Reusing Force Deployment Plans

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Abstract

This paper describes how the prototype system ForMAT (Force Management and Analysis Tool) combines CBR and knowledge acquisition/engineering techniques to acquire knowledge of how military forces are deployed; and to support the creation, development, management, reuse, and modification of force deployment plans. Modification challenges are identified.

Introduction

ForMAT is a knowledge-based prototype that uses Case-Based Reasoning (CBR) techniques to build, modify, index, store, and retrieve references to the military forces that are part of a force deployment plan used to support a given operation plan (OPLAN). Within the military transportation planning domain, this force deployment planning information is often encapsulated in a data structure called the force module (FM). In ForMAT, the FMs are the cases in the casebase.

Using ForMAT, a user can modify a given force deployment plan to support a new or changing situation, or create a new force deployment plan by copying FMs (in total or in part) from other existing plans. ForMAT provides various query mechanisms for finding similar FMs and various methods for constructing the new deployment plan, e.g., copying a hierarchy of force modules and changing the name of the plan accordingly. While ForMAT maintains consistency between FMs, the richness of the domain and the variety of modification strategies exhibited to date by domain specialists has inclined the developers to prohibit ForMAT from automatically modifyng FMs to fit the specifications of a new (but similar) situation.

ForMAT has been used actively in several exercises and major demonstrations, and currently contains 322 force module cases derived from or used in 17 plans.

Domain Background

The United States deploys military forces to support a variety of problem situations (missions); from combat to humanitarian, large and small, anticipated and crisis. The United States Transportation Command (USTRANSCOM) is responsible for determining the transportation capability for all types of missions. For large and very large missions the process by which transportation plans are constructed can be very complex and time consuming (Coley et al. 1991).

Plans built to satisfy "anticipated" (or likely) situations are called deliberate plans. In order to build a deliberate plan, representatives from the various services and commands involved in developing the plan must collectively decide how best to allocate the limited transportation resources (aircraft, ships, trucks and trains) so as to achieve the many military objectives of the mission. The end result of this process is an Operational Plan (OPLAN) which describes the mission and specifies where and when the forces involved in a mission are to be deployed. The OPLAN for deliberate planning is stored and maintained until such time as its execution is called for, which may be years after it was first constructed. At this time the plan will generally have to be modified to fit the particular details of the current situation, which often is a crisis situation.

Associated with an OPLAN is the TPFDD (Time Phased Force and Deployment Data). The TPFDD is a deployment plan that specifies the combat forces and support units required, equipment and supply support, and transportation phasing and mode. The development of the deployment plan requires input from and collaboration among individuals involved in: overall mission operations, force employment, logistics, and transportation.

Within the TPFDD, force information is often encapsulated in a structure called the force module (FM). The FM prescribes a force or set of forces that can be used to satisfy some planning requirement. The FM is typically a grouping of combat, combat support, and combat service support forces, and ranges in size from the smallest combat element to the largest combat element. However, it is not uncommon for the FM to be used administratively, e.g., to track the usage of some particular force or to track the flow of forces over time to a particular destination.

In the early phases of deployment plan development, combat forces and support units may be specified generically (e.g., fighter aircraft), as can movement times (i.e., latest departure, earliest departure, latest arrival, earliest arrival), origins and destinations (Kahn & Mulvehill 1995). As the deployment plan matures, each specification for a generic requirement is replaced by information associated with the actual unit(s) or equipment that will be used. Once the planners have identified what is to move, they must check to see if the plan is logistically and transportationally feasible.

ForMAT (Force Management and Analysis Tool)

ForMAT is a research tool, developed as part of the RL/ARPA Knowledge Based Planning and Scheduling Initiative (PI), to acquire information on, and to support the development of force deployment plans. ForMAT employs case based reasoning (CBR) techniques to store, index, and retrieve FMs; and knowledge acquisition/engineering techniques to facilitate classification and to monitor how the system is being used (Cross et al. 1994). ForMAT can interact with other PI systems that focus on: the more general operations planning (TARGET); the more detailed equipment and supply support requirements (i.e., LOGGEN); and the temporal aspects of the plan (i.e., TPEDIT) (Walker & Cross 1994).

