialist, marketing people, and user researchers. To obtain the creative synergy of group work, design teams often face challenges due to spatial and temporal distance, as well as ideological and technological differences (Fischer 2004). According to Fischer, these are barriers that designers of collaborative technologies should pay heed to in creating socio-technical environments that enhance "social creativity" of design community.

Excellence in the design of GUIs requires creative problem solving. A good design will not simply represent the "least common denominator" of the ideas advanced by different designers. Rather it will combine the best elements in a creative fashion and often with a result that could have been anticiKateed by no single designer. A facilitator for the design process must therefore promote creative problem solving.

It is widely accepted that creative problem solving is most effective when individuals or groups employ a cyclic process of divergence-convergence consisting of three phases: (1) divergent thinking that generates a variety of ideas or approaches, (2) freeflowing discussion of the ideas and approaches that surfaces strengths and weaknesses, (3) convergence on a subset of ideas and approaches that seem promising, with repetition of this cycle from steps 1 to 3 continuing until a final solution emerges (Whetten and Cameron 1998). Divergent thinking can be promoted in a variety of ways including brainstorming, use of analogies (synectics), drawing, etc. This view is echoed by systems designers. In the context of systems design, Geisler et al. (Geisler, Roger et al. 1999) modeled a six-stage process in which designers travel back and forth between individual space and public/group space in an iterative manner through which design ideas become mature.

Convergence can be promoted by evaluation methods such as rating and voting, as well as discussion and negotiation. A number of procedures and tools for facilitating divergence and convergence have been advanced over the years. In the *divergence* phase, individuals create new ideas and designs, and the emphasis is on taking advantage of the diverse talents, education, and experiences of members. To engage in divergent thinking it is important to help team members overcome conceptual blocks such as "we've always done it this way" or "there's only one right answer" so that they can let their minds freely range over design possibilities. Once it gets rolling, a group engaged in effective divergent thinking has a sense of excitement and members feel free to express ideas, no matter how wild.

The phase of *freeflowing discussion* represents a transition from divergent to convergent thinking. In this phase a group shifts back from a sense that "the sky's the limit" and begins to consider ideas in light of what is practical and within available resources. This will often surfaces differences of opinion that may lead to conflict. If the team has handled the divergence stage properly, it will have a range of ideas, and freeflowing discussion will create respect for the potential of those ideas, and a sense that it is now important to come to agreement on a final design. At the end of an effective discussion phase the team will not have come to agreement. There may even be a feeling of tension and conflict, but the conflict will be constructive conflict over ideas, not counterproductive person-oriented conflict.

In the *convergence* stage the team takes the ideas and designs developed in the divergent stage and moves toward a common decision. In some cases the team selects one idea or design, but more often it combines elements of several ideas. In a successful convergence stage the members will develop a solution that all are committed to and that reflects the values and principle of all members. The team will not attain consensus through compromise on the least common denominator, but will work to create a final decision that is of high quality and that all can be proud of. This requires the team to confront and solve problems and conflicts that arise along the way. It also requires the team to identify characteristics of a good solution and ensure that the final design satisfies them. In some cases the team will recognize that their current solution is not adequate or faces problems it did not anticipate and will "recycle" to phase 1, starting a process that continues through the cycles until a final high quality design results.

It is important to note that the previous description describes an *effective* creative problem solving process. It is also, of course, possible (and quite common) for a team to approach these stages in an ineffective manner that results in an inferior design, conflict and tension that undermine the team's ability to work effectively in the future. Indeed, many of the habits

and tendencies people have in working in teams are counterproductive and undermine effective convergence and divergence (Poole, 1991). An effective facilitator, human or machine based, counters common problems that emerge in team interaction (Straus 2002).

