Building the Mega-Collaboration Interface: Behavioral, Cultural, and Cognitive Factors in Visualization Support

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Abstract

Technology has enabled mega-collaboration on an unprecedented scale. A tool is needed to coordinate these activities and link them to government response efforts. However, in defining and responding to problems, teammates need to be able to visualize each other's mental models. The tool must encourage the team to advance promptly through team "forming, norming, storming, and performing." Finally, it must help individual teams visualize efficiently the "big picture," using agents to enhance the process. The usability of a prototype mega-collaboration interface has been tested, the second generation interface is being implemented, and a novel agent-based interface is being planned.

Keywords— **Computer-mediated communication, data grid, disaster recovery, human-computer interaction, mental models, treemap**

1. Introduction

Mega-collaboration denotes the emergence of vast numbers of ordinary citizens, empowered by information and communications technology (ICT), coming together to tackle tough, complex problems. Although this kind of collaborative project forms to confront any large-scale problem, the phenomenon is most dramatically manifest in disaster response. A specification of a tool to support mega-collaboration was outlined in 2006. [17] A major goal was to enable the coordination of citizen-generated information with that of the formal response effort. [20]

The main idea behind the design is that a response effort can be divided among dynamically formed sub-teams with the aid of web-based software agents. Each sub-team can develop its own model to define its part of the problem. Sub-team representatives can then consolidate these models in agent-facilitated compare-merge sessions, thus enabling large teams to agree on a problem definition and coordinate effective action. The information developed by this method can be dynamically organized into a shared knowledge base to link the public's mega-collaboration to the government's command-and-control structures.

HCI visualization techniques must support frontend processes, while agents support backend processes. This paper examines prototype interfaces and the role of agents. The next section discusses the emergence of mega-collaboration and why a support tool is needed. Section 3 examines the functional dynamics of the process the tool is designed to support. Section 4 offers a detailed discussion of tool design considerations.

2. The Mega-Collaboration Model Emerges

Recent years have seen the growth of two divergent empowerment models for confronting disasters and other societal challenges. The first is a top-down, single-chain-of-command model, exemplified in the United States by the National Incident Management System (NIMS.) The second is a bottom-up, community-based collaboration model, empowered by information and communication technology—the *mega-collaboration model*. [18]

While Congress mandated NIMS use for disaster response in 2002 [20], mega-collaboration has grown rapidly. Hastily formed networks (HFNs) coordinating immense humanitarian responses were in evidence following the World Trade Center attack, the Indian Ocean tsunami, the Pakistani earthquake, and Hurricane Katrina. [5] The months after Katrina's landfall saw a massive flow of information through hundreds of thousands of blogs, listbots, and bulletin boards, soliciting resources from donors and channeling them to victims. [17]

Unfortunately, these two models have not worked well together. Divergent empowerment models result in divergent organizational cultures, methods, and outcomes. During Hurricane Katrina, the mega-collaboration model succeeded where the NIMS model had failed. [17] NIMS functioned poorly in situations with many victims or volunteers. [20] Neither model is necessarily sufficient to provide complete disaster recovery, but with no easy way to pull together the top-down and the bottom-up activities, their combination may add to the chaos instead of reducing it.

3. Dynamics of Mega-Collaboration

A support tool could help to coordinate these two approaches. To develop, however, a device that can visualize these activities through of a user interface, we must first understand the dynamics of mega-collaboration and the cognitive processes involved in it.

3.1. Emergent Goals

In a top-down organizational structure, the head decides on a goal and initiates a "chain of command" that can be many layers deep. [14] The mega-collaboration model, however, empowers people through a bottom-up process. The power to act is spontaneously generated by groups of people working together. Both top-down and bottom-up methods are based on shared goals. However, for top-down methods, the goal is elaborated from the vision of the head; for bottom-up models, it emerges from the visions of many people. To understand how to support the bottom-up process, we need a clear picture of how bottom-up organization happens, viewed from individual and group perspectives.

3.2. Mental Modeling

Although mega-collaboration implies a massive set of players in the conversation space, the interface must support each player individually; it must support problem-solving at the individual level by facilitating mental modeling.

An individual encountering a problem attempts to understand it by forming a mental model of its salient aspects. The individual: 1) builds a system of analogies—a description of subjective entities and the relations among them and 2) uses the model to imagine alternative courses of action, to assess the imagined outcomes of each, and to select the best one. [4] Expert modelers break large problems into smaller pieces, developing models of each. This allows them to move between the levels of the decomposed problem, developing each model based on experience with other parts of the problem.

