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Analyze the Action Planning Problem in Disaster Responder Teams

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Synopsis

Strategic planning of activities of field units (agents) is a critical mechanism for coordination of agents by the top level of a disaster response team. Because of significance of strategic action planning (SAP) in efficient disaster emergency response, it is important to analyze the SAP problem in order to support development of proper approaches for SAP. The contribution of this paper is a model of the SAP problem that presents several dimensions of this problem including the problem domain, geographic information, geospatial-temporal macro tasks, strategic action planning, strategic action scheduling, and disaster emergency response team.

Keywords: analyze, strategic planning & scheduling, coordination, incident commander, disaster emergency response

1. Introduction

Review of the past disasters/crisis recognizes the importance of efficient emergency response. Urban search & rescue (USAR) are considered as the major part of disaster emergency response operations that their objective is to reduce number of fatalities in the first few days after disaster (Fiedrich et al., 2000). Emergency response teams are responsible for doing all operations in the area.

Effective coordination is an essential issue for emergency response management (Chen et al., 2008). Actions coordination is necessary to manage disasters and emergencies. Variants in a disaster originate from hazard uncertainty; uncertainty as to the course of incident development; informational uncertainty; task flow uncertainty (whether sequential, consequential, or cascading); organizational structure uncertainty; and environmental uncertainty. Due to these factors, coordination of emergency response is difficult to achieve (Chen et al., 2007).

In the coordination theory, coordination is the act of managing interdependencies among activities performed to achieve a goal (Malone et al., 1994). Coordination in emergency response management includes management of task flow (tasks and interdependent relationships), recourse, information, decision, and responder (Chen et al., 2008). Inefficient coordination results in “idle” agents or “redundant” actions that make duration of USAR operation longer.

Planning and scheduling are considered two major coordination mechanisms /processes for managing task dependencies and managing shared resources. Crisis response systems should utilize planning, scheduling, task allocation, and resource management tools to help in formulating crisis management plans and tracking (Khalil et al., 2009), (Jain et al., 2003). An approach to coordination in agent-based systems is to engage the agents in multi-agent planning by central multi-agent planning and distributed multi-agent planning (Nwana et al., 1996).

Strategic planning is an important coordination process for managing tasks relationships by objectives (goal selection and goal decomposition) and grouping people into units. In the organization theory, strategic management consists of four basic elements: environmental scanning, strategy formulation, strategy implementation, and evaluation and control in order to achieve organizational objectives (Hunger et al., 2003). It is important to establish a strategic planning module in the multi-incident response management system to oversee the individual responses and to propose the overall objectives and strategies of multiple incident responses.

The incident action planning function is central to the incident command system (ICS) (Buck et al., 2006), (Bigley et al., 2001). The ICS is a top-down approach that applies strategic/macro planning for coordination of actions of operational unites. The NIMS' ICS system makes an incident action plan in five phases: 1) understand the situation, 2) establish incident objectives (priorities, objectives, strategies, tactics/tasks), 3) develop an action plan, 4) prepare and disseminate the plan, 5) continually execute, evaluate, and revise the plan (FEMA, 2006).

A team is a hierarchical organization that essentially includes two levels: the top level and down level. An IC as a human planner is located at the top node in the hierarchy that his or her important role is to make macro / strategic action plans and schedules for agents' actions. Fig. 1 shows the structure of a team and characteristics of two levels.

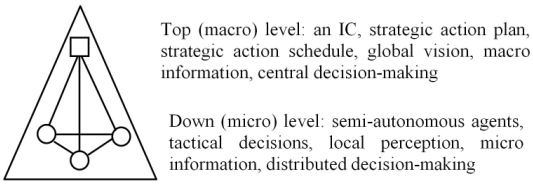

Fig. 1 the structure of a team

Consequently, in a team, SAP is an import process/mechanism to coordinate actions of agents in achieving team's goals in a minimum time during disaster/crisis response. SAP aims to make strategic plans & schedules of actions of agents by the top level of the team for coordination of tasks flow and shared recourse (agents) during crisis/disaster response. Made decisions as macro decisions constrain and limit the domain of activities of agents in the down level in time, space, goal-types etc. Because of the important of SAP in a team, it is necessary to apply an appropriate intelligent system as an ideal approach for SAP.