Within ForMAT, a FM is represented as a case within a case base. Through ForMAT the user can create, view, retrieve, modify, and manage FMs; as well as import and export the TPFDD to/from other systems. In ForMAT a user can create a FM by specifying a FM identifier (the FMID) and then linking appropriate unit information to it; or the user can build a FM by reusing existing FMs (by making a copy of an existing FM). Users can modify a FM in a variety of ways, e.g., cutting and pasting unit information between FMs, creating links between any number of FMs - thus generating a FM hierarchy, and/or adding indices.

Currently, ForMAT contains 322 cases derived from 17 plans (TPFDDs). Approximately 10 of the 17 plans were built over a two year period either during user training, or during military exercises and demonstrations. Each of these 10 plans were built through the reuse of FMs in the other plans.

Retrieval, Reuse, and Modification

Early knowledge acquisition sessions with deployment planning specialists indicated that deployment planners use past experience to solve current problems, especially when time is a factor, e.g., in a crisis situation. Through ForMAT the user can search for FMs by creating "exact" or "generalized" FM queries. For example, the user might search the case base for a FM that exactly satisfies some search criteria, e.g., function = military-police AND service = air-force. If there are few or no results, the user can use the same search criteria, but set the system to do a "general" search. In this case, ForMAT will walk up any search term (index) hierarchy in a search for matches. In this example, ForMAT would walk up the "function" hierarchy and return FMs that satisfy function = security AND service = air-force. The user can also refine retrieval results by repeatedly executing queries on the results of previous queries. ForMAT keeps track of all retrieved FMs within a session and generates a prioritized listing of the FMs (and associated plan) that are retrieved. This list is called the FM Query Report and is available to the user at any time.

If the conditions associated with the current problem are similar to a past saved plan, and if these conditions are adequately reflected by the user's FM queries, several FMs from that saved plan will be displayed in the the FM Query Report. This is often an indication to the user that the situation in the past plan is similar to the current situation.

At this point, the user can visually review the referenced plan. The referenced saved plan may be made up of one large FM, a hierarchy of FMs, or some combination of single and hierarchical FMs. The user can selectively reuse a single FM, or an entire hierarchy of FMs, by copying the selected FM(s) from the old plan(s) into the new plan. ForMAT provides extensive consistency checking during this process; but, once the FMs are in the new plan, most FM modification, particularly FM unit composition, must be manually performed by the user. The user may refer to any FM stored in the system for guidance in FM modification, and ForMAT supports this activity through its interface and through report mechanisms such as the FM-Comparison-Report.

Even when a previous plan has been identified as similar in the FM Query Report, the user might choose to use "template FMs" instead of modifying FMs from a previous plan. Template FMs are generated by some services to describe a generic force package (e.g., a F-15 aircraft has the following standard combat support and combat service support requirements), or a common force deployment composition (e.g., small, medium and large sized Marine Expeditionary Unit). Use of template FMs may be favored over usage of FMs from a previous plan when (a) there is no information on the success or failure of the past plan, (b) the user does not know how to modify the past plan, or (c) the user does not have time to determine how to modify the past plan.

Modification Challenges

All user interaction, including user-guided FM modification is recorded by ForMAT's "history mechanism". To date, the trace provided by the history mechanism has been used by a knowledge engineer to study how users create, retrieve, modify, and incorporate FMs into a plan. Additionally, several reports have been created to monitor and describe FM and plan modification. Through use of these reports during a recent military exercise, we were able to identify the changing data fields and FM indices. For example, it was noticed that once FMs are copied into a new plan, the first items the users change are the "origin" and the "destination" data fields of the force unit and/or unit supply.

As the plan solidifies, users may include the specification of a "mission-name" and "supported-command". Specifications of this type should be attached globally to each FM in the plan. ForMAT provides support for global changes through its "default index setting menu". Once global specifications like the "supported-command" and "mission-name" are defined, ForMAT will automatically attach them as indices to each FM that is created or copied into a plan during a session. As the plan matures, other systems (e.g., LOGGEN, TPEDIT) are used by the planner to specify logistical support and to make temporal changes. Although logistics specifications and temporal changes are made outside of ForMAT; the temporal changes can be imported back into ForMAT; and ForMAT will detect and record the changes.