Expert modelers increase their cognitive capacity by breaking information into chunks, which reduces its load on working memory. They anchor aspects of their mental models as external visualizations, since comparing mental images and external figures lets them determine whether items are missing or have been mistakenly included. [4] To support mega-collaboration, the tool should first support the visualization of this mental modeling process.

3.3. Teaming

Even though mega-collaboration refers to a massive set of players, decision-making teams must be much smaller to bring discussions to a close. Unfortunately, as the Katrina response revealed, it is one thing to be a group of individuals and another to be a team. The process of spontaneously forming bottom-up teams becomes increasingly difficult as the conversation space widens. Cultural barriers can make it especially hard. [11][21] Denning [5] predicts they will be a persistent problem for the HFNs tackling a disaster. Therefore, the tool must support group problem-solving by facilitating the spontaneous formation of small teams and the negotiation of team activities. This is a process with particular visualization needs.

The bottom-up emergence of teamwork across the Internet can be illustrated by the way people form spontaneous teams in massively multiplayer online role playing games (MMORPG). Rauterberg [22] studied this, detailing levels of interaction similar to Tuckman's classic observations on team development. [28]

When encountering a dangerous situation, an individual's course of action is usually motivated by survival and a desire to help others. [10][15] This causes the individual to reach out to others to obtain or give information, thus arriving at the first level of interaction, which Rauterberg [22] calls *informing*. As the individuals exchange information, they must make a trade-off between entering into competition or collaboration. [22] Although competition may be a common choice in a MMORPG, in a real emergency, collaboration is typical, though competition does occur during mass panics. [10][15] Once individuals choose to collaborate, they achieve the next level of interaction, *coalition*, in which they agree to support each other. This stage is the "forming phase" of the team. [28]

As the teammates get acquainted and begin to work out their relationship, they reach the next level of interaction, *coordination*, in which they share resources, but still lack common goals. At this stage the purpose of the team is relatively undefined, [1][22] and cultural differences can be an issue. If teammates have different expectations, they will have to negotiate common ground or the team will disintegrate. [2] A support tool, however, can help at this stage. For example, Ess and Sudweeks [8] and Hewling [11] describe how online teammates from different cultures engage in an ongoing process of negotiation to generate a new "third" culture constructed from the participants' online encounters.

Based upon the forming of this "third" culture, the team's agreement on both its purpose and common set of goals leads to the next level of interaction, called *collaborating*. At this level, the participants have collectively attained the same goals, but have different roles, which are individually assessed. [22] The team passes through two stages of development, because collaboration may be adversarial or cooperative, depending on whether the participants are attempting to maximize individual or group outcomes. [13]

The first is an often turbulent "storming phase" identified by Tuckman [28], in which the team members are in adversarial mode as they argue their way through defining team rules and roles. [1] However, to achieve efficiency, the individuals must develop skill at harnessing each other's expertise to accomplish the task at hand. [13] To do this, individuals need *awareness* [7]—an understanding of the activities of others, which provides a context for one's own activity. Continually updated awareness lets teammates move easily between close to loose collaboration as the situation demands. [7] A shared team plan is also required, translating the goals, roles, and awareness into a set of behavioral norms that governs the moment-by-moment operations of the team. [13] As the team works out its issues, it enters the second, "norming phase" [28], in which competition turns into cooperation, as rules, roles, and responsibilities are understood, and the team's decision-making process is agreed on. [1]

Once the team becomes proficient at its roles and processes, it moves to the next level of interaction, *cooperating*, in which participants subordinate their individual interests and goals, and work together to reach a common goal, with decisions carried out together. Here, at what Tuckman calls the "performing stage" [28], the members are a fully functioning team, with the ability to constructively criticize each other and work through conflicts. [1] One sign of this is the members' willingness to switch roles.

3.4. Scaling Up

To move to the next level of functionality, virtual teams forming separately have to be able to find each other in cyberspace. Crisis situations make this harder. People may lack the time needed to search the Web for other forming teams. However, the tool could perform this function by using autonomous software agents to monitor the emerging conversation space on the Web for similarities. Each human team could spawn an agent that detected the formation of other human teams, analyzed their developing models, and formed agent teams with the agents of teams that had similar models. [23] Agents could then monitor for synergistic or detrimental interactions between sub-teams and alert their members of the need to coordinate.

