ANTICIPATORY PLANNING TO SUPPORT INFORMATION OPERATIONS

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ABSTRACT

The doctrinal definition of Information Operations (IO) focuses exclusively on offensive and defensive activities. This paper proposes extending the definition of IO to include *information efficacy*. Then it describes a new approach to military planning and execution called Anticipatory Planning. This approach seeks to merge planning and execution, and replaces reaction to events with anticipation of events, making more effective use of the information that is available during the conduct of military operations. This paper presents a methodology for building an automated system to support Anticipatory Planning. A Plan Description is developed to manage the many tree-like branches that occur in planning and execution of an operation. A Planning Executive can use the differences between the plan and the actual operation to control the activities of Planners and Execution Monitors in anticipating future branches to the plan. At the heart of the system are inference mechanisms for determining branches in the plan and simulations for predicting future states. The methodology described in this paper enables the development of a prototype *decision support system* (DSS) for military decision makers, called the Anticipatory Planning Support System (APSS). This DSS facilitates in-depth analysis of the voluminous data that is available to military decision makers during the course of military operations. It accomplishes this through the application of simulation and intelligent agent technologies.

INTRODUCTION AND MOTIVATION

The current definition of Information Operations (IO) focus on offensive and defensive operations. This definition should be expanded to include information efficacy. In order to gain important synergies the planning and execution of IO and conventional operations should be considered a single activity. The Anticipatory Planning process discussed in this paper accounts for the chaotic nature of warfare in which possibilities appear and disappear. A proposed Anticipatory Planning Support System (APSS) addresses information efficacy by providing a sophisticated decision support system for the planning and execution of operations. With the advent of APSS, other information age technologies, and the melding of IO and conventional operations, U.S. military planners will have the capability to plan faster and better and stay inside the enemy decision cycle [17].

INFORMATION OPERATIONS

In recent years, the term *information operation* has been *en vogue* as information technologies play an ever-increasing role in military operations. Information Operations (IO) are defined by the Department of Defense (DoD) as “actions taken to affect adversary information and information systems while defending one’s own information and information systems.” [1] This formal definition places strong emphasis on the offensive and defensive aspects of IO. Unfortunately, while offensive and defensive actions are obviously essential components of IO, this definition neglects a critical issue – the respective *value* of the information available to decision-makers on both sides of the conflict. The value of information can be measured in term of its usefulness and its usability, or in the most general sense, in terms of its usage. The significance of information usage can be clearly seen a recent statement made by Secretary of Defense William Cohen. In a March 18, 1999, speech at the National Training Center he stated that “The Army's ability to *use* information to dominate future battles will give the United States a new key to victory, I believe, for years, if not for generations to come.” [Emphasis Added] [2]

Information usefulness includes timeliness, accuracy, and analysis of information. The expressed purpose of the methodology is to provide timely and accurate analysis of discrepancies between the planned operation and the actual operation. When agents detect significant differences that impact on the likelihood of success of the mission, the system alerts planners and decision makers so that current and future plans and actions may be adjusted to compensate.

Information usability concerns the decision maker’s ready access to the resulting information. International Standards Organization (ISO) Standard 9241 defines usability in terms of the effectiveness, efficiency, and satisfaction of a specified set of users for a specified set of tasks in a particular environment. The proposed system efficiently provides warnings through a familiar and effective web browser interface. Preliminary results indicate that target users, military planners and decision makers, are satisfied with this interface to make adjustments to ongoing operations in a tactical operations center environment.

Figure 1 depicts the activities and capabilities of Information Operations as they are viewed by the DoD [1]. The two large circles illustrate the activities of offensive and defensive IO respectively. The overlap includes activities that are included in both offensive and defensive IO.