FACILITATION and FACILITATION AGENT FOR GSS

A Group Support System (GSS) is a type of groupware that combines communication, computer, and decision technologies to support decision-making and related group activities (Bostrom, Watson et al. 1992; Fjermestad and Hiltz 1999; Fjermestad and Hiltz 2001; Poole 2002). GSSs have been designed to support both small and large groups that are either co-located or distributed. While GSSs support information sharing, meeting management, and other group activities, their main functions of interest here is support for creative problem solving in the design process. GSS tools such as brainstorming, brainwriting, and shared whiteboards can be used to support divergent thinking. Conferencing, chat, and commenting tools support discussion. Convergence is supported by tools such as rating, ranking, commenting, and multi-criteria decision making.

The tools provided by a GSS will foster creative problem solving only if they are used appropriately. A good deal of research suggests that a facilitator can greatly enhance team effectiveness in the GSS environment (DeSanctis and Gallupe 1987; Poole and Jackson 1992; Fjermestad and Hiltz 2001; Jarboe 2002; Poole 2002), especially when the team is inexperienced with the GSS technology. Traditionally facilitators have been human experts, but with the advancement in areas such as text and voice recognition and agent based systems it has become possible to meet important elements of human facilitators' functions through automation with intelligent agents. The effectiveness of agent facilitators has been supported by preliminary empirical studies (Dennis, George et al. 1988; Poole 1991).

Two types of agent-based facilitator have been advanced: *content-oriented* and *process-oriented.* Though both work towards the same goal of achieving a high quality group decision, these two types of agent facilitator take different approaches and provide different functionalities. A content-oriented agent facilitator enhances the effectiveness of GSS by alleviating the problem of information overload through helping the group with idea organization (Chen, Houston et al. 1996), identification of relevant information, and recommendation of solutions. A great number of studies have proposed solutions to tackle the problem of organizing or categorizing ideas. Mostly grounded in an AI perspective, these studies focus on machine learning algorithms such as automatic indexing, classification, and cluster analysis that focus on the content of the communication (Chen, Houston et al. 1996).

A process-oriented agent facilitator, on the other hand, concerns itself with helping the team manage the group dynamics involved in divergence and convergence, rather than with the specific content of the discussion. Most discussions of facilitation emphasize that the facilitator should focus on process, leaving the team to deal with the specific ideas and content of the discussion (Broome and Keever 1989; Phillips and Phillips 1993; Vreede, Boonstra et al. 2002; Vreede, Davison et al. 2003).

In order to promote creative problem solving, research on facilitation suggests that, among other things, a good facilitator should:

- Balance participation in the group in order to ensure that all ideas are thoroughly discussed and fairly considered (important in all three phases).
- Protect minority and unpopular viewpoints (important in divergence phase)
- Focus group discussion on differences among members to help the team work toward agreement (important in discussion and convergence phases)
- Assist the group in defining criteria for making decisions (important in convergence phase)
- Summarize and pull together discussions to test for agreement among members (important in all phases)
- Encourage the team to make decisions that all can accept rather than letting votes which may divide the team be the final choice mechanism (important in the convergence phase)

Another important role for the facilitator is to head off counterproductive processes and reroute them in more productive directions. In the case of design processes, moving through the phases of divergence and convergence effectively requires the group to avoid certain well-documented dynamics, including:

- Avoiding premature convergence, which often happens when groups are attempting to resolve or avoid conflict (Hall & Watson, 1970) (important in all phases)
- Avoiding bandwagons in which the members become so enamored of one idea that they accept it without considering other options in any degree of detail (Maier, 1970) (important in discussion and convergence phases)

Based on interviews with thirty-four professional facilitators on the issues in distributed meetings, Niederman et al. (Niederman, Beise et al. 1993) summarizes several challenges regarding the process, task and facilitator that echo the concerns in the previous lists. In particular, professional facilitators expressed concerns with uneven participation, as well as difficulties in resolving conflict and reaching consensus. This study result has been echoed in Clawson and Bostrom's study of the facilitation role in group support systems environment (Clawson and Bostrom 1993) which derived sixteen dimensions of facilitator behavior using a grounded approach. In designing agent-based facilitation, these functions and concerns should be addressed.