4. Implications for the Interface

We have developed a mega-collaboration prototype, written in AJAX, PHP, and MySQL [16] with which to examine the implications of collaboration dynamics.

4.1. The Mental Modeling Interface

The information in a developing mental model must be viewed in a number of different contexts, each a type of hierarchy. Together, these individual hierarchies form a complex network. The object-oriented paradigm [3] offers a couple of clear advantages as a method to support visualization of this network. First, the paradigm was designed with exactly this problem in mind. Second, it will be easier to interface the resulting mental models with other software tools if the underlying paradigm of both is the same.

Therefore, we can assume that the model visualization interface will need to describe: 1) the parts of a decomposed entity (its class structure), 2) specific instances of the entity's general categories (its object structure), 3) the relations among the physical components of the entity (its module structure), and 4) the relations among the dynamic components of the entity (its process structure).

More specifically, the items of information that need to be defined are: 1) the domain in which an entity exists, 2) the goals of the entity, 3) the tasks necessary to achieve the goals, 4) roles and their task assignments, and 5) the team players who will fill those roles.

The class structure of the tasks, including relations between subtasks, must be represented. These are decomposition level, sequence, selection, and iteration. It is necessary to follow the process flow of work objects as they pass through the domain from role to role, and from task to task. [20] Types of variables that might need to be recorded include function, structure, dimensionality, degree of certainty, temporal reference, degree of generality, degree of closure, and degree of quantification. [5] Most coordination requires cross comparison, so the support of matrix views will be important. A longer-term goal will be giving the team the ability to define its own data input and data output widgets.

The interface of our prototype currently addresses the requirements of mental model building with an expanding entry form (Fig. 1) to help the modeler maintain a visualization of the hierarchical sub-models. The entry form lets the modeler give each entity a name and a text description. It also permits the addition of unstructured lists of attributes to each entity, and ensures

Figure 1 Expanding Form – Currently in Use

the modeler defines the relations among the entities. However, the current entry form is simplistic compared to the specifications listed above. Not surprisingly, when we conducted usability testing, the test participants struggled with it.

The prototype also provides a treemap (Fig. 2) to visualize the model by showing the entities at each level, and enabling the modeler to click up and down the hierarchy. However, the prototype's treemap does not perform chunking by visually representing both the divisions and the recursive subdivisions of each category. [12][27] As a result, it is more memory intensive for our test participants than we had hoped.

We have conducted testing on 23 participants to date, and our conclusion is that data tree and data grid methods of entry will solve both problems. In particular, a data tree (Fig. 3) will allow more flexibility in describing the hierarchy, because icons can be used to denote different types of entities. The example illustrates the model of a test participant, showing how much easier it is to see discrepancies.

