APPLYING INTELLIGENT AGENT TECHNOLOGY TO PLAN EXECUTION MONITORING

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1. INTRODUCTION

The amount of available, tactical operations data is increasing at an impressive rate. In many cases analysis of current data can lead to timely identification of potential problems and their global ramifications. While attempts to centralize information in shared data environments may result in greater accessibility to data, bandwidth and resource limitations hinder its availability. Thus, the usefulness of pertinent information often expires before it becomes available. Furthermore, analyzing how such information impacts plan execution often requires significant time and resources. Our new agent-based execution monitoring architecture—*Monitoring Execution with Distributed Intelligent Agents* (MEDIA)—over-comes the data availability problem and provides automated monitoring of plan execution without sacrificing network bandwidth or computational resources. This architecture is built upon our prototype Execution Monitoring system *Vigilant Advisor* and is currently being applied to the USMC Future Naval Capabilities program: Ground Logistics Command and Control (GLC2).

2. VIGILANT ADVISOR

2.1 Overview

Vigilant Advisor is a tactical agent-based plan execution monitoring and response coordination system being developed and demonstrated for the Army's Agile Commander and LogC2 Advanced Technology Demonstration programs. Built using the Lockheed Martin Advanced Technology Laboratories (ATL) Extensible Mobile Agent Architecture (EMAA), it employs sentinel agents to detect environmental deviations from a Commander's mission contingency set.

2.2 EMAA

EMAA is a mature agent architecture used as the foundation for over a dozen agent systems for DARPA and DoD programs. Three components comprise the heart of the architecture: agents, docks, and servers (Figure 1). The dock provides the controlled operating environment for the agents, including access to local resources via servers. Mobile agents are realized in EMAA as independent threads of processing that can execute an itinerary of tasks at one or more docks on a network, with its state preserved along the way (Lentini et al., 1998)

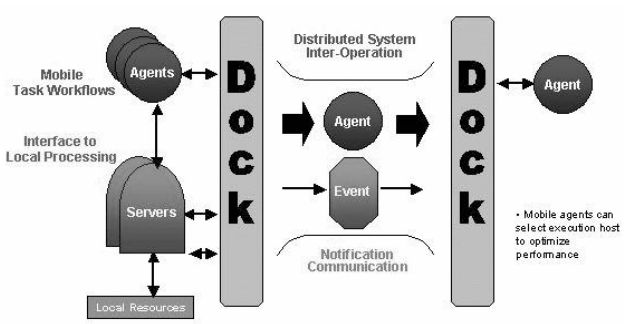

Figure 1. ATL's Extensible Mobile Agent Architecture

2.3 Mobile Sentinel Agents

The mobile sentinel agent itinerary provides controllable persistent monitoring and alerting behavior that can be dynamically tailored at run-time (McGrath et al., 2000). After migrating to operational data sources, the sentinels analyze incoming operational data against user-defined criteria and trigger responsive actions to mission–critical contingency violations, such as alerting the user and activating course of action generation systems. Scheduling and prioritization features built into the agents enable performance tuning to maximize monitoring needs against resource constraints.

2.4 Benefits

Vigilant Advisor's sentinel agent-based approach to execution monitoring provides the following benefits:

(1) ***Autonomous monitoring of data sources***: Commanders can set monitoring preferences, disconnect, and intermittently reconnect to retrieve sentinel results, thereby facilitating Command on the Move

(2) ***Reliable performance over unstable networks***: Agent migration routes are configured at run-time. Thus, alternate data-sources are used when primary sources are unavailable.

(3) ***Robust monitoring behavior***: Changes to monitoring behavior can be invoked dynamically at run-time without halting the system.

3. MEDIA

3.1 Overview

MEDIA is intended to support Execution Centric Operations by extending the capabilities of Vigilant Advisor to automate the dynamic link between battlefield data sources and the mission plan. Our advanced MEDIA architecture provides automated execution monitoring at a global level by enabling mobile agents with knowledge-based reasoning and inference capabilities.

3.2 Plan Representation

In MEDIA mission plans are represented as hierarchical structures of interrelated Tasks. Each Task is composed of descriptive fields and, optionally, other subtasks. The descriptive fields provide data relating to task begin/end time, unit information, and task constraints and contingencies. The *constraints* field lists the other tasks that are constrained by this one according to the plan. The *contingencies* field lists the environmental conditions that must be true in order for the task to be successfully completed. For example, a *Resupply Task* is contingent upon a *Route Clear* condition.

3.3 Agent Architecture

Two types of agents are used to perform execution monitoring. The *Monitor-Infer-React* (MIR) agent is an EMAA agent with an imbedded Java Expert System Shell (JESS) Knowledge Base. While the itinerary is the same for each MIR agent, an agent's knowledge base is composed of a rule-set representing domain knowledge for a particular Task and facts about the world. Sentinel agents then provide information reconnaissance for the MIR agents (Figure 2).

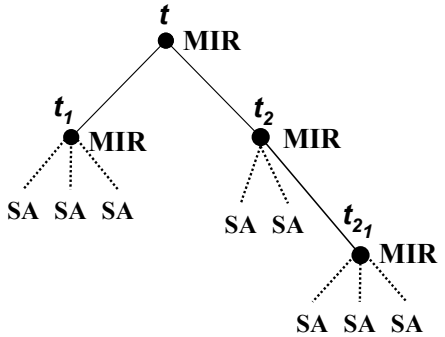

Figure 2. In MEDIA, MIR agents create sentinel agents to monitor data sources

MIR Agents are dynamically constructed according to the mission plan. Each Task in the plan is represented by a MIR agent with an appropriate rule-set. The MIR agent creates sentinel agents to monitor data sources for changes in environmental conditions related to Contingencies. The Sentinel Agents notify their controlling MIR agents with logical assertions about the state of the environment. These facts are applied to the rule-set and the MIR reacts to any resulting inference. Reactions are governed by the rule-set and may include task status notification to humans or higher echelon MIR agents.

3.4 Benefits

MIR agent technology provides the following key benefits to Execution Monitoring systems.

(1) ***Automated monitoring on Commander's behalf***: MIR agents represent, infer, and act upon an impressive amount of operational knowledge associated with a task, thereby reducing human workload.

(2) ***Information aggregation and dissemination***: MIR agents aggregate lower level information into higher-level knowledge and disseminate it up the MIR/Task hierarchy, and to human Commanders, when appropriate.

(3) ***Impact analysis***: MIR agents are capable of using task constraint information to analyze the impact of task failure to the overall plan and present results to Commanders.

(4) ***Robust scalability***: MIR rule-sets are tailored to individual tasks, and subtasks. Then MIR agents are constructed and dynamically configured at run-time according to the rule sets, layout of the mission plan, and live data sources.

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