Several designs for agent facilitators in GDSS have been advanced   (Angehrn 1993; Limayem, Lee-Partridge et al. 1993). We model the agent facilitator after the one proposed by Poole et al. (Poole, Bjorklund et al. 1998) for the following reasons. First, the essence of Poole et al.'s model is an automated facilitator who "listens" to the group discussion attentively and whose radar is tuned to detect undesirable group behaviors such as domination or one-sided opinion. It embodies the vision that we have in mind of a less intrusive but empowering facilitator. Secondly, the model's strong feedback mechanism is facilitative of group discussion and idea convergence. Thirdly, the model builds high transparency among all group participants into the collaboration process. Previous research on non face-to-face groupware systems such as that reported in (Patel, D'Cruz et al. 1997) has indicated design weakness in low understandability of the decision making process. In the proposed model, the final decision is not imposed by the facilitator or any members in the organizational hierarchy, but rather it is constructed iteratively through the group discussion until a consensus is achieved. This open forum is implemented as a chat room mechanism, which will be further illustrated in the following section

AGENT FACILITATED COLLABORATION PROCESS

In instantiating Poole's model, we adhere to three principles regarding the behavior of the agent facilitator and the technology of the system, respectively, to maximally preserve the spirit of Poole's model. The first principle is the principle of communication balance, which requires even participation and supports multiple perspectives. The second principle is the principle of outcome-focus, which helps to keep the team focused on the tasks, to ensure relevancy of the comments from participants, and to organize the team interaction towards the same goal of achieving a design consensus. The third principle is the principle of communication transparency, which requires a prompt feedback loop between participants and the facilitator, as well as open discussion among participants. This principle entails technical specification of the system that would provide asynchronous chat environment in which group members can see what was being written by fellow group members and message from the agent facilitator (AF thereafter).

In alignment with previous research, we conceived a two-stage agent facilitated collaboration process. The first stage focuses on idea generation (divergence), where new design proposals are advanced or modified from the initial few proposals in a iterative manner. The second stage concentrates on idea convergence, where final candidate proposals are being evaluated against a set of GUI evaluation criteria.   Two distinctive roles are involved in the process: participants are GUI designers who are to propose design ideas, critique designs, or express opinions. The agent facilitator (AF) is responsible for mediating and smoothing out the entire process. AF's messages include instructions for participants on how the discussion should proceed and AF's final decision based on each designer's rating or voting.

The overall collaboration process follows a structured iterative loop, as shown in Figure-1. Within any given iteration, discussion does not follow a particular order as participants self-select themselves to speak. We classify participants' communication into the following categories:

- *Proposal*. A GUI design advanced by a participant (a GUI designer. A collaboration session typically involves multiple designs, each of which, may be modified, dismissed, or selected in the upcoming iterations of discussions. All proposals have a unique ID number.
- *Comment*. A text message entered by a designer during the discussion. A participant can qualify a comment by proposal, valence, and evaluation topic.

- *Valence*: A comment can be informational (e.g. "FYI: the three dimensions of usability evaluation is effort, performance and user satisfaction...") or transitional (e.g. "I'm taking a water break now"), in which case the designer would mark the comment as neutral. If a comment is to critique a proposal, the commenting party would enter either a positive or a negative valence.
- *Evaluation topic*: aspects for evaluating GUI design including content, presentation, structure, and behavior. When participants send out a comment about a given proposal, they have to specify what topic is this comment about.
- *Rating*: represented as interval variable, rating is the number (from 1 to 5) entered by each designer for the evaluation of a single proposal
- *Vote*: the proposal number of top choice selected by each designer for an iteration of discussion.