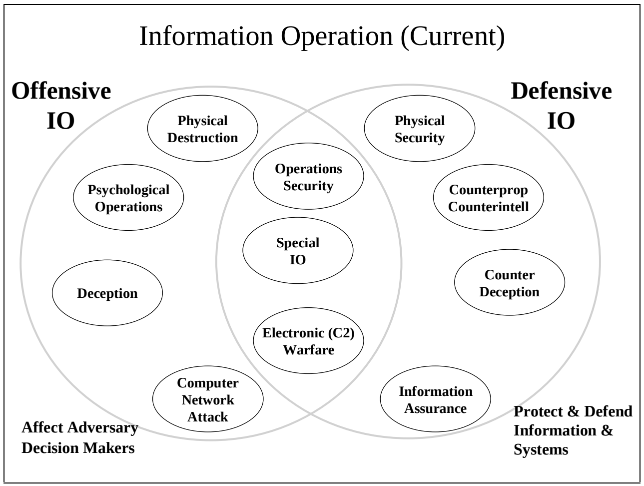

Figure 1: Current Doctrinal Definition of Information Operations

Figure 2 depicts the proposed addition of Information Efficacy to IO. IE is depicted as a foundation for offensive and defensive IO. This addition allows us to add the capabilities of Situational Awareness, Decision Support, and Command and Control to the activities of Information Operations, as shown in the figure. The methodology proposed in this paper directly addresses the darker oval, Decision Support.

Information technologies, such as computers and telecommunication and, in particular, simulation and decision support systems enable the execution of sophisticated information operations in which highly useful and usable information is made available to decision makers on one side of a conflict while denying an adversary's access to such information.

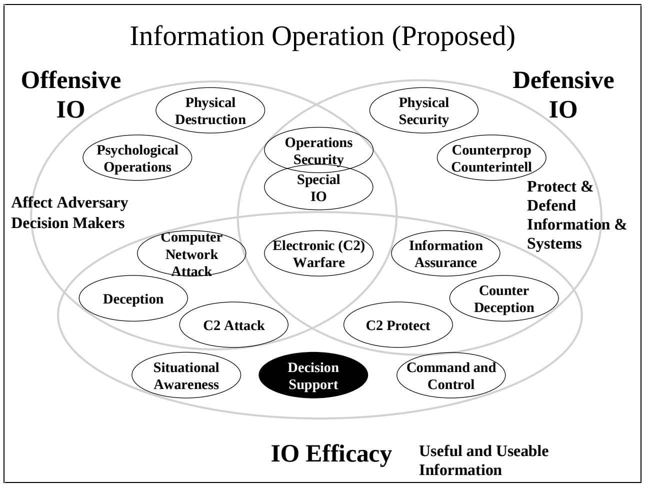

Figure 2: Proposed Definition of Information Operations

In a military operational setting, some of the most useful information comes from information systems that provide *situational awareness* and *decision support*. According to Army manual for Information Operation, FM 100-6, "situational awareness combined a clear picture of friendly and enemy force dispositions with the commander's assessment of the situation and the commander's intent." [3] The enhanced situational awareness that the proposed system provides will help to reduce the *fog of war* that permeates actual military operations.

Decision support systems are "are a collection of tools designed and developed to aid managers in their decision-making processes." [4] The agent-based simulation-enable methodology described in this paper provides highly useful information to provide for both decision support and situational awareness for military decision makers. In addition, the prototype implementation of this methodology puts this information in a very usable form.

While there are no "how we fight" manuals describing the conduct of Information Operations as there are for conventional operations, it is clear that the conduct of offensive or defensive IO will have many parallels to conventional military operations. One way to make these parallels clear is to have the IO community redefine the traditional military terminology, such as seize, secure, destroy, defend in depth, etc., to apply in this new domain. For instance, the conventional definition of seize is to gain control of a piece of terrain and deploy to prevent its destruction or loss to enemy action. In IO, this might mean to gain control of an enemy database server and block all enemy access to the database for some amount of time.

Traditional military operations and Information Operations are usually seen as disparate activities, with one possibly in support of the other. In order to gain important synergies the planning and execution of IO and conventional operations should be considered a single activity, much as indirect fire or aviation planning is part of the overall plan of operations. New definitions of old terms are insufficient to integrate IO into military operations; a full range of IO procedures, processes, and tasks must be developed.