However, several approaches which most of them are based on the multiagent systems have been developed for coordination of disaster/crisis emergency response, unfortunately they do not address the SaP2 adequately and completely. Thus they do not provide appropriate approaches for SAP. They only address a subset of the dimensions of the SaP2.

According to the SaP2, limitation and caps identified in the related works are classified into four categories. First one is that they are automated planning systems that do not let human planners (ICs) be involved in strategic action planning. These systems are not mixed with human's intuition and do not collaborate with human for SAP. The main obstacle is scale as it is currently infeasible for a fully automated system to effectively reason about all the possible futures that may arise during execution of tasks in a complex environment (Maheswaran et al., 2010). Mixed-initiative planning systems are systems in which humans and software/agent collaborate in the development and management of plans by providing capabilities each one does best (Burstein et al., 1996). In general, they can often produce better solutions for complex problems. Humans are still better at formulating the planning tasks, collecting and circumscribing the relevant information, supplying estimates for uncertain factors, and various forms of visual or spatial reasoning that can be critical for many planning tasks. Machines are better at systematic searches of the spaces of possible plans for well-defined tasks, and in solving problems governed by large numbers of interacting constraints. Second cap is that decisions, which are made by these systems, are tactical ones that only concern the micro level and exactly specify actions of agents. Actually, it is impossible for high-level strategic action plan & schedule to fully specify detailed actions of agents at the down level. Using strategic action plans & schedules, the top level constrains the behaviors of agent at the down level.

Third deficiency is that the related works are not integrated with geographic information and neglect the importance of geographic information in SAP. SaP2 requires geographic information systems (GIS). GIS provide sufficient tools for the IC to analyze, visualize, and manage geographic and location-based information (Johnson, 2000), (Fuhrmann et al., 2008). Last limitation is that micro tasks are used to make a global view of the whole SaP2 while the top level (IC) does not access to micro tasks information. ICs have inaccessible, global, and uncertain information of the state of whole tasks environment, but agents have direct, complete, and accurate information about their local environment's state and tasks. With regard to the limitations addressed in previous works, it is necessary to propose and develop intelligent systems to collaborate with ICS to make strategic/macro action plans & schedules of agents with regard to macro tasks information and geographic information.

The objective of this paper is to analyze the SsP2 in order to support development of an ideal intelligent system for SAP. The data model is one of the most critical tasks in the entire systems development process (Moody et al., 2003). The data model is a major determinant of system development costs, system flexibility, integration with other systems and the ability of the system to meet user requirements. A data model presents elements of a problem, their properties, and relationship and interaction among these elements. Two research questions arise in this paper. What is a SaP2? What is the SaP2 data model?

Because of the importance of SaP2 data modeling and limitations addressed in related works, the objective of this paper is to analyze the SaP2.

The contribution of this paper is a model of the SAP problem that presents several dimensions of this problem. Those include the problem domain, geographic information, geospatial-temporal macro tasks, strategic action planning, strategic action scheduling, and disaster emergency response team.

2. Analyze the SaP2

The goal of this section is to understand the SaP2 and assess requirements of ICs for SAP. This problem is studied and analyzed from six dimensions.

2.1. The problem domain

USAR is the problem domain chose by this paper because of its major role in earthquake disaster response. The global goal of USAR operation is to rescue the greatest number of people who are trapped under the debris of damaged buildings in the shortest amount of time.

USAR tasks involves a sequence of dependent tasks: (1) reconnaissance and assessment by collecting information on the extent of damage; (2) search and locate victims trapped in collapsed structures; and (3) extract and rescue trapped victims; and (4) transport/dispatch injured survivors to hospitals or refuges. Rescue tasks, also, themselves are classifies into three categories: light rescue, medium rescue, and heavy rescue. In addition, there are other supporting tasks such as road-clearing tasks and fire-fighting tasks that facilitate and support USAR tasks.