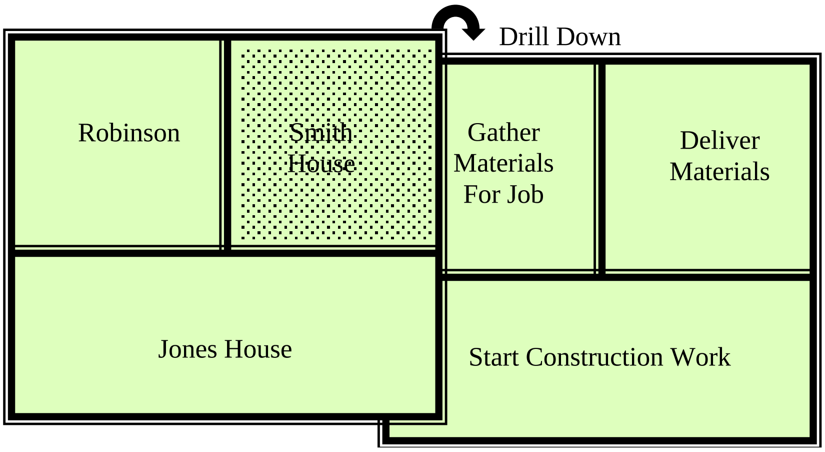

Figure 2 Tree Map – Not Well Received

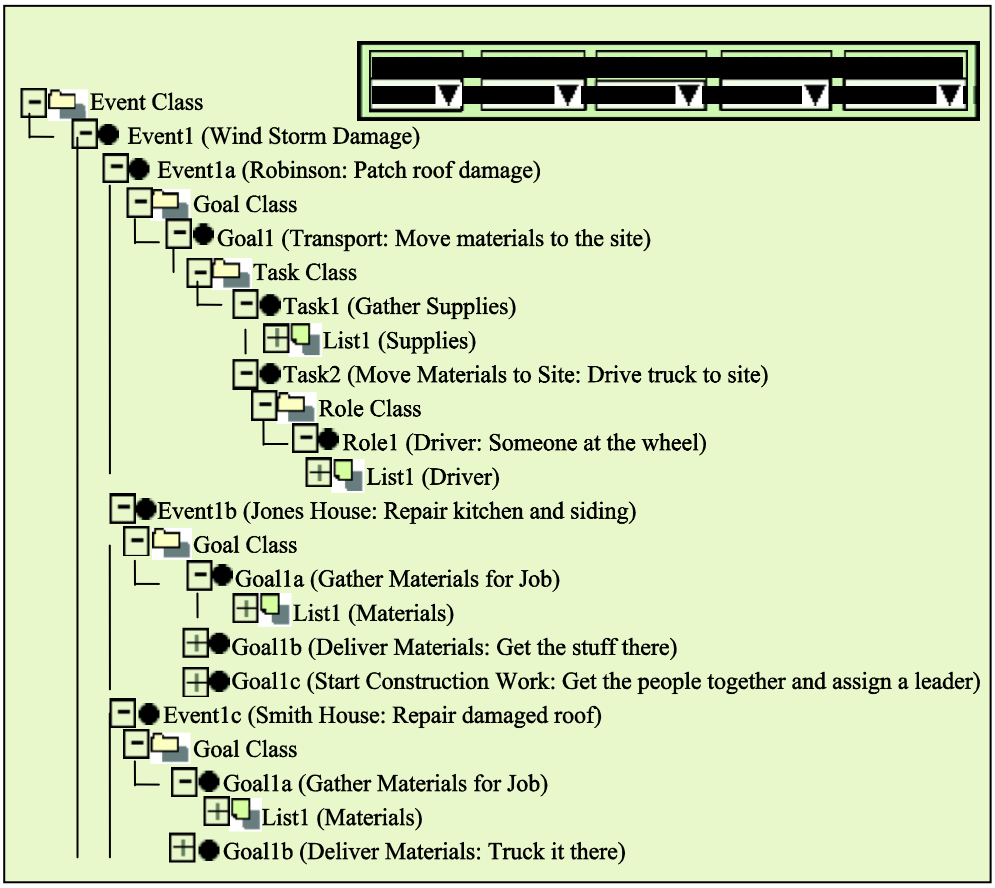

Figure 3 Data Tree – Under Development

4.1. The Teaming Interface

A small amount of scripted guidance in the team's forming stage can jump-start team-building. [9] The interface should provide such a script, encouraging the teammates to create explicit mental models of the team's developing culture, and should also provide a structured environment in which cultural negotiation can take place and common ground can be established.

The current prototype interface supports the negotiation process with script windows, a chat window, and a timed negotiation protocol. The script encourages each teammate to develop an individual model of the problem, to compare this model with those of other teammates, and to negotiate consolidation of the models into a team model. The team then develops an action plan based on this consolidated model. Although our usability tests have identified a few shortcomings in this protocol, in particular, in meeting the user's need to repeat segments and adjust time intervals, the interface still shows promise in moving teammates from coalition through coordination and collaboration to full cooperation. Each test team succeeded in creating a group model with the participation of each its members.

Another issue is how best to support team formation. One model already available that addresses this type of problem is the spontaneous teaming protocol of MMORPGs. [22] Typically, someone will propose a quest and issue a recruiting call in the game's general chat room. Those who want to participate will answer. The nascent team will then establish its own private conversation, and the quest will begin. Other recruiting methods are the use of friends' lists (e.g., from the major social networking sites), and letting participants scan the topics and teams already established and join a team according to their preference. The interface should also allow formation of restricted participation teams, with assigned participants, via a chain-of-command structure.

The initial experimental interface will use the MMORPG model, providing a general chat room where prospective teammates can meet and create team chat rooms. A name and description of each active team will be shown in a data tree in the general chat room, serving as a link to the team chat room for latecomers. In this way, the experimental interface can support formation of the initial coalition in addition to the later team phases.

4.1. The Scaling Interface

The next step is for autonomous agents to assist small teams to coalesce into mega-teams. Agents spawned by the formation of each team can continually scan the developing team models as they are added to the shared database. The agents can then form teams of their own with the agents of other human teams that have similar team models, and coordinate the human teams.