ANTICIPATORY PLANNING

General (ret.) Wass de Czega has proposed a radically new approach to military planning and execution, which he calls Anticipatory Planning [5]. There are two main thrusts of the General's proposal. The first is that planning and execution should be treated as a tightly coupled, single process, rather than as distinct events. The second is that Anticipatory Planning is necessary in a dynamic and information-rich battlefield environment of the future.

In the traditional Military Decision Making Process (MDMP) various enemy courses of action (COAs) are posited by the intelligence officers, and the operations and planning officers propose various friendly COAs to counter them [6]. Each of these friendly COAs are war-gamed in order to determine their viability. A COA is viable if it is suitable, feasible, and acceptable. *Suitable* means the COA accomplishes the mission and complies with the commander's guidance. *Feasible* means that constraints of available time, space, and resources are met. *Acceptable* means that the tactical or operational advantage gained justifies the cost in resources, especially casualties. Commanders often describe viability concerns in terms of desired end-state conditions at the conclusion of execution. The result of this analysis is a single, chosen COA for use in execution.

There is a well-known axiom that the plan never survives the first shot, which is another way of saying that a branch that was not considered in planning has occurred in execution. Consequently, the commander and staff are forced into a reactive planning mode. Rather than a long detailed plan stemming from comparisons of complete friendly and enemy COAs, the planners need a methodology that merges planning and execution. Such a methodology would develop and consider as many reasonable branches in the plan as possible in the initial planning process, and continuously update the plan as execution progresses. This coupling of planning and execution requires a new process.

According to Wass de Czega, it is futile to try to predict one most likely future and build a plan just for that case. Such plans have too little chance of survival. Uncertainty about the success of an operation is caused by clever, unpredictable enemy commanders who want to win as badly as do friendly commanders. Another source of uncertainty is how successful the friendly forces will be. Staffs are as often surprised by successes, which they are unable to exploit, as they are about slower than anticipated progress or higher than anticipated losses [5].

What is needed, he argues, is to plan against as many of the enemy's options as possible, and to create a plan that addresses those most likely and most dangerous ones. The plan for the conduct of the upcoming (or currently being executed) operation must provide as many branches as planning time allows to deal with the next most likely or dangerous eventualities in priority. As a general rule, Wass de Czega argues, the initial course of action must be able to deal with several of the most likely eventualities with simple, “muscle movement” adaptations. The current generation of planning tools does not help planners generate the many-branched plans rapidly enough to stay ahead of the pace of decisions. Those that were available seemed too simplistic or attrition-paradigm oriented [5].

The ability to develop and consider many branches in a plan necessitates an Anticipatory Planning process. Rather than choosing a single course of action and following it to conclusion, Anticipatory Planning involves maintaining as many possible friendly actions against as many enemy actions as possible. The plan is then considered to be a tree. The nodes of the tree represent states (i.e., snapshots of planned or anticipated dispositions of forces on the battlefield) and decision points in the plan. The branches represent the transition to a new state based on a particular enemy or friendly action. As new branches are developed, the Anticipatory Planning process will continue planning along those branches. In this way, Anticipatory Planning for a branch can be done well in advance and many options can be maintained as long as possible, rather than reactive planning once the branch occurs. Anticipatory Planning will increase the importance of the information collection plan to quickly confirm or deny the viability of branches.

ANTICIPATORY PLANNING SUPPORT SYSTEM

This paper presents a methodology for building an automated system to support Anticipatory Planning. See Figure 3 for a depiction of the methodology. A Plan Description is developed to manage the many tree-like branches that occur in planning and execution of an operation. A Planning Executive can use the differences between the plan and the actual operation to control the activities of Planners and Execution Monitors in anticipating future branches to the plan. At the heart of the system are inference mechanisms for determining branches in the plan and simulations for predicting future states.

Information from a World Integrator provides a World View that represents the actual status of execution. As discussed in Section 0, the location and/or status of some entities in the actual operation may be estimates. A Planning Executive controls the Anticipatory Planning process and the use of system resources. A Plan Description represents and manages the plan tree. Execution Monitors compare the Anticipated State of the plan derived from the Actual State of the operation with the Planned State at that Node and notify the Planning Executive if there is a potential problem.