To save a person, it is necessary to define a set of the USAR tasks. Sometimes several persons are trapped by a destroyed building. USAR tasks are location-based entities that are distributed in an extensive geographical area.

To accomplish each task needs a considering duration and a specific capability or several synchronous capabilities. Capability requirements determine what agents are allowed to to do what tasks.

In this domain, coordination is managing task flow. The “Enabling” dependency between tasks specifies that when a task is done completely, it makes possibility of performing another dependent task. In other words, time that a disenabled task gets enabled is dependent to the finishing time of a task that makes it enabled or released. For example, the rescue of a trapped person is dependent to the search of that person.

2.2. Disaster emergency response team

A variety of responsible or supporting teams are involved in disaster emergency response and crisis management such as Red Crescent Society rapid response teams, INSARAG teams, volunteer teams, fire-fighting teams, medical services, or

road-clearing bulldozers. A team is essentially composed of an IC in the top level of the team and several agents (field units) in the down level. They cooperate with each other to achieve objectives of the team.

2.2.1. Agents

Operational or field units/personals of the team are considered geospatial, mobile, and semiautonomous agents that are distributed in a geographic area. Their main role is to do tasks using their capabilities in the operational area.

Agents may possess heterogeneous capabilities that allow them to engage in doing tasks for which they can provide required capability. Moreover, agents execute their capabilities with different speed. They are categorized according their capabilities and performance into several agent types: (1) “Reconnaissance”, (2) “Canine Search”, (3) “Electronic Search”, (4) “light Rescue”, (5) “Medium Rescue”, (6) “Heavy Rescue”, (7) volunteer etc.

Agents are required to coordinate their actions with each other for three reasons. First reason is to manage interdependencies among actions of agents because of dependency relationships between tasks. Second one is to manage redundant actions for doing joint tasks. Third reason is to manage agents as shared resources which are assigned to time-consuming tasks. Efficient coordination minimizes the operation time in which all tasks are accomplished.

2.2.2. Incident commander

An IC is a human planner who is located at the top node in the hierarchy of the team. His or her main role is to plan and schedule actions of agents for coordination of disaster response management. Fig. 2 shows the activity diagram of an IC in a team regarding SAP.

The IC has inaccessible, global, and uncertain information about the environment’s state. His perception/observation of disaster situation is global that is different with agents’ perception of their local environment.

2.3. Geographic information

The problem domain is done in a geographical environment which includes different geographic layers such as buildings, city blocks, road network, etc. Each layer is composed of geographic objects. These layers provide base layers to which to geo-locate tasks information, agents, strategic action plan and schedule information.

There are topological relationships between spatial objects of geographic layers (Egenhofer et al., 1991) e.g. each building is contained within a specific city block while that building is adjacent to a certain road segment.

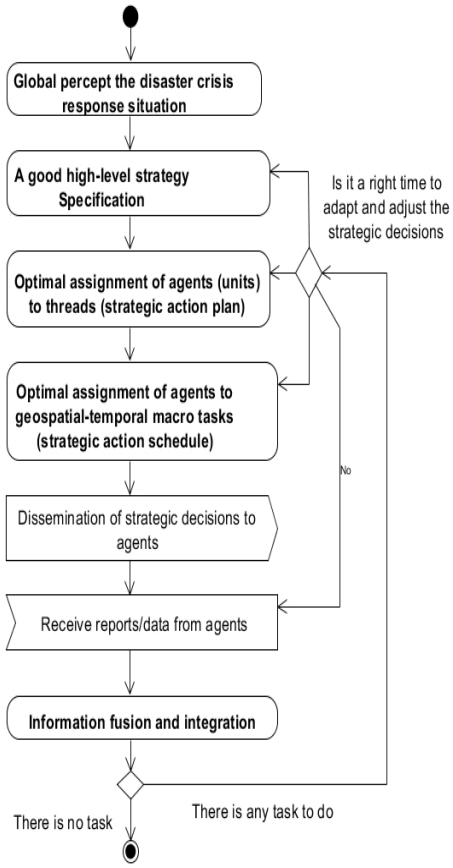

Fig. 2 The activity diagram of an incident commander in a team

2.4. Strategic action planning

The goal of SAP is to coordinate agents of a team by the IC of the team using global vision which he has from the problem.

