DEVELOPMENT OF A COMPREHENSIVE LOGISTICS AND WARFIGHTING SIMULATION SYSTEM

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ABSTRACT: An efficient logistics system is critical to the success of military operations. Recently, the Department of Defense (DoD) has begun to move from a “just in case” logistics system that relies on large stores of inventoried materials toward a “just in time” system based on obtaining and delivering supplies when and where they are needed. For this new logistics concept to operate smoothly and responsively and be highly robust, one must understand the interrelationships between warfighting and logistics, such as the impact of losses of logistics links/nodes and the changing pace of warfighting operations.

Two DoD programs, the Distributed Intelligent Agents for Logistics (DIAL) and the Warfighting Logistics Technology and Assessment Environment (WLTAE), are focusing on different aspects of this problem. These programs are being integrated to develop a Comprehensive Logistics and Warfighting System (CLAWS) that can be used to address a variety of logistics applications in the military arena. In this paper, we describe how CLAWS will be developed, including the development of a generalized Federation Object Model that could be used in a variety of logistics and military operations applications.

1. Introduction

An efficient logistics system is critical to the success of military operations. Recently, the Department of Defense (DoD) has begun to switch from a “just in case” logistics system that relies on large stores of inventoried materials to a “just in time” system based on obtaining and delivering supplies when and where they are needed. For this system to operate smoothly and responsively, one must understand the interrelationships between warfighting and logistics, such as the impact of losses of logistics links/nodes and the changing pace of warfighting operations.

Two DoD programs, Distributed Intelligent Agents for Logistics (DIAL) and Warfighting Logistics Technology and Assessment Environment (WLTAE), have focused on different aspects of this problem. These programs are being integrated to develop a Comprehensive Logistics and Warfighting System (CLAWS).

There are two primary drivers for developing a tool like CLAWS. The first is that the U.S. military is moving toward a highly maneuverable and responsive form of warfare. This approach, coupled with a “just in time” inventory system, will mean that the logistics will have to be more dynamically coupled to the needs of the warfighter. The second driver is that recent events have demonstrated that enemy actions against our logistics infrastructure may become more commonplace — and that these attacks may occur anywhere in the logistics chain extending from the theater back to the Continental United States (CONUS). As a result, all elements in the logistics system must be visible as potential targets in warfighting models.

2. Overview of DIAL

DIAL is an open system architecture, based on the Dynamic Information Architecture System (DIAS) developed by Argonne National Laboratory (ANL). DIAS allows existing logistics models to interface and commu-
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nicate in a distributed network environment. The design is based on the use of intelligent agents that monitor the outcomes of various model components against a set of user-specified criteria. When these criteria are exceeded, indicating a "problem," the agents propose alternatives to the user for analysis and selection.

The DIAL proof-of-concept includes a "confederation" of models that perform by the functions shown in Figure 1, the movement of troops and supplies from "fort to port." Force generation is performed by using the FORCEREGEN model. Forces (personnel and materiel) are moved within CONUS using the CONUS version of the Enhanced Logistics Intratheater Support Tool (CONUS ELIST). The loading of materiel onto ships is handled with the port simulation model PORTSIM. The final results from the CONUS ELIST and PORTSIM simulations are data that would be used externally by MIDAS to move forces by air and ship to the theater. Intelligent agents monitor the state of the force generation process and the movements within CONUS by comparing the projected Available-to-Load Date to the corresponding dates in a Time-Phased Force Deployment Data (TPFDD) source. If there are discrepancies in the dates, rules have been established to provide the agent with a strategy on how to reconcile the projected dates with those in the TPFDD.

The specific models used in the DIAL proof-of-concept effort were chosen simply for convenience due to their ready availability — FORCEREGEN, CONUS ELIST, and PORTSIM were developed at ANL where there is a ready source of expertise and experience with these models. The DIAL concept, however, was developed to be general. The data shared among models and analyzed by the agents represent the kinds of general information that would be produced. By taking this approach, the individual models used in the initial effort could be replaced with other models or data sources. A High Level Architecture (HLA) compliance plan for DIAL has been submitted and approved, so DIAL will be able to operate in an HLA federation.

The use of DIAL offers another significant advantage to the development of CLAWS; that is, it can provide environmental representation for studying the environmental impacts on logistics and warfighting. DIAL, as an instantiation of DIAS, can access the extensive library of environmental objects that are resident in the DIAS object library. These objects and the corresponding environmental effects models have been used to provide environmental representation and effects for programs sponsored by the Joint Staff/J-8, the Defense Modeling and Simulation Office, and the Joint Warfare System (JWARS).