The Planning Executive launches Planners to generate and evaluate new Branches. A Branch Generator uses inference mechanisms that consider possible friendly or enemy actions and produce new Branches. A Branch Evaluator examines a Branch to provide the Planner or the Planning Executive with viability measures and outcome confidences. The Execution Monitors and Branch Evaluators use simulations to perform their evaluations.

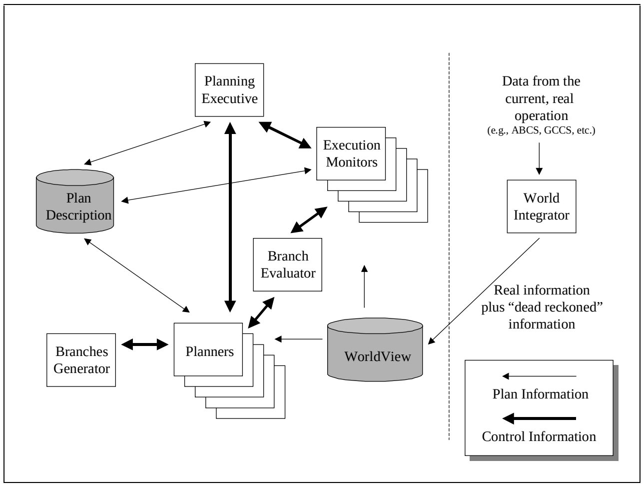

Figure 3: Anticipatory Planning Support System

The human planners will not accept or rely on the system unless they understand the system's "logic." If the recommendations of the system "make sense" to the human planners, or if the system provides a reasonable explanation capability, then it is more likely to be accepted and used. Regardless of how flexible and sophisticated the simulation and analysis system is, it still may not provide results that the planner will accept. Accordingly, the system provides the means for the planner to override the results with an outcome that makes more sense. This postpones the need to re-code the event resolution mechanism or the simulation.

World View and World Integrator

The methodology requires a representation of the Actual State of the operation. Surdu and Pooch describe the use of the World Integrator and a World View in providing the Actual State [7].

The World View module is a representation of the real operation. In order to make the job of the Execution Monitors easier, the representation of the state of the real operation and the Plan Description should be as similar as possible. World View receives information about the state of the real operation through a series of APIs. It then transforms this information into a form that the Execution Monitors can easily interpret.

The World Integrator has the onerous task of monitoring the real operation, processing that information, and passing it to World View. In some systems, such as the Global Command and Control System (GCCS), this may involve querying a database [8]. In other systems, this may require "eavesdropping" on the network. The reason for this intermediate step is that in real operations, reports on some entities may be intermittent. It is the job of the World Integrator to "dead reckon" these intermittent reports and pass them into World View. Clearly, when an entity has been "dead reckoned," this must be reflected in the information that World View gives to the Execution Monitors.

The World Integrator and World View involve issues in sensor, data, and information fusion. World Integrator must determine when an entity has been unconfirmed long enough that its actions must be dead reckoned. When some sensor reports a similar unit, World Integrator must determine whether this is merely the lost unit reappearing or a different unit. These and other issues regarding sensor, data, and information fusion are open research issues.

Planning Executive

The mission of the Planning Executive (PE) is to control the overall operation of the APSS. The PE creates and dispatches Execution Monitors (EMs) and Planners. The PE controls how many EMs and how many Planners are operating at any time, sets the maximum branching factor at any Node, and tracks the state of the (computer) system on which the APSS is running.

When an EM determines that re-planning should be conducted at a given Node, the EM gives the PE a handle to the Node in question and a certainty associated with its recommendation. The list of Nodes for which re-planning is required as well as those Nodes at which re-planning is currently being conducted is called the Planning Frontier (see Figure 4). Nodes to the right of the frontier in the figure have been nominated for re-planning by an EM, and Nodes to the left of the frontier have not been nominated.