Due to the interplay of systems, and the reliance on data from many individuals, the problem of modification in the force deployment domain becomes a distributed collaborative problem. ForMAT does not modify the constituents of a FM to meet a new problem, because there are too many possible ways to modify a FM, and the choice of the modification strategy is a function of information from many sources both within and outside of the local plan. Additionally, each service has its own protocol for modification, and even if this protocol were completely invariant, it is not uncommon for there to be multiple simultaneous world crises that require the same or similar force support. Furthermore, the local deployment planner does not generally have the authority to change force utilization across concurrent plans. Instead, he/she can use a FM to determine what forces are being used in some particular period in time, then, using this information, determine what similar forces are still available. Even when the planner determines that a similar force is available, he/she has to go to other information systems to determine the readiness status of the force.

User Expertise Automated modification in this domain is further complicated because there is a wide range of user expertise. To date, ForMAT has been used by both seasoned planners and novice users. Seasoned planners tend to use the system differently from novice systems for several reasons; a main one being their exposure to the methods provided by their current system, i.e., the Joint Operations Planning and Execution System (JOPES). Additionally, seasoned planners tend to reuse their own plans, while novice operators use the template FMs or copy FMs from any plan that "appears" to satisfy their requests. Additionally, seasoned planners have the advantage of understanding the data in the TPFDD and knowing what data fields are associated with each other. For example, the seasoned planner will automatically know that if the "transport-type" is a ship, than the "origin" needs to be a seaport. The novice user might change the "transport-type" but not realize that the value of "origin" may also need to be changed accordingly. If the novice user is not using a system such as TPEDIT (which supports constraint checking on TPFDD data fields) to make such a change, the plan will become inconsistent.

Some Solutions

Although ForMAT does not support the automatic modification of FM composition, ForMAT does supports the user in better describing and understanding the FMs that exist in the case base. ForMAT provides an extremely flexible indexing mechanism that can be used by the operator to describe any type of information about a FM. Through ForMAT the user can define indices that are automatically applied to each FM created or copied within a session; or the user can create a new index for a given FM at any time. Relationships between TPFDD data fields and among indices can be specified and automatically maintained through ForMATs feature augmentation rules (FARs). For example, when the user changes the composition of a FM (adds an air-force fighter aircraft), the FM indices that are defined by FARs (e.g., function and service) will be automatically updated to reflect this change. While most FARs are invariant across theaters and services, (e.g., FARs that parse country codes, service codes, and transport-type codes) some of the FARs, particularly those that parse the unit function codes, are service and/or theater dependent. Additionally, a user may modify a FAR to fit his/her specific needs.

FM indices can be nominal or hierarchical. Hierarchical indices, e.g., "function", are used to support generalization during retrieval. For example, if the user is searching for "fighter-aircraft" and there are none available, the system will generalize to "mission-aircraft". This can provide the planner with two types of information: (a) there are no "fighter-aircraft" available; and (b) what "mission-aircraft" are available. In some cases, determining that there are no "fighter-aircraft" in a plan is indicative of an error in the plan. In fact, during several instances where ForMAT was used, the indices have proved useful in error-checking plans. However, at other times, determining that there are no "fighter-aircraft" available indicates an extreme force constraint situation - which is a clue to the planner that one or more contending plans need to be modified, or that resource substitution methods need to be pursued.

ForMAT currently contains 47 indices (attribute-value pairs), however, 7 of these indices have never been used to index more than one FM. Research efforts are underway to study the usage of indices: which indices are most frequently used in retrieval; which indices are most frequently changed (the value of the attribute is changed); and what indices are synonyms. Additionally, ForMAT maintains an index dictionary that allows the user to search for defined indices by attribute or by value. The dictionary is provided to offset index proliferation.

