Leveraging Mobile Context for Effective Collaboration and Task Management

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ABSTRACT

Collaboration and task management is challenging in distributed, dynamically-formed teams, typical in large scale disaster response scenarios. Ineffective collaboration may potentially result in poor performance and loss of life. The increased adoption of sensor rich mobile devices allow for mobile context to be leveraged. In this paper, we present Overseer, an agent-based system that exploits context information from mobile devices to facilitate collaboration and task allocation. We describe how mobile context can be used to create dynamic role-based assignments to enhance collaboration and effective task management.

Keywords

Collaboration, Emergent Volunteer, Mobility, Command and Control, Multi-agent.

INTRODUCTION

Efficient collaboration and task management in fast changing environments such as large scale disaster response is challenging. This is further aggravated by the presence of data explosion in large scale disasters, as events may get lost or delayed in large amounts of data. Well-informed decisions must be made rapidly and continually reassessed to monitor their effectiveness. Thus, mobile context is an essential element that needs to be incorporated in the decision making process.

This is significant in scenarios where the surrounding environment is rapidly deteriorating, or in the face of an imminent threat. For example, in the recent earthquake in Japan where people need to be evacuated immediately, notifications to move to higher ground could be sent to individuals who are actively engaged with their mobile device, as they would be immediately be aware of the task notification. These individuals could in turn alert other members of their community through out of band communication.

The rapid adoption of mobile devices (Entner, 2010) equipped with a rich array of sensors and increased processing power enable management systems to continuously monitor the mobile context of individuals. In this paper, we present a system called Overseer, which explores how context, specifically data and contextual information obtained through sensors on a mobile device, can be leveraged to enable efficient collaboration and task management for disaster response. For the rest of this paper, we will describe our system design and evaluation metrics. We then review related work and discuss possible challenges. Finally, we conclude with future work.

SYSTEM OVERVIEW

In this section, we describe our overall system architecture. We envision an *ad hoc* system where the disaster response engine is distributed amongst various agents, running on a heterogeneous set of devices and servers. Figure 1 is a high-level view of our system, consisting of an *ad hoc* disaster response team communicating with a disaster response engine. Team members communicate with the engine through software agents on their mobile devices which interact with various sensors.

Reviewing Statement: This paper represents work in progress, an issue for discussion, a case study, best practice or other matters of interest and has been reviewed for clarity, relevance and significance.
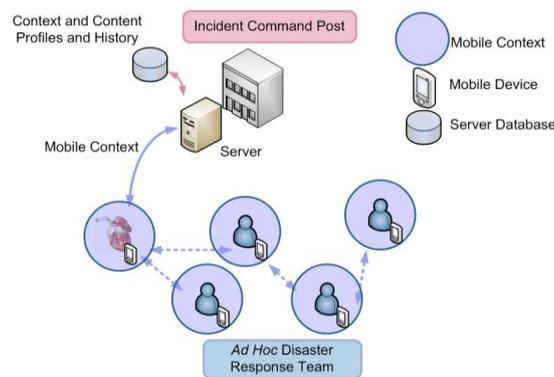

Figure 1. Overseer system architecture

The Overseer system leverages various sensors and mobile device capabilities to send contextual information about the user to the disaster response engine periodically. The engine receives and automatically monitors every team member's mobile context, current task, and calculates the probability of task completion continuously. Depending on the team member's mobile context and probability of task completion, the engine automatically recommends and/or assigns additional resources to existing tasks and reassigns tasks as needed.

Mobile Device Sensors

In Figure 2, we describe some of the sensors we are considering for gathering mobile context.

Ambient light sensor captures level of environmental light

Capacitive sensor and front facing **camera** with facial recognition measures level of engagement and attentiveness

Bluetooth and **wi-fi** measure density of surrounding team members and network conditions, as well as interface with Bluetooth capable biometric sensors to monitor team member's vital signs

Microphone measures of noise surrounding team member

GPS captures location, movement speed and direction

Accelerometer measures level of activity and task intensity

Figure 2. Sensors on a Google Nexus S mobile device

Mobile Context

The data measured by the sensors provide our system with mobile contextual information. We use Dey's definition of context (Dey and Abowd, 2000): "Context is any information that can be used to characterize the situation of an entity". In this paper, context includes any information that can be used to characterize the situation of a team member as ascertained by the team member's mobile device, including network latency.