3. Overview of WLTAE

WLTAE is intended to dynamically link warfighting and logistics models and databases to provide more realistic warfighting simulations. A key element of the WLTAE concept is to make these linkages through a flexible simulation interface that makes it easy for the user to study a variety of combat/logistics issues. This WLTAE interface will run these models in a distributed computing mode in compliance with the HLA standards mandated by DoD. Initially, legacy warfighting and logistics models will be used, but the HLA compliance will make it easy in the future to incorporate the new models currently under development, such as JWARS. Another key element of WLTAE will be the use of top-level screens and reports, using the advanced visualization tools developed by the Defense Advanced Research Projects Agency (DARPA) Advanced Logistics Program, to help the user easily and quickly understand the results and impacts of these linked simulations.

![Figure 1. Schematic Representation of the DIAL "Confederation".](image-url)
During FY-97, WLTAЕ demonstrated the feasibility of linking legacy warfighting and logistics models by exchanging data through their input/output files. ELIST and the U.S. Air Force THUNDER campaign model were selected as the initial models for a proof-of-principle demonstration of this concept, and the initial coding to directly link them dynamically was written and demonstrated using a modified TPFDD. A WLTAЕ interface testbed was also designed to allow users to set up constructive simulations using these models and run them in an HLA-compliant, distributed computing mode. This HLA linkage was demonstrated with ELIST.

WLTAЕ, in the near-term, will be designed as an operational tool for the warfighting commanders and their staffs, helping them to evaluate the impact of logistics constraints on their warfighting strategies and to assess the likelihood of enemy damage to our logistics systems (e.g., theater ballistic missile attacks on seaports of debarkation). In the longer term, WLTAЕ will incorporate additional capability to allow the user to easily pose and answer “what if” questions, such as the impact on the warfighter of alternate approaches for providing logistics support. This longer-term capability will allow the user to assess the out-year impact of major changes in the DoD logistics infrastructure, such as reducing inventories and relying more on commercial support.

4. Overview of CLAWS

CLAWS will exploit two significant contributions from the DIAL and WLTAЕ programs. DIAL will contribute to the integration of intelligent, context-driven agents with CONUS logistics models. WLTAЕ will contribute the linking of in-theater logistics and warfighting models in an information-rich environment for understanding the interrelationships between logistics and warfighting.

Two implementation approaches are possible for CLAWS. The first involves the use of the evolving HLA, while the second approach would use DIAS. Two approaches are possible because the needs of the user community differ. Planners working with distributed models might wish to use the HLA, while users operating in a more closed environment, such as CINCs, might find the DIAS approach more attractive. For demonstrating the usefulness of the CLAWS concept, we focus first on the HLA implementation.

Figure 2 shows the implementation configuration based on the HLA with a generic Logistics-Warfighting federation represented. The WLTAЕ system serves as the federation controller, providing the tools to set up and monitor conditions during the simulation and performing the post-simulation analysis. The HLA Runtime Infra-
structure (RTI) interconnects the simulation federates. The example in Figure 2 shows one warfighting federate, represented by the Air Force’s THUNDER model, and two logistics federates. Under the CLAWS concept, however, there is no limit to the number of federates that could be included. The first one simulates logistics being supplied into the theater of operations, and the second one simulates logistics supplied in the theater. In this example, the inter theater logistics is represented by DIAL, and the intra theater logistics is represented by ELIST.

We intend to take a “user centric” approach rather than a “model centric” approach. That is, the Federation Object Model (FOM) will be developed based on the kinds of data and information that commanders would use in an actual operation (e.g., TPFDDS, situation reports, weather forecasts, air tasking orders, etc.). It is felt that a user centric approach would make CLAWS a more powerful planning tool because the user would be able to focus on the analysis and significance of the data rather than on the models/applications producing the data.

CLAWS will exploit intelligent agent technology, such as that implemented in DIAL, to provide monitors of critical data that could be indicators of existing or developing problems requiring a commander’s attention. For example, key logistics links/nodes could be threatened by opposing forces, requiring a reanalysis of how to get troops and materiel from “here to there.” Another example could involve the monitoring of the “pace” of a battle to assess if the logistics supply chain is able to keep up with the battle— an issue of critical importance with a “just-in-time” logistics philosophy.