The PE uses the confidence measures provided by EMs to determine which Nodes along the frontier will get Planners allocated to them and in what order they will be allocated. If the system is very busy, the PE may determine that it can only afford a small number of running Planners and so Planners will have to be allocated to Nodes sequentially based on the criticality of creating new Branches from the Node. If, however, the system is not busy, the PE may determine that it can afford to allocate a Planner to each Node along the frontier.

Similarly the PE determines how many EMs are running at any given time. Again, if the system resources are not heavily used, the PE might put EMs on many Nodes. On the other hand, in a resource-constrained situation, the PE might have only a few EMs that hop from Node to Node under the control of the PE.

The PE also receives inputs from the interface with the user. Through the interface, the PE allows the user to manually insert Branches or to override work being done by EMs or Planners. For instance, the commander may want to do a “what-if” analysis of some alternative action he has in mind. Through the interface and PE, this new Branch could be added to a Node and a Planner launched. The Planner will create new Branches and determine each Branch's viability. The commander might also want to manually delete a Branch, for whatever reason, and this is also done through the PE.

Finally, in a resource-constrained or very dynamic environment, it is possible that the creation of many Branches will exhaust available memory. In this case, the PE can set the maximum branching factor at Nodes to some small number (e.g., five). In this case only the five most-viable, representative Branches would be retained. This is similar to the combat simulation trajectory management research done by Gilmer, et al. [9-12]

The level of autonomy of the PE is a tunable parameter. It is likely that the intuition of some commanders might be a better predictor of a Branch's viability than the decision of a Branch Evaluator. The user, therefore, might want to confirm the removal of all Branches.

By performing the actions described, the PE helps limit the scope of responsibility of the EMs and Planners as well as the search space that must be explored by them. The EMs and Planners do not need visibility of the global state of the plan or the Planning Frontier, just the Actual State of the operation. The EMs and Planners need to know only how to conduct their analysis or planning, respectively. This makes the job of designing and implementing EMs and Planners much more tractable. When dispatching a Planner, the PE must provide the Planner a handle to the Node in question, the Actual State, and the mission/objective of the operation. An EM only needs to know the Node - and its associated Planned State - that it is supposed to monitor as well as the Actual State.

Plan Description

The Plan Description is a representation of the possible ways the operation can proceed (see Figure 4 for a depiction). The Plan Description is a directed tree with the possible states of the plan held by Nodes. The Branches of the tree represent the significant changes between states caused by the actions of the friendly and enemy participants. These transitions can be the result of multiple actions by multiple entities[1].

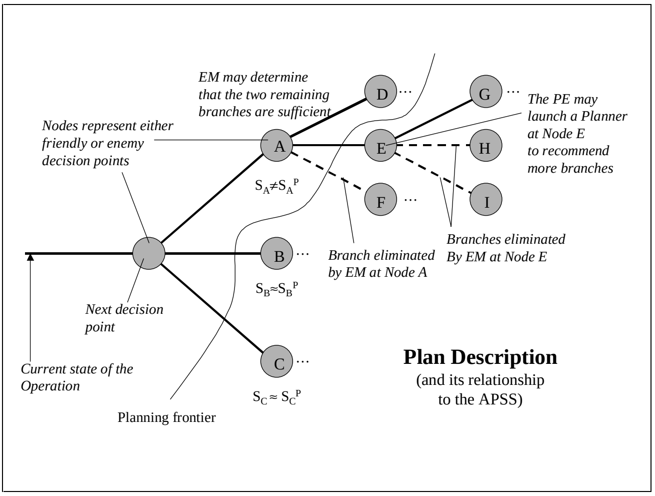

Figure 4: Plan Description

Note that the Plan Description is not a game tree for resolution of a minimax problem, in which each level represents a turn by the adversaries. Russell and Norvig describe the use of such a tree and the minimax algorithm [13]. Each Node is the result of actions taken by *either* of the participants that result in a significantly new state.