As shown in Figure-1, the collaboration starts with one or more proposals. Participants engage in the discussion by sending comments on any of these initial proposals and rating them as they see appropriate. These comments with the associated proposal number, valence value, and topic specification are stored in a database in the agent facilitator engine. The AF monitors the discussion for undesirable behavior based on encoded rules, such as dominance or one-sided opinions. Once a rule fires, the AF participates in the discussion by broadcasting a message to the participants. We discuss the details of the facilitator rules in the next section.
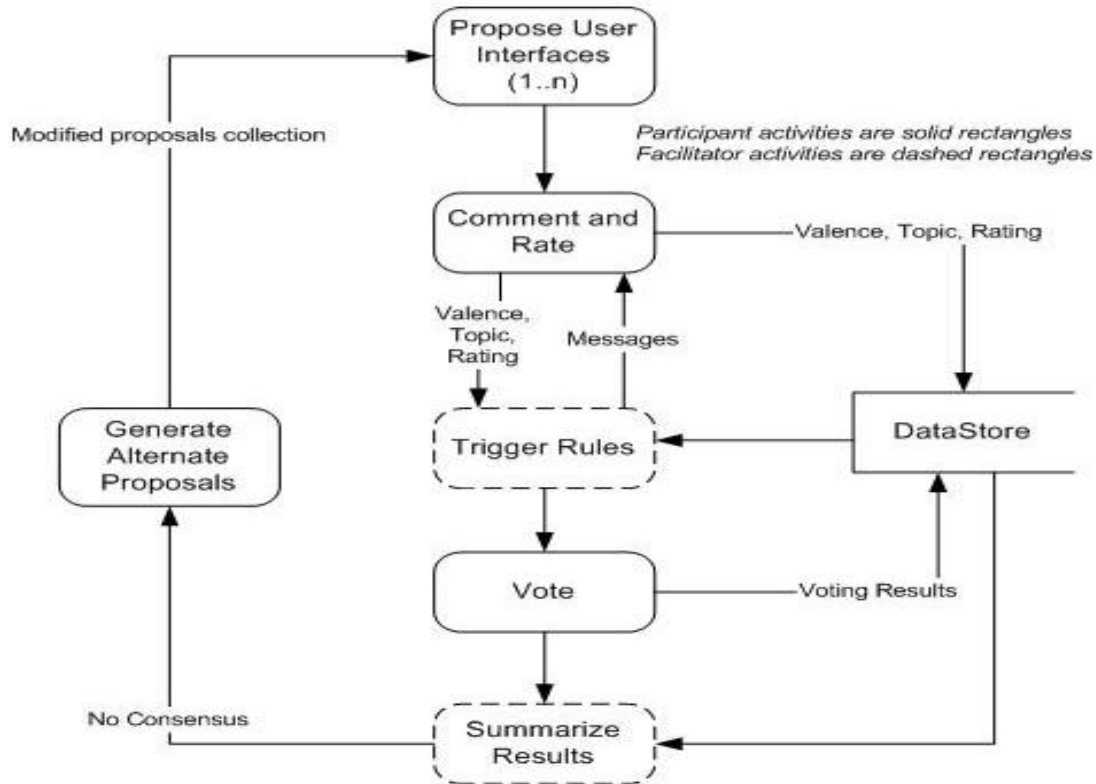

Figure-1.TheFacilitatedCollaboration Process

FACILITATION RULES

Facilitator Rules (FR) offer support for the two-stage process of divergence and convergence. Poole et al. (Poole, Bjorklund et al. 1998) compiled a list of 18 rules for an agent-based facilitator. In this design we use the six of their rules. Each rule includes specifications of when the rule should be triggered, what conditions trigger it, and the message that is sent when the rule is triggered. In illustrating these rules, we use specific numbers such as "45 minutes" or "3 rounds". These numbers are given for illustration purpose only. We expect individual teams adapt these rules to fit their own situation. In presenting the rules, we separate those appropriate for the divergence stage and those for convergence stage.

