Adaptive Plan Monitoring Systems for Military Decision Support

James P. Allen and John M. McCormick

Lockheed Martin Advanced Technology Laboratories
3 Executive Campus, 6th Floor
Cherry Hill, NJ 08002
{jallen, jmccormi}@atl.mco.com

Abstract

As military tactics evolve toward hyper-tempo operations, the ability to analyze vast amounts of mission relevant data is essential to command-and-control decision-making. Plan Monitoring (PM) systems provide mission status decision support to military commanders by correlating execution observables against an operational plan.

The primary challenges faced by PM systems in the military domain are threefold. First, execution data is often distributed in disparate data stores connected by low-bandwidth, ad-hoc networks. Second, plans are not permanent entities but dynamic, evolving structures that are frequently modified to reflect the changing operational requirements of the commander. Third, the monitoring behavior – how the elements are to be monitored – must adapt to the needs of the commander as well as the changing tactics and entities within the operational domain. Over the past five years Lockheed Martin Advanced Technology Labs (LM ATL) has developed two PM systems that meet these challenges. Our prototype PM system, *Vigilant Advisor*, provides operational support for Army maneuver and logistics operations, while our current effort, an *Air Campaign Monitor*, provides effective monitoring of continuous air campaign operations.

Vigilant Advisor

Overview

Vigilant Advisor is an agent-based PM and response coordination system developed and demonstrated for the Army's Agile Commander and Logistics Command and Control Advanced Technology Demonstration programs to provide autonomous decision support for commanders in the field. Mobile agents provide controllable, persistent plan monitoring and alerting behavior that can be dynamically tailored at run-time (Allen, et al., 2004). After migrating to operational data sources, the agents analyze incoming operational data against user-defined criteria and trigger responsive actions to mission-critical contingency situations, such as alerting the user and activating course of action generation systems. Scheduling and prioritization features built into the agents enable automated performance tuning to maximize monitoring needs against both computational and bandwidth constraints.

This agent-based system adapts to both the monitoring requirements of its users and the data sources available during run-time. Users are able to specify not only what contingencies to monitor, but also the parameters for monitoring. At any point, the user can modify the monitoring parameters, and the agents will dynamically adapt their workflow to meet the user's new requirements. Agents choose data sources to monitor based on both the availability of information and computational load at the data source.

Benefits

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

1. ***Continuous Plan State Situation Awareness***: Commanders can maintain focus on plan deviations and risk management through timely mission alerts and course of action feedback.
2. ***Autonomous monitoring of data sources***: Agents provide continuous PM on behalf of the operator. Command personnel do not have to be tethered to the system or network during monitoring. Additionally, monitoring behavior can be changed dynamically without halting the system.
3. ***Reliable performance over unstable networks***: Agent migration routes are configured at run-time, permitting alternate data-sources to be used when primary sources are unavailable. Agents persist in ad-hoc network environments, caching information during times of intermittent connectivity and reconnecting when network service is restored.

Air Campaign Monitor

Overview

LM ATL's Air Campaign Monitor (ACM) provides a PM capability for continuous, model-adaptive planning and execution in air campaigns. Unlike Vigilant Advisor, whose monitoring behavior is explicitly guided by command staff, the ACM automatically changes its monitoring behavior to reflect operational knowledge

captured in dynamically adaptive domain models. The system is composed of three components, each designed to provide specific decision support capabilities for air campaign command personnel. The Plan Analysis component merges new plans into the system, maintains the state of the executing plan, and configures monitoring behavior based on the plan. The Evidence Gathering component analyzes available incoming data to determine the presence of anomalous situations as they relate to the plan, and maintains the state of battlespace entities. The Impact Assessment component determines the significance of the anomaly based on both its severity, and its impact on the greater plan.

Model Adaptation

The ACM makes extensive use of operational knowledge captured in domain models. The models represent both tactical and entity information about the air campaign domain represented in the Unified Modeling Language. During run-time, new activities are periodically added to the models along with new entities and new configurations of entities with weaponry. The models are submitted to the ACM and maintained by a Model Service that provides an interface to query the lineage, interrelationships and attributes for both activities and entities in the models. Each ACM component interprets and reacts to new information in the models independently.

Plan Analysis. The Plan Analysis component reflects upon the information in the models when configuring monitoring behavior. Each activity in the plan has a specific set of contingency situations that can affect the outcome of the activity. The ACM is responsible for detecting these contingency situations. For example, a Navigate activity can be adversely affected by if it is determined that a pilot has flown outside of his designated corridor. During initialization, the component is loaded with a predefined map of contingencies for each activity type. When an unrecognized activity is added to the plan, the component queries the Model Service for the lineage of the new activity, and assigns an appropriate, minimal set of contingencies based on the aggregate of the contingencies in the activity's lineage.

Evidence Gathering. The Evidence Gathering component leverages entity attribute information in the models to maintain state information about battlespace entities. As entity state attributes in the models are added and deleted, Evidence Gathering must modify its data stores accordingly to maintain situation awareness. Using techniques developed by the Object Management Group's (ref web-site) Common Warehouse Metadata Initiative (CWM) (ref OMG web-site) the Evidence Gathering component modifies its data stores to reflect the new state attribute information for the entities. More information on the CWM can be found at (ref. CWM forum web-site).

Impact Assessment. The Impact Assessment component utilizes a fuzzy reasoning system to determine the severity of anomalous events in battlespace. For example, aircraft may occasionally drift a few meters from their planned corridor. While this situation is anomalous, it is not severe. The fuzzy reasoning system allows the ACM to distinguish such situations from genuine threats to planned operations.

Fuzzy reasoning requires domain knowledge captured in fuzzy set representations. The Impact Assessment component contains predefined fuzzy set representations for each anomalous condition applied to each activity in the models. However, when new activities are applied to the system, there is no predefined fuzzy set to draw upon. By querying the Model Service for the lineage of the new activity, the Impact Assessment component selects and applies the fuzzy set representation of the parent activity. We have found that, while this process does not render a representation tailored to the new activity, it does provide an adequate representation for the new activity, and we are currently exploring techniques for fuzzy set adaptation based on operator feedback.

Benefits

The ACM's domain model-based approach to plan monitoring provides the following benefits:

1. ***Dynamic Plan State Situation Awareness***: Commanders maintain command and control focus in dynamic tasking environments while the system automatically adjusts monitoring behavior upon plan updates.
2. ***Domain flexibility***: The model-adaptive capability means the system will not become obsolete as new tactics and entities enter the air campaign domain.
3. ***Reduced Manning for Battle Command***: The ACM is designed to provide continuous plan monitoring for air campaign decision support, thereby reducing the number of command and control personnel required to effectively execute air campaign missions.

REFERENCES

Allen, J., Barry, K., McCormick, J., Paul, R., "Plan Execution Monitoring with Distributed Intelligent Agents for Battle Command," SPIE, Defense and Security Sym-posium 2004, Orlfando, Florida.

Lentini, R., Rao, G., Thies, J., and Kay, J., "EMAA: An Extendable Mobile Agent Architecture," Fifteenth National Conference on Artificial Intelligence (AAAI '98), Madison, Wisconsin.

McGrath, S., Chacón, D., and Whitebread, K., "Intelligent Mobile Agents in the Military Domain," Fourth Inter-national Conference on Autonomous Agents 2000: Workshop on Agents in Industry, Barcelona, Spain, June 3, 2000.

Object Management Group, http://www.omg.org

Common Warehouse Metamodel, http://www.cwmforum.org.