The concept of SAP proposed by this paper is close to incident action planning process (Hunger et al., 2003), (FEMA, 2006). An incident action plan (IAP) It is built by an incident command system on five phases: (1) Understand the situation; (2) Establish incident/response objectives (priorities,

objectives, strategies, tactics, tasks, and work assignments); (3) Develop the plan; (4) Prepare and disseminate the plan; (5) Execute, evaluate, and revise the plan.

SAP assigns/allocates a subset of agents to a subset of GTM tasks. SAP includes two phases: (1) to specify human high-level strategy guidance and (2) to execute and adapt the specified strategy (Maheswaran et al., 2010).

A strategic action plan constrains and limits behaviors and actions of agents. It is obvious that a strategic action plan strongly influences performance of the team. IC, so, plays a major role in defining good strategy, smartly executing strategies, monitoring the situation, and refining and adjusting strategies to adapt crisis situation.

2.4.1 Human high-level strategy guidance

High-level strategy guidance enables an IC as a human planner to express and encode his or her intuition for SAP.

A strategy is composed of a set of parallel threads which are prioritized from high to low according to their importance. Furthermore, threads can operate in parallel during execution based on agent availability. A thread, itself, is composed of a unique ranking, a sub-team (a subset of agents), a sub-objectives (a subset of task types), and sub-locations (a subset of geographic objects). Agents may engage in several threads because of restricted resources.

A strategy decomposes a difficult and complex problem into simpler problems that can be solved by traditional AI techniques and automated systems. In another word, high-level strategy guidance partitions and decomposes the whole problem space into a set of small problems under human supervision. Decomposition of a coordination problem into some threads generates two new types of interdependency among threads: 1) agents who are shared among threads and 2) "enabling" dependencies that are formed among GTM tasks of threads.

2.4.2 Strategic action plan

A strategic action plan is the problem of appropriate assignments of agents to threads in a definite time. Because agents are shared among threads, an agent should be allocated to only one thread in a time. As a result, it is necessary for the IC to dynamically execute the specified strategy and adapt the made strategic plan regarding new disaster situation and availability of agents by optimally assigning agents to threads or smartly releasing agents from their thread into the next thread.

Assignment of a specific thread to a specific agent forces that agent to adapt his behaviors and actions regarding the thread definition. The made strategic plan will be sent from operation center (incident command post) to each agents so that they can make their own tactical plan/decision for distributed multiagent coordination for doing tasks in the tactical level.

2.5. Strategic action scheduling

The SaP2, moreover, includes strategic action scheduling to estimate operation time (makespan) and assign (allocate) agents to time-consuming GTM tasks according to the made strategic action plan. Strategic action scheduling does not fully schedule detailed actions of agents for doing tasks in the tactical level.

The structure of a strategic action schedule contains assignment (allocation) information as follows: (1) location (geographic object) of the GTM task; (2) task type of the macro task; (3) start time; (4) finish time; (5) amount of tasks which are going to be done during this duration; (6) a set of agents who are assigned to this schedule; and (7) amount of dependent tasks which will be released/discovered within this location. The key point is that strategic action scheduling can be applied to different geographic layers.