States: A state is the “minimal collection of information with which the system’s future state can be uniquely predicted in the absence of chance events.” [14] There

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[1] Normally in simulation literature, an event is that which causes a change in state. APSS is only concerned with significant changes in state, so Branches correspond more directly with transitions rather than with events, in the traditional simulation sense of “event.”

are three kinds of states maintained in this system: the Actual State, the Planned State, and the Anticipated State. The Actual State comes from the World View. A Planned State is generated when a Planner initially creates a Branch in the plan, and is held in a newly created Node in the Plan Description. If an Execution Monitor is observing a Node, it periodically creates an Anticipated State by using simulations to project the Actual State forward to its observed Node.

Nodes: Each Node maintains a Planned State of the plan, as described above. The Nodes connect to any Branches that have been produced by Planners. The Nodes also provide an important function in communicating the viability measure associated with the Branches. Measures of viability are computed for Branches after planning or re-planning.

Branches: A Branch represents significant state transitions caused by actions taken by the friendly or enemy forces. This is similar to the action-based approach to planning Lansky presented in the COLLAGE system [15]. The difference lies in the way that COLLAGE uses unsatisfied constraints to direct the execution of the system, whereas APSS incorporates a priority scheme that the Planning Executive uses to control when and how much planning is done. If the Planning Executive decides that further planning is required for a Node, a Planner is launched and given the state (Planned State or Anticipated State) of the Node. The Planner examines the outcomes of different possible transitions. The transitions have associated preconditions, viability measures, and a confidence measure. Within the constraints placed on the Planner by the PE, several of the best transitions become Branches in the Plan Description.

The commander may desire to add a decision point to the plan manually. The decision point is represented in the Plan Description as a Branch from whichever Node contains the state that holds when the decision has to be made. Then a Planner is used to assess the Branch's viability.

Execution Monitor

Execution Monitors have access to the Plan Description (PD) as well as the Actual State of the operation. The Executive can re-assign an EM to monitor another Node, but each EM is only concerned with one Node at any given time. The Actual State of the operation will be provided by real command and control assets, such as Maneuver Control System (MCS) or the Joint Common Tactical Database [16] through World Integrator and World View. The Joint Common Tactical Database does not currently exist, and there is no easy mechanism for pulling information from MCS, but this capability will exist within the near future.

The purpose of the Execution Monitor (EM) is to periodically compare the Planned State of the operation at a Node versus the Anticipated State at that Node extrapolated from the current Actual State. When the planner builds the various Branches from a Node, it also creates an initial Planned State of the operation at each new Node. An EM must infer when the Anticipated State of the operation differs "significantly" from the Planned State.

The EM uses simulation to create the Anticipated State. The simulation can be initialized with the current Actual State or by the Anticipated State generated by an EM analyzing an antecedent node in the Plan Description. For instance, assume EMs running on Nodes A, E, and C in Figure 4. The EM at Node C would have to begin with the current Actual State of the operation, while the EM at Node E could begin with the Anticipated State generated by the EM at Node A.

The Anticipated State is generated through simulation by applying the transitions leading from the Actual State to the Node of interest through each Node in between. During this simulation, the EM may discover that one or more of these transitions is impossible (e.g., required resources are not available, required entities no longer exist, etc.). In this case the EM terminates the simulation and immediately informs the PE.

When significant differences exist between the Anticipated State and the Planned State the EM at the Node performs several important tasks. First, it conducts a breadth-first traversal of the PD. At each Node in the PD, the EM determines whether the change in state invalidates any Branches leaving the Node. Recall that in the PD preconditions are associated with each outgoing Branch from a Node. When the differences between the Planned State and the Anticipated State indicate that conditions associated with a Node cannot be met, that Branch of the PD *may* be pruned.

Second, after this pruning has been completed, the EM must determine whether there are "enough" viable Branches from the state. A Planner has previously determined the viability of the Branches. EMs will also determine the likelihood of a Branch. For instance, in the absence of information the likelihood of being able to execute each of the three Branches leaving Node A in Figure 4 might be equal. When intelligence is gathered about enemy activities, for instance, an EM at Node A might determine that Node F is less likely. In any event, the likelihood as well as the viability (i.e., utility as shown in Figure 5) of Branches and the number of available

Branches will be used to determine the overall utility of the Node on which the EM is operating.