Some Remaining Issues

ForMAT currently runs in an unclassified environment. There are a variety of deployment plans in ForMAT, none of them have been executed, and none of them contain any definitive information on success or failure. Hence, there is no sufficient information to base "successful" modification on. The system could just as easily turn a reasonably good plan into a poor plan through modification. It would be interesting to see how the system would perform given a case base of real plans with information on success and failure. Additionally, the history mechanism of ForMAT could be used to generate modification schemes if the "intention" of the user was also captured, and if the system were being used in a real environment.

Even with information on success and failure, deployment plans are built by multiple users and each user has permission to write to his/her assigned data fields. How is modification to handle the multiple user problem, especially with the added complication of permissions?

ForMAT currently supports consistency checking on mundane bookkeeping values that the planners do not necessarily want to pay attention to. However, if ForMAT were to use modification strategies to suggest how a force module from a past plan could be modified to be used in a current situation, how should this suggestion be carried out? Should the system present the modified FM for use with just a "modified" tag? Should detailed explanation and/or justification be provided on the modification? And, what about repercussions of modifications to other FMs within a plan, or within plans that are being executed in tandem? Finally, how does one prevent the planner from being suspicious of automatic modification and conducting serious testing and evaluation of the modification instead of building the deployment plan.

Conclusion

ForMAT currently contains 322 force module cases derived from or used in 17 plans (TPFDDs). ForMAT has been used actively in several exercises and major demonstrations. ForMAT provides support to the deployment planner in the development, management, and maintenance of deployment plans by supporting the creation, indexing, retrieval, and reuse of FMs. ForMAT provides an environment where the planner can modify FMs that he/she chooses to reuse from previous plans or from FM templates. ForMAT supports FM reuse and modification primarily in a consistency maintenance mode through use of feature augmentation rules and other consistency maintenance mechanisms. More sophisticated modification may be provided in the future through the evaluation of the history collected during ForMAT sessions, and once ForMAT is used in real world situations where information on the success and or failure of a plan is available for consideration.

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Appendix: Describing the contribution
A. Reasoning framework:

1. The reasoning framework is comprised of CBR and knowledge acquisition/engineering methods.
2. Speed in force deployment plan development is the main benefit from reuse.

3. The specific benefit of the approach was the availability of plans and of domain specialists. The specific limitation was the lack of "executed plans" and associated failure/success information.

4. While changes are made in the TPFDD data structure, the structure of the TPFDD required to communicate with other systems remains invariant.

5. The basic knowledge representation scheme of ForMAT is the attribute-value pair. Indices are associated with FMs and FMs are part of plans which are part of the case base. When the force composition of a FM is modified manually by a user, many of the FM indices are automatically updated to record the modification. In turn, modifications captured by indices can serve as retrieval mechanisms. While whole plans can be reused, typically one or more FMs from one or more plans is reused in creating a new deployment plan. The cost is the heavy use of indexing, increased consistency maintenance requirements, and uncontrolled growth of the case base. The benefit is the easy retrieval of FMs, and the ability of any given user to personalize the case base.

B. Task:

1. The task is the creation and maintenance of force modules. The domain is force deployment planning.

2. The inputs include: mission information, environmental information, and the major force list.

3. The outputs are the revised case base, a series of reports and the revised or generated force deployment plan (TPFDD).

4. The output TPFDD is constrained in that it's data structure must still be readable by other systems; additionally, the case base may not contain more than one version of a deployment plan (TPFDD).

5. The main characteristic of the domain that the method relies on is the tendency of planners to reuse parts or all of existing plans.

C. Evaluation:

1. The hypothesis - experienced planners quickly build plans for a crisis situation by reusing plans (or parts of plans) from the past.

2. The hypothesis was evaluated by presenting planners with problems and past plans and observing whether they reused past plans or built the new plan from scratch.

3. The tendency to reuse a force module or element from a past plan was compared with the tendency to use template force modules.

4. The evaluation showed that experienced planners tended to reuse their own plans while novice users tended to use any plan that appeared to satisfy their planning needs.

5. The primary contribution of the research was the success of the method employed (combining CBR with knowledge acquisition/engineering methods) to acquire force deployment planning information.

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