Below, we describe the various components of mobile context collection and their application in Overseer.

Movement speed: Our system tracks every team member's current movement speed using the GPS. Highly mobile team members can be assigned tasks requiring scouting or searching with time constraints. Accelerometers can be used to give a much more immediate indication of current activity and movement.
Location and direction: Location-specific tasks can be assigned to those who are nearest to the destination. Members headed in a certain direction can be assigned a task along their projected route.
Activity and task intensity: A user's current activity and level of intensity affects the ability to perform a task (Barnard, Yi, Jacko and Sears, 2007). High priority tasks are assigned to those who haven't engaged in a long period of intensive activity.
Attentiveness: Tasks that must be completed immediately are assigned to users with the highest level of attentiveness. We assume that those currently engaged with their mobile devices will immediately receive and respond to newly assigned tasks.
Lighting: Tasks requiring visual clarity may be assigned to those with better lighting. Lighting can also be used to determine locations where injured survivors requiring medical attention could be moved.
Network latency: Network latency is continuously measured. High priority tasks are supported by or reassigned to other team members if the network latency reaches a certain threshold. The team member can also be requested to take measures to improve network latency such as switching locations or moving outdoors. Alternatively, nearby inactive team members can be requested to go to the same location to provide support or to serve as a proxy to preserve communication with the disaster response engine.
Team density: Critical tasks can be assigned or reassigned to members with a high concentration of other members close to them.
Audio: Tasks that could be affected by noise levels and require a high level of concentration could be assigned to team members with low noise levels.

Dependency Graph

The dependency graph, Figure 3, is a tree structure showing the dependency between various sub-tasks needed to accomplish a larger objective. It is used to calculate the probability of a task succeeding.
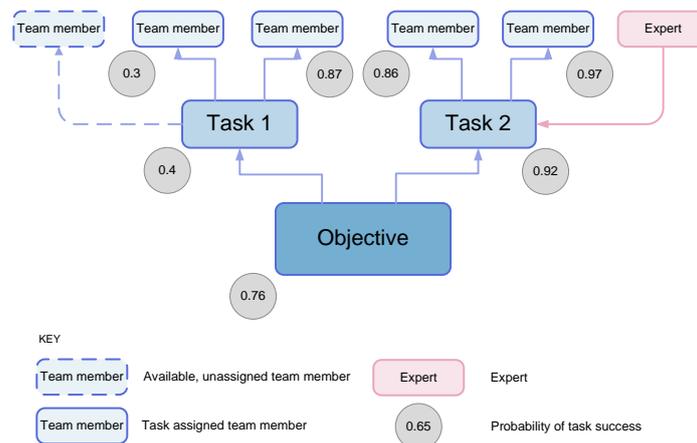

Figure 3. Task dependency graph and task completion probability.

To create the graph, the main objective is decomposed into smaller sub-tasks, which are then further sub-divided amongst team members. The number of levels in the graph corresponds to the number of times the objective is sub-divided, which depend on its size and complexity.

This dependency graph could be used as a status display for monitoring by emergency and contingency managers at various levels. In addition to displaying the names of members who are assigned tasks, the dependency graph also shows unassigned team members, as well as expert feedback.

Probability of Task Completion

Each node in the dependency graph is assigned a success probability value, determined by the mobile context and other factors such as external monitors and expert input.

If the value for a given node drops below a threshold, the engine alerts the team leader and takes steps to increase this value. This may be done by assigning additional resources, such as idle team members nearby, that will give the highest impact to the tasks. For example, to assist with the task of finding medical supplies, team members who are closest to the search site (location) and fast (movement speed) may have a higher impact on the probability value. The success probability value based on mobile context is described below.