Although similar agent technologies are already available, their use has been limited because of an inability to interface with real human organizations. [18] We hope to address this gap with our mega-collaboration support tool. We plan to extend prior research by Paul Scerri on Carnegie Mellon University's small-world networking architecture. This has already been used successfully to test the goal coordination of large agent teams facing an emergency response scenario, and to allocate roles and tasks to these teams [24][25][26]. However, by adding human teams that essentially serve as methods of the agent teams, we believe that significant functionality can be achieved.

The agent network will facilitate the mega-team-building process. The relationship of independently forming teams to each other is similar to the relationship of individuals to each other. In fact, if each team is represented by an individual, it will actually *be* the relationship of individuals to each other. Therefore, the entire process, from coalition to cooperation, which we have just examined, can happen whenever multiple teams work together. A meta-team can be formed through the facilitation of an agent-managed interface.

As the collaboration progresses, the agent teams can use preprogrammed rules to determine the conditions under which the continually dividing and merging streams of activity will be synchronized, allowing humans on the meta-teams to renegotiate common views of the data. [6] The agent network can also mediate the division of teams that have grown too large.

Another function of the agent network can be managing communications. The communication function must deliver needed information and filter out the rest. In a chaotic situation, such as a disaster response, the amount and accuracy of the "pre-filtering" that teammates do for each other can have a dramatic impact on the efficiency of the team. [25]

Ideally, each individual should be able to calculate the trade-off between the expected cost and value of sending information. Scerri and Xu [25] demonstrated that knowledge of four parameters can significantly improve the ability to judge this trade-off. These are: 1) who has recently asked for that type of information, 2) who has recently sent information related to that type of information, 3) who has paid a big reward for that type of information, and 4) who has already sent the team member that particular piece of information. The first three parameters increase the expected value of sending information, while the last parameter reduces it. The agent network can monitor these parameters and use them to direct the information flow.

Although the autonomous agents will work in the background, communicating through messages, their improvement on people's ability to visualize the big picture is expected to be dramatic. By managing the synchronization and efficient communication of information, the agents will expand people's ability to visualize by telling them where to look.

4.2. User-Centered Development Process

This project has moved through its inception stage following a user-centered development regimen. We completed the first stage of a usability study using paper prototypes of the system, and followed it with a second stage using an interactive prototype of the team negotiation interface. Currently, we are completing an experimental Web site that will feature another generation of the interactive prototype, which we will elaborate with an agent-driven mega-collaboration interface. This fully functioning system will undergo a range of user-centered heuristic inspections, task studies, and questionnaires to further examine its usability.

Conclusion

Mega-collaboration is an emerging phenomenon, driven by the growth of information and communication technology. A new type of interface is called for to efficiently coordinate these activities, linking them to those managed in the traditional chain-of-command manner. This interface must provide support by enabling individuals to visualize their own mental models, and by enabling them to visualize their teammates' mental models. It must support the developing team as it moves from its first tentative coalition through coordination and collaboration to its final achievement of full cooperation, allowing the team's developing internal culture to become part of its negotiated team model. Finally, it must enable individual teams to visualize efficiently the big picture by providing agents to optimize the time and attention given to the view.

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References

[1] Barnum, C.: 2000, Building a team for user-centered design. Proceedings of IEEE Professional Communication Society International Professional Communication Conference and Proceedings of the 18th Annual ACM International Conference on Computer Documentation, 325-332.

[2] Beers, P., Kirschner, P., Gijselaers, W., Boshuizen, H. (2005) Coercing knowledge construction in collaborative learning environments. Computer Support for Collaborative Learning Proceedings of the 2005 conference on Computer support for collaborative learning: learning 2005: the next 10 years! Taipei, Taiwan Pages: 8 - 17

[3] Booch, G., Maksimchuk, R., Engle, M., Young, B.,Conallen, J., and Houston, K. (2007) *Object-Oriented Analysis and Design with Applications* (3rd ed.). Boston: Pearson Education, Inc.

[4] Crapo, A., Waisel, L., Wallace, W., Willemain, T. (2000) Visualization and the Process of Modeling: A Cognitive-theoretic View. In Proc KDD '00 (2000) 218-226.

[5] Denning P. Hastily formed networks. Communications of the ACM, 49, 4 (2006) 15-20.

[6] Dourish, P. 1995. "The parting of the ways: divergence, data management and collaborative work." Proceedings of the Fourth European Conference on Computer-Supported Cooperative Work. 215 – 230.