Rules for Divergence Stage

1a. Protecting Against Premature Convergence
When To Trigger: when needed
Condition for Triggering: If one particular proposal is discussed for more than 70% of total comments
Message: You have focused your discussion on just <u>proposal name (insert here)</u> proposal. To make an effective decision, it is important to consider a range of ideas. It would be a good idea to consider alternatives before finalizing your decision.

1b. Maintaining Balanced Participation
When to Trigger: Every 15 minutes
Condition for Triggering: If each designer has not contributed 20% of the comments in a 15 minute period OR if any one user's participation is greater than 40% of total comments in that 15 minute period.
Message: Some members have not participated as much as others during the last session. It is important that everyone's opinion be heard. Please make sure all members have a chance to contribute.

1c. Bringing Out Positive and Negative Points in a Balanced Fashion
When to Trigger: when needed
Condition for Triggering: If any single proposal in one session gets 70% or more negative or positive comments
Message: You seem to be favoring / disfavoring (select one) proposal <u>(proposal name insert)</u>, There have been mostly favorable/unfavorable (select one) comments about it. Are there negative/positive points (select one) you need to consider?

1d. Voting and rating summary
When to Trigger: after group votes or rates proposal
Condition for Triggering: Send after every group vote or rating
Message: Based on the last rating/voting, you are in agreement on <u>(proposal name insert),</u> you have less agreement on <u>(proposal name insert).</u> You definitely need to discuss the latter one(s) first in the next session.

Rules for the Convergence Stage

2a. Prompting for criteria selection
When to Trigger: after 45 min
Message: now that (insert number of proposals discussed) proposals have been discussed in the past 45 minutes, it is a good time to evaluate each proposal on a set of criteria. Please evaluate these proposals against each evaluation topics.

2b. Promoting Criteria Convergence
When to Trigger: When needed
Condition for Triggering: If one particular criterion entered is discussed for more than 80% of total comments
Message: You have focused your discussion on just <u>criterion name (insert here)</u>. To make an effective decision, it is important to consider a range of criteria. It would be a good idea to consider other criteria too.

2c. Prompting for Voting and Rating
When to Trigger: After 3 rounds of iteration
Message: now that you have several different ideas and opinions about criteria on the floor, it might be beneficial to determine the reaction of all designers. The rating and voting tools will help you do this. Rating the proposals against the criteria will enable you to discover areas of agreement and disagreement. Voting for the proposals will help you narrow down the choices of proposals.

2d. Voting and rating summary
When to Trigger: after group votes or rates proposal
Condition for Triggering: Send after every group vote or rating
Message: Based on the last rating/voting, you are in agreement on <u>(proposal name insert),</u> you have less agreement on <u>(proposal name insert).</u> You definitely need to discuss the latter one(s) first in the next session.

We base the operation of the AF's heuristics (*Facilitator Rules*) on several factors:

- Time interval

- Number of comments made by each designer at any given time interval

- Number of comments made on any specific proposal at any given time interval

- Valence of comments on any specific proposal at any given time interval

- Usability criteria discussed on any specific proposal at any given time interval

At the first stage, FRs are more concerned with balance participation and thorough discussion of each proposal. At the second stage, FRs focus on evaluating the usability aspects of each proposal again the usability thesaurus compiled from several sources (Nielsen 1992; Wiklund 1994). Although the AF itself is domain independent, it makes use of domain knowledge by treating an evaluation topic analogous to a proposal. In other words, every facilitator rule (see below) that applies to a proposal also applies to an evaluation topic. The only difference is in the priority of broadcasting messages. If two rules, one related to a proposal, and the other related to a topic fire simultaneously, the AF broadcasts the message related to the topic first, before broadcasting the other message after a preset delay.