Individual tasks: The probability of success for a task assigned to a single individual is determined by the relevant mobile context, as illustrated in Figure 4.
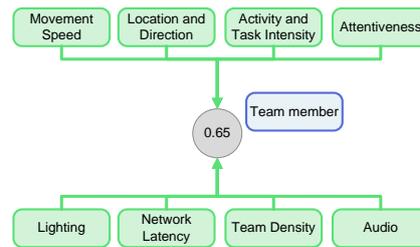

Figure 4. Mobile context used to determine probability for individual tasks.

The effect of specific mobile context will vary according to the task being performed. For example, if a team member is foraging, searching or carrying items, movement speed and location will carry most weight. If observing and reporting critical events, network latency, lighting and audio are more important. In the default case where the effect of specific mobile contextual information cannot be determined, all such information will be weighted equally.

Overseer currently uses a rule-based system to determine the weights of different mobile contextual information for different sub-tasks; more work to create a powerful statistical learning system is planned.

Dynamic Task Allocation

In Overseer, the response engine continuously monitors and assigns tasks based on each member's mobile context values using a rule engine. For example, if a scout's movement falls below a threshold and stepped out of a given radius, Overseer attempts to add or reassign the task to team members who fit the criteria in the rule engine.

EVALUATION

To evaluate the effectiveness of our system, we propose two different metrics, situational and effectiveness. The situational metric measures the phase and state of the collaboration, while the effectiveness metric measures the success of the collaboration and task management.

Situational metric: The state and phase of the collaboration are captured by the situational metric, which refers to the forming-storming-norming-performing model of group development (Tuckman and Jensen, 1977). Our system solicits team members for measures of their expertise on several key areas and uses this knowledge in addition to their mobile context to match queries with experts who can provide the best advice. Thus, our system accelerates the transitional phases of collaboration towards the performing stage by facilitating the storming and norming processes.

Effectiveness metric: The effectiveness metric measures the success and progress of the collaboration and of task management. We compare the performance of our system against a baseline collaboration environment that does not consider mobile, context awareness. Specifically, we compare the speed of completing the main objective, the number of failed sub-tasks, and the overall effort expended.

To validate our system, plan to run an experimental evaluation using Android based mobile devices in a simulated disaster response scenario at the collapsed structure testbed at NASA Ames Research Center. Finally, we plan to leverage knowledge gathered by researchers and first responders in recent disaster relief efforts, such

as in Haiti, Chile, San Bruno (Stamberger, 2010) and Japan towards designing and modeling realistic scenarios and constraints.

DISCUSSION

In general, we are satisfied with our initial design. To get to this point in the design, we placed several constraints on our initial system, which must be addressed to produce a system capable of working in a more realistic environment.

We assume that the *ad hoc* disaster response team has been formed a priori. We plan to add features in Overseer, such as anonymous voting, and to use expert characterization and mobile context to augment the initial formation of the team. Additionally, mobile devices are also constrained by limited battery life. Radio communication consumes a significant amount of power. Thus, unnecessary communication should be reduced to conserve energy. We plan to use the agent program to determine and send only significant mobile context information to the engine using statistical analysis.

The use of mobile devices in dynamically changing and critical scenarios can be challenging. For example, smoke from fires obscures vision, and small interfaces can be difficult to read while running or performing intensive tasks. The interface should be designed to be easy to interact with when wearing gloves and incorporate visual and tactile feedback in order to be effective in noisy environments. We also plan to incorporate additional design aspects to make our system more general and suitable for other domains other than disaster response.

CONCLUSIONS

In this paper, we describe Overseer, a mobile context-aware collaboration and task management system for disaster response that monitors and dynamically manages task assignment based on team members' mobile context. In designing Overseer, we make two important contributions. First, we discuss the use of data and context awareness obtained from sensors on mobile devices to facilitate collaboration and task management in a dynamically formed disaster response team. Second, we describe how our system can be used to create dynamic-role based assignments using mobile context awareness and expertise.

ACKNOWLEDGMENTS

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