The intelligent agents would be located at the federation and individual federate level in CLAWS. At the federation level, the agents would be included in the WLTAЕ Federation Controller and would monitor the data flow passing between the individual federates. At the federate level, the agents would monitor the data used by the model(s) and/or application(s) making up the federate. Used in this fashion, the agents would act as decision support tools, alerting commanders to situations requiring their attention and informing them of decisions made at a lower level, including the nature of the problem and that action taken to resolve it. In all cases, it is proposed that the agents would employ user-specified rules to describe what should be monitored, what constitutes a “problem,” how to develop alternatives, who needs to be alerted of the problem, and what changes can be implemented without advanced approval from a higher command authority. It is proposed that the agent’s rules would be based on “professional military judgment,” doctrine, and approved policies.
5. Development of a Generalized CLAWS FOM

CLAWS is intended to have a broad applicability for a variety of problems. For this reason, we are striving to develop a generalized FOM that could span a variety of logistics and operational applications. The development of the CLAWS FOM will be based on a Conceptual Model of the mission space-type approach.

5.1 Entity Representation

Figure 3 shows the high level entities and their definitions that are believed to be sufficient to represent the CLAWS mission space. The individual entities can be expanded further as needed. For example, the Materiel entity can be expanded into categories based on the ten classes and subclasses of supply used by the Army. Figure 4 shows an expansion of the Environment entity that could be used to incorporate environmental effects, such as weather, on air operations or ground mobility. The expanded environmental taxonomy shown in Figure 4 is based on the approach used by the Dynamic Environmental Effects Model developed by ANL to support analytical applications. The objects shown have been developed to utilize authoritative sources of data such as the surface representation data provided by the National Mapping and Imagery Agency and weather data available through the Master Environmental Library.

5.2 Potential Interactions between CLAWS Entities

Figures 5 - 8 show the potential interactions that could occur between the CLAWS entities. The interactions are termed potential because one does not know the specific details of how CLAWS will operate in an actual federation FOM. The verbs used to denote the interactions (shown underlined in Figures 5 - 8) are also deliberately general because the specific representation of the interactions will depend on the details of the federation CLAWS participates in.

In each figure, the entity in the heavy lined box is the entity initiating an interaction, and the arrows denote the entity that is the recipient of the interaction. The notes with each figure describe the nature of the interaction. The interactions are expressed notationally and do not detail specific algorithmic or model representations. The Data entity is not included because it is not an initiator of interactions in the CLAWS mission space, but is only a recipient of interactions.

In the mission space that CLAWS is intended to serve, the notational interactions can be grouped into four basic categories: Command and Control, Operational Support, Warfighting, and Environmental. Figure 9 shows a listing of specific interactions in this grouping that is believed to be reasonably generic and able to encompass a wide range of CLAWS applications. For example, both the Operational Support and Command and Control interactions could be performed by military and non-military entities. This grouping is not intended to imply that the listed interactions only occur in the given regimes because some of the interactions overlap into other areas. For example, the Move_Resource interaction can be applied for entities with warfighting or operational support roles.

Table 1 gives details of the CLAWS federation interactions in the Command and Control category. The table includes a description of what the interaction is intended to do, the entities that could participate in the interaction, and a representative set of interaction parameters. Depending on the specific makeup of the federation, different entities could be on the initiating and receiving ends of the interactions. For example, a Person, Organization, or a Materiel entity could request data from another entity. (An example of a Materiel entity requesting data is a sensor system requesting a transponder to send a signal identifying itself.) The details of the interaction parameters (e.g., types, formats, units, resolution, etc.), as required to fill out the HLA Object Model Template tables, will also depend on the specific details of the federation CLAWS participates in.
Person - An individual human that can interact with other entities as an initiator or recipient of an interaction.

Materiel - Equipment and supplies, real or conceptual (e.g., money), that can be used to perform an interaction or be the subject of an interaction.

Organization - An abstract collection of persons or groups with specific responsibilities to accomplish a stated goal.

Data - A collection of information in an organized form. Can be organized as a set of instructions or details (e.g., a Plan) that can then be used to accomplish a goal. Data may be documented via some medium or be abstract, such as a verbal order.

Environment - Land, water, air, and space components and infrastructure components encompassed in the area of interest.

Figure 3. High-Level Entity Representation of the CLAWS Mission Space.