While the exact computation of a Node's utility will be determined as part of this research, the EM will determine whether it thinks a Planner is needed to generate more options for the human user. If the EM thinks that there are insufficient Branches from a Node or that the viability of the existing branches is poor, the EM makes a recommendation to the PE with some measure of confidence. It is then up to the PE to allocate a Planner to the Node (as discussed previously).

It has already been noted that EMs have access to the Actual State of the operation via World View. EMs can make single, *ad hoc* queries of either World View or the Plan Description. In addition, so that EMs do not have to do exhaustive searches to look for needed information, EMs have the ability to "subscribe" to information from either the Plan Description or World View. For instance, if the Branch leading from Node A to Node F was based on the enemy moving in a certain direction, but the enemy has uncooperatively moved in another direction, an EM at Node A would probably want to know this. If an EM existed at Node A it could subscribe to information about enemy units within the geographic area of interest. In this sense, while Branches are analogous to Decision Points and Targeted Areas of Interest in military plans, subscriptions can be thought of as roughly analogous to Named Areas of Interest [6, 17].

In addition to comparing the Anticipated State to the Planned State, the EM also looks at all conditions associated with the Node's Branches. The EM periodically checks each Branch's conditions and looks at the Actual State of the operation. If something necessary to fulfill a condition is eliminated (e.g., a mine-clearing device has been destroyed or an infantry company has been wiped out) the EM must notify the PE that the Branch should be considered for pruning.

Although it would be tempting for the PE to eliminate Branches that cannot be reached, this must be done with care. It may be possible that some event in a Node closer to the trunk of the tree will allow the condition to later be met. On the other hand, the PE should automatically prune Branches associated with conditions that can never be met, such as the destruction of a bridge or dam. Branches associated with conditions that might conceivably be met in the future should be retained. For instance, a battalion might receive another mine clearing device, replacement unit, sortie of close air support, or other assets from a higher headquarters. When a "recoverable" condition cannot be met, the EM should notify the PE, so that the PE can notify the user. *If the EM is monitoring a Node sufficiently far into the future, it might be possible for the user to take an action that will allow the condition to be met.*

Surdu and Pooch [18] and Surdu, Haines, and Pooch [19] developed a system called OpSim, designed to monitor the current operation. The result of that reseach verified the feasibility of EMs as described here. OpSim uses a dynamic hierarchy of rational agents, called Operations Monitors to compare the current situation with the plan. The top-level Operations Monitor informs the decision maker when the success of the plan is at risk. OpSim, or a system like it, could be adapted for use as an EM. When OpSim was developed, the PD described in this research did not exist. OpSim could be modified to access and understand the PD. Then in addition to the inferences it makes based on state information, it could also look at whether conditions associated with Nodes can be fulfilled.

Planner

The planner receives a state (Planned State, Anticipated State, or Actual State) and a mission/objective from the Plan Executive. The Planner invokes a Branches Generator (BG) and passes it the state and mission/objective. The BG returns some number of Branches to the plan, along with their associated preconditions and confidence measure. At the end of the Branch is a new Node and the Planned State that the Planner predicts will exist after that Branch is followed. In an unconstrained environment, the Planner continues to execute a BG at each newly created Node until either the desired end state is reached or the BG determines that the desired end state cannot be reached. The PE can place constraints on the Planner that limits the planning in terms of time, depth, system resources, etc.. A Branch Evaluator (BE) evaluates each Branch and returns a viability measure.

If the Planner is operating on a Node with existing Branches (i.e., the Node has already been run through a Planner, but now has an Anticipated State different from the Planned State), the Planner compares the newly generated Branches to the existing Branches. If a new Branch is the same as an old Branch, the old Branch can be considered revalidated. If an old Branch is not revalidated based on the Anticipated State, the Planner notifies the PE that the Branch may be considered for Pruning.

This planning process is effective for all operational domains that have well-defined tasks, procedures, and processes. When traditional military operations and Information Operations are fully integrated, the Planner can choose options from both domains. For instance, when Planners are generating courses of action, one

Branch from a Node might represent an attack on an enemy communications node with long-range, precision-guided munitions while another Branch might represent a denial-of-service attack against the node. The methodology proposed in this paper, when implemented carefully, will facilitate this seamless merging of IO and conventional operations in a radically new way.