Because of the geospatial, temporal, and macro aspects of tasks, strategic action scheduling takes into account eight rules. (1) More than one agent can be assigned to a GTM task, in fact, assigned agents form a coalition to execute this decision cooperatively; (2) Assignments are dynamic. It means that over time, new agents can join the coalition which have been scheduled for the GTM task; (3) Agents assigned to a GTM task are kept for that task until all task are accomplished; (4) Scheduling should follow the made action strategic plan; (5) Agents need a considering amount of

travel time to reach a GTM task by moving from one point to another via the road network; (6) heterogeneous agents provides different capabilities which are required for heterogeneous tasks; (7) A coalition formed by many and professional agents can do a GTM task faster than another coalition; (8) GTM tasks may have a dynamical number of enabled tasks and a dynamical number of disenabled tasks because some agents may complete some tasks while other agents may release new tasks.

2.6. Geospatial-temporal macro tasks

Macro tasks information forms the global view/perception of ICs from the tasks environment. A macro task is the accumulation of all tasks (enabled tasks and disenabled tasks) that are from a same task type and are spatially contained within a specific geographic object in a definite time. Topological relationships between geographic objects enable the ICs to extract and present macro tasks information for different geographic layers.

A macro task indicates the total number of capability requirement for doing a set of homogenous tasks. It gives an estimation of number of required teams and an estimation of operation duration.

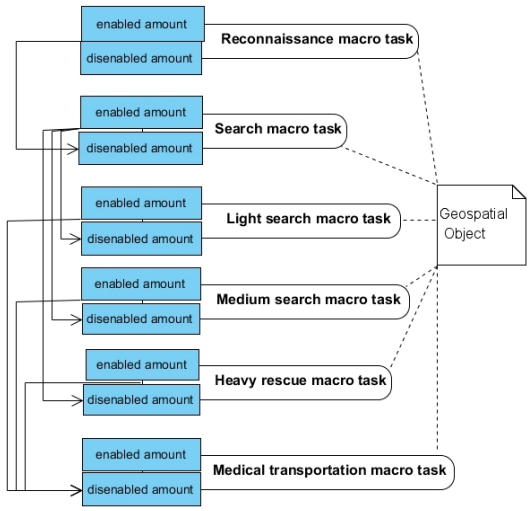

Fig. 3 The task flow of geospatial-temporal macro tasks

Because of the temporal environment, the enabled amount and the disenabled mount of macro tasks vary over time. It leads to a series of discrete temporal macro tasks.

Four sources generate tasks information: 1) estimate and forecast, 2) observe and gather tasks data directly, 3) information shared by other teams, and 4) fuse and integrate information.

Macro tasks have the “enabling” dependency among themselves in the USAR problem domain. Fig. 3 shows a task flow of six GTM tasks which are defined for a geographic object. It is clear for e.g. both “Reconnaissance” enabled tasks and “Reconnaissance” disenabled tasks can release and discover “Search” tasks which are disenabled.

3. Result

Fig. 4 shows characteristic of the SaP2 problem. The contribution of this paper is a model of the SAP problem that presents several dimensions of this problem including the problem domain, geographic information, geospatial-temporal macro tasks, strategic action planning, strategic action scheduling, and disaster emergency response team

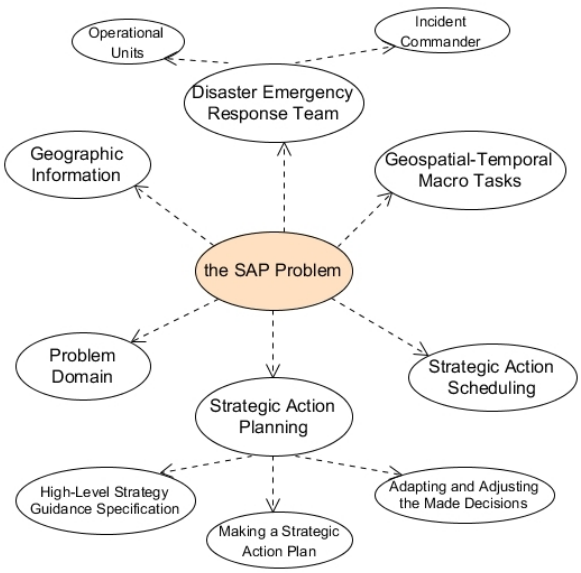

Fig. 4 A model of the SaP2 problem

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