Examples for facilitator rules

Now that we have specified facilitator rules, we further illustrate the use of these rules through some concrete examples. Suppose four GUI designers Kate, Lucas, Frances, and Sanjay join in the web design of an online bookstore. Inspired by real web sites, these four designers present four different design ideas, which served as the initial seeding ideas. Respectively, Sanjay proposed the "amazon" style, Frances advanced the "barnes and noble" style, Lucas had the "bookpool" style, and Kate presented the "read me doc" style. In the first 15 minutes of the discussion, "barnes and noble" got the most attention, with 11 out of 15 comments. At this juncture, the AF fired rule 1a. After the first AF intervention, designers realized that "read me doc" had not received any comments at all and diverted their attention to this "unpopular" idea. This time the AF fired a second rule, 1c, pointing out the one-sided negative opinion about "read me doc", which got 7 negative valenced comments in a row. Frances opined that "read me doc" had some enticing features. At the end of the first iteration, the discussion focused on combining the nice-and-familiar features of "barnes and noble" with the challenging-and-enticing features of "read me doc." As a result, Lucas proposed a brand new proposal, "doc and barnes" at the beginning of the second iteration.

SYSTEM ARCHITECTURE AND IMPLEMENTATION

We patterned our prototype implementation after the online games model such as the ones for chess and bridge, by Yahoo (http://play.yahoo.com) and MSN (http://www.msn.com). Figure 2 shows its primary components. Due to the paucity of space we present only its highlights. While implementing the user interface for the system, we provide support for two important issues: 1) ease of data entry through a keyboard oriented data entry technique, and 2) detecting partial comments and continuations to avoid skewing the results due to incomplete sentences ("phrase-oriented" communication) which occurs frequently in online chats. Figure 3 shows a screenshot of a discussion in progress, while Figure **4** shows how the participant can rate and vote a proposal.
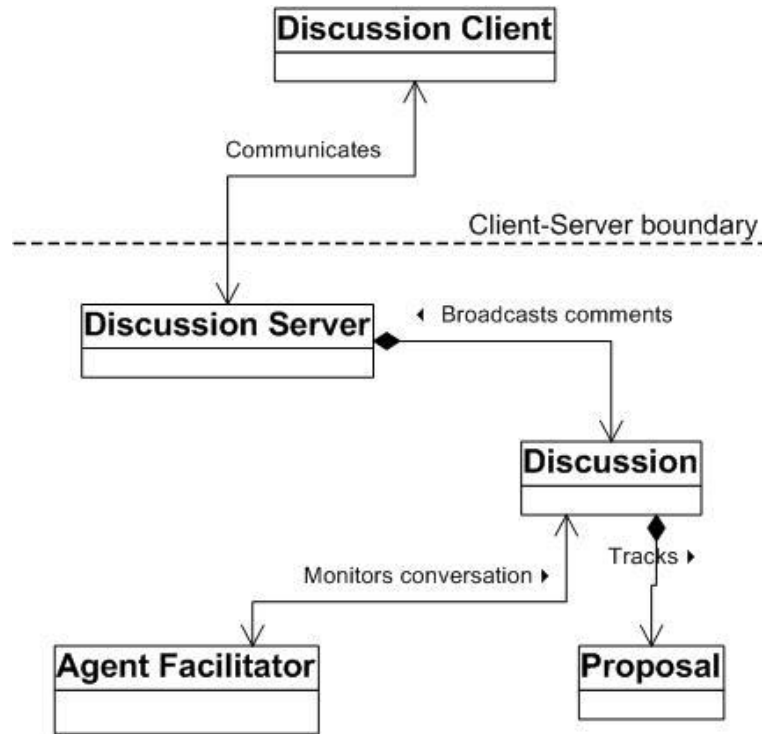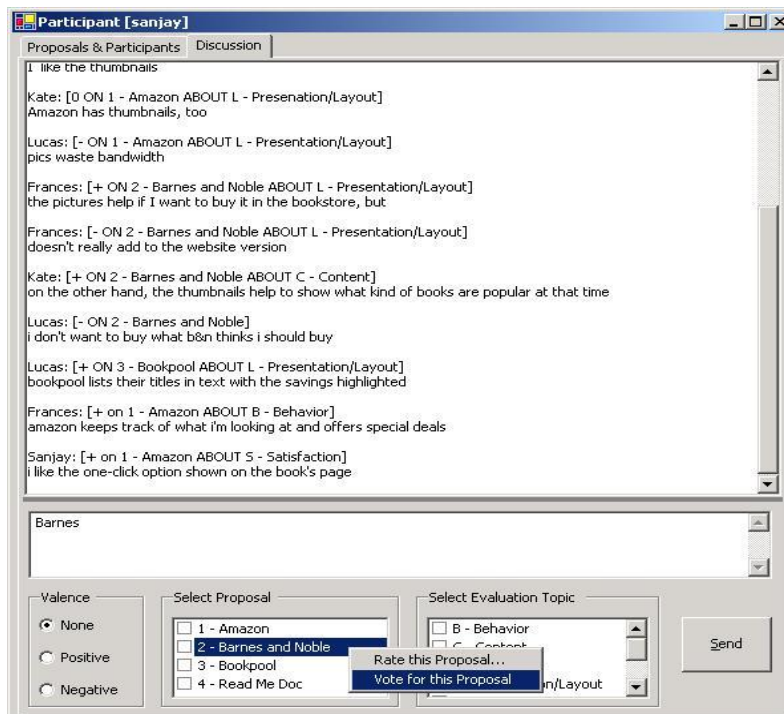
Figure 2. System Architecture