Figure 4. Proposed Expansion of the CLAWS Environment Entity Representation.
Potential Interactions Initiated by a Person:
1. A Person Can Evolve (e.g., Grow Older)
2. A Person Can Move (under Their Own Power in the Environment)
3. A Person Can Impact Another Person
4. A Person Can Create Material (e.g., Give Blood)
5. A Person Can Use Material
6. A Person Can Impact Material
7. A Person Can Create an Organization
8. A Person Can Impact an Organization
9. A Person Can Create Data
10. A Person Can Use Data
11. A Person Can Impact the Environment

Figure 5. Potential Interactions Initiated by a CLAWS Person Entity.

Potential Interactions Initiated by Material:
1. Material Can Evolve
2. Material Can Use Material
3. Material Can Impact Other Material
4. Material Can Impact a Person
5. Material Can Impact an Organization
6. Material Can Create Data
7. Material Can Use Data
8. Material Can Impact the Environment

Figure 6. Potential Interactions Initiated by a CLAWS Material Entity.

Potential Interactions Initiated by an Organization:
1. An Organization Can Evolve
2. An Organization Can Impact Another Organization
3. An Organization Can Use a Person
4. An Organization Can Use Material
5. An Organization Can Create Data
6. An Organization Can Use Data
7. An Organization Can Change Data
8. An Organization Can Impact the Environment

Figure 7. Potential Interactions Initiated by a CLAWS Organization Entity.
6. Summary

An efficient logistics system is critical to the success of military operations. For this system to operate smoothly and responsively, one must understand the interrelationships between warfighting and logistics, such as the impact of losses of logistics links/nodes and the changing pace of warfighting operations. The Comprehensive Logistics and Warfighting System is being developed to address these kinds of problems.

CLAWS will benefit from two DoD programs, DIAL and WLTAE, that are addressing different aspects of the CLAWS intended mission space. These two programs are being integrated to serve as the cornerstone of CLAWS.

Work is continuing on the development of CLAWS and the generalized warfighting and logistics FOM. We plan to report on the progress of the CLAWS effort, the FOM development, and its use at later meetings.

References


Table 1. An Example of Federation Interactions Related to Command and Control Activities in an Integrated Warfighting and Logistics Federation.

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Description/Comments</th>
<th>Interacting Entities</th>
<th>Interaction Parameters</th>
</tr>
</thead>
</table>
| Request_Data    | This interaction is of the “Push” form in which it directs an entity to generate data for another entity. It would be most likely followed by the Send_Data interaction. | Person → Person  
Person → Organization  
Person → Materiel  
Organization → Person  
Organization → Organization  
Organization → Materiel  
Materiel → Person  
Materiel → Organization  
Materiel → Materiel | time_sent  
data_type_requested  
time_required  
requested_by |
| Send_Data       | Sends data, in any form, between entities. | Person → Person  
Person → Organization  
Person → Materiel  
Organization → Person  
Organization → Organization  
Organization → Materiel  
Materiel → Person  
Materiel → Organization  
Materiel → Materiel | sent_to  
time_sent  
data_type_transmission_medium  
data_content |
| Analyze_Data    | This interaction directs an entity to analyze data for another entity. It would be most likely followed by the Send_Data interaction to send the result back to the Requesting entity. | Person → Person  
Person → Organization  
Person → Materiel  
Organization → Person  
Organization → Organization  
Organization → Materiel  
Materiel → Person  
Materiel → Organization  
Materiel → Materiel | time_sent  
analysis_requested  
time_required  
requested_by |
| Generate_COA    | This interaction, which is a special variant of the Analyze_Data interaction directs an entity to generate COA for another entity. It would be linked to other interactions to accomplish a given task. | Person → Person  
Person → Organization  
Person → Materiel  
Organization → Person  
Organization → Organization  
Organization → Materiel | sent_to  
time_sent  
number_of_options_requested  
time_required  
requested_by  
respond_to |
| Create_Organization | This interaction can be used to create permanent or temporary organizations, such as a JTF command, crisis response team, etc. | Organization → Organization  
Person → Organization | time_created  
organization_name  
organization_purpose  
organization_location  
creating_organization  
duration_of_existence  
extent_of_authority  
organization_reports_to  
organizations_reporting_to_it |
| Remove_Organization | This interaction can be used to remove an organization, such as from a reorganization, disbanding, etc. | Organization → Organization  
Person → Organization | time_removed  
organization_name  
organization_location  
removing_organization |
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