[7] Dourish, P. and Bellotti, V. 1992. "Awareness and coordination in shared workspaces." Proceedings of the 1992 ACM Conference on Computer-Supported Cooperative Work. Pages: 107 – 114.

[8] Ess, C., and Sudweeks, F: 2005, Culture and computer-mediated communication: Toward new understandings. Journal of Computer-Mediated Communication, 11(1), article 9. http://jcmc.indiana.edu/vol11/issue1/ess.html.

[9] Farnham, S., Chesley, H., McGhee, D., Kawal, R. and Landau, J: 2000, Structured online interactions: Improving the decision-making of small discussion groups, Proceedings of the 2000 ACM Conference on Computer Supported Cooperative Work, 299-308.

[10] Fritz, C & Williams, H. (1957) The human being in disasters: a research perspective. *Annals of the American Academy of Political and Social Science*, (vol. 309, pp. 42-51).

[11] Hewling, A: 2005, Culture in the online class: Using message analysis to look beyond nationality-based frames of reference. Journal of Computer-Mediated Communication, 11(1), http://jcmc.indiana.edu/vol11/issue1/hewling.html.

[12] Johnson, B. and Schneiderman, B: 1991, Treemaps: a space-filling approach to the visualization of hierarchic information structures. Proceedings of the 2nd Conference on Visualization '91, pages 284 – 291.

[13] Johnson, H. and Hyde, J: 2003, Towards modeling individual and collaborative construction of jigsaws using task knowledge structures (TKS). ACM Transactions on Computer-Human Interaction (TOCHI), 10:4, 339 – 387.

[14] Lupia, A. 2001. "Delegation of Power: Agency Theory." Published in Neil J. Smelser and Paul B. Baltes (eds.) International Encyclopedia of the Social and Behavioral Sciences 5: 3375 - 3377. Oxford, UK: Elsevier Science Limited

[15] Mawson, A. (2005) Understanding mass panic. *Psychiatry* 68(2) 95-113.

[16] Newlon C. Developing a Tool for Mega-Collaboration. (2007) http://archive.nmc.org/events/2007summerconf/materials/Mega-Collaboration.pdf.

[17] Newlon C, Faiola A. Support for mega-team collaboration with cultural tools: Providing a framework for the dynamic development of team culture. In Proc Cultural Attitudes towards Communication and Technology (2006) 235-254.

[18] Newlon, C, MacDorman, K, and Scerri, P. (2007) A New Model for Mega-Collaboration. Submitted for publication in Proceedings of First International Workshop on HCI for Emergencies, CHI 2008

[19] O'Neill, E. and Johnson, P: 2004, Participatory task modelling: Users and developers modelling users' tasks and domains. ACM International Conference Proceeding Series, Vol. 86 Proceedings of the 3rd Annual Conference on Task Models and Diagrams, 67 – 74.

[20] Palen, L. & Liu, S., Citizen Communications in Crisis: Anticipating a Future of ICT-Supported Public Participation. In Proc CHI '07 (2007) 727-736.

[21] Raybourn, E: 1997, Computer game design: New directions for intercultural simulation game designers. Developments in Business Simulation and Experiential Exercises, 24. http://www.cs.unm.edu/~raybourn/games.html.

[22] Rauterberg, M: 2003, Determinantes for collaboration in networked multi-user games. Ryohei Nakatsu & Junichi Hoshino (2003; eds.) Entertainment Computing--Technologies and Applications. IFIP Kluwer Academic Publishers, 313-321.

[23] Scerri, P. (2007) Personal communication

[24] Scerri, P., Farinelli, A., Okamoto, S. and Tambe, M: 2004, Allocating roles in extreme teams. Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems - Volume 3, 1502 – 1503.

[25] Scerri, P., Xu, Y., Liao, E., Lai, J. and Sycara, K: 2004, Scaling teamwork to very large teams. Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems - Volume 2, 888 – 895.

[26] Scerri, P., Farinelli, A., Okamoto, S. and Tambe, M: 2005, Allocating tasks in extreme teams. Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems, 727 – 734.

[27] Schneiderman, B. Tree visualization with treemaps: 2-d space-filling approach. ACM Transactions on Graphics, Vol. 11, No. 1, January 1992, Pages 92-99.

[28] Tuckman, B. W: 1965, Developmental sequence in small groups, Psychology Bulletin, 63, 384-399.