Figure 3. Discussion Screen showing fields for structured communication
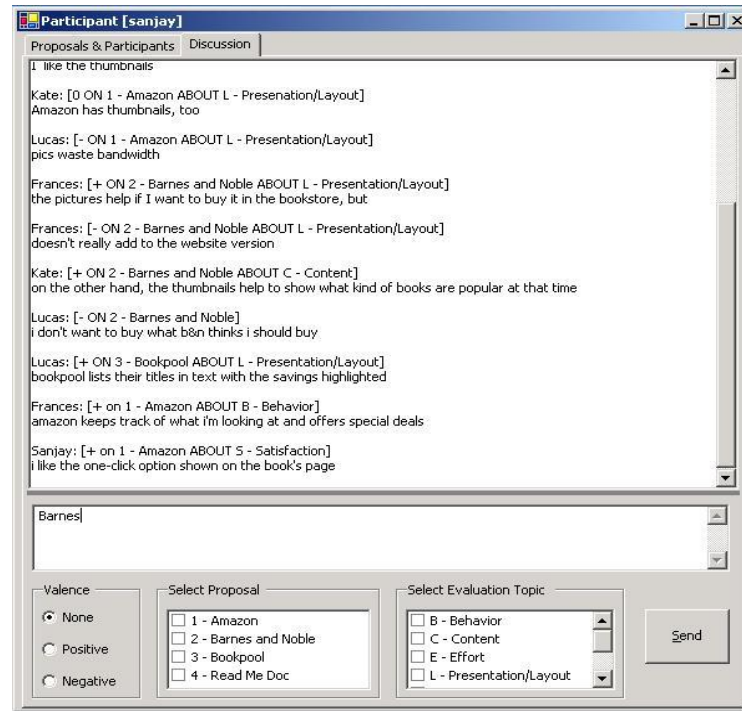
Figure 4. Discussion Screen showing rating and voting menu options for a proposal

SUMMARY

In this paper we propose a collaborative environment for evaluating GUI layouts, at the core of which is a process-based Agent Facilitator (AF). The advantage of this AF lies in its 1) focus on process of managing group dynamics rather than the content of the discussion, 2) democratic and non-obtrusive facilitation style, 3) strong feedback mechanism and 4) transparent collaboration and consensus making process.

We also present the system architecture and the implementation of a prototype extending the online chat mechanism. While, we have conducted a simple evaluation with just four participants in a controlled setting, we are yet to conduct experiments with variable numbers of participants, proposals (layouts), and discussion time in a real-world setting. We surmise that there is some optimal range of these parameters that will facilitate a team to arrive at a consensus.

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