After the Planner is finished, the new Nodes at the end of the Branches may or may not be explored further. It is up to the Plan Executive to decide whether to place Execution Monitors on those Nodes and whether to act on any recommendations from the EMs for further planning.

Branches Generator

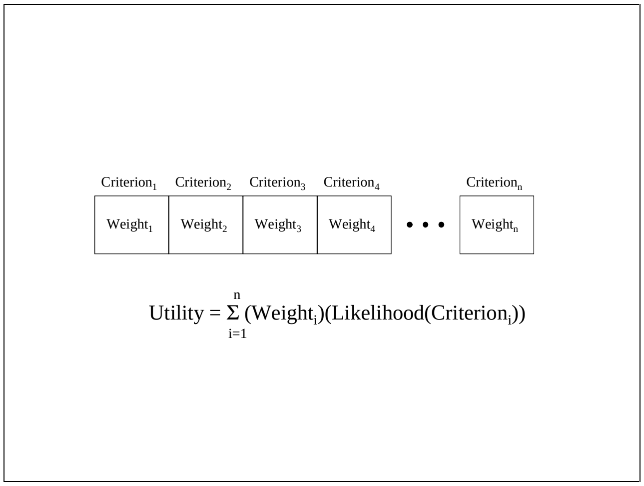
The Branches Generator (BG) receives and examines a state and a mission/objective, then uses inferencing systems to generate different options. Prototype systems such as Fox-GA [20], Tactical Event Resolution [21], and the modified version of ModSAF used by Porto, et al. [22] have demonstrated the feasibility of automatic generation of courses of action in the military domain. The output of the BG is some number of distinct transitions, the Planned State that will hold after each transition, and the associated confidence measures. The new Planned State will contain differences in the conditions of the entities (battle damage, destruction) and in resource consumption (ammunition, fuel, time). The BG creates a new Branch for each of the transitions, and at the other end of the Branch creates a new Node containing the Planned State.

Branch Evaluator

The Branch Evaluator (BE) is given a Branch to evaluate and the mission/objective. The BE compares the Planned State at the end of the Branch with the desired end state of the operation. Using an inference mechanism, the BE determines the impact of the action associated with the Branch on the feasibility, acceptability, and suitability of the plan (i.e., its viability). If the plan is in danger of failure at the new state, the Branch is assigned a low viability measure. If there is little danger of failure, the Branch is assigned a high viability measure. These viability measures are first generated at the leaves and propagated back up the tree. Execution Monitors will use this viability measure when they analyze Nodes.

The purpose of this methodology, along with maintaining as many viable options for the commander as long as possible, is to reduce the "search space" of creating and monitoring the operation. To this end, the system is not designed to explore every possible option. Additionally, branches that have low viability ratings can be pruned so that the evaluation of their children does not consume resources. This increases the difficulty of computing the viability of branches. There are two choices:

- simulate the branch until the simulated operation reaches end state or fails or
- determine a means of inferring the viability of the Anticipated State based on action indicated by that Branch.



$$\text{Utility} = \sum_{i=1}^{n} (\text{Weight}_i)(\text{Likelihood}(\text{Criterion}_i))$$

Figure 5: Computation of Branch Utility

The problem with the first alternative is that it requires all subsequent branches between the current Node and the end state or failure to be generated. This defeats the purpose of limiting the search space of the overall system. The challenge with the second option is to develop heuristics which adequately predict the likelihood of achieving an end state precondition based on the current Anticipated State. Given that such heuristics exist, the computation of the viability, or utility, of a branch is as shown in Figure 5. The Likelihood function uses the heuristics to generate a number in the range [0, 1] of the *likelihood* that a given criterion (i.e., precondition for successful end state) will be achieved based on the current Anticipated State. The *weight* is a user-tunable parameter, again in the range [0, 1], that allows the user to rate the importance of the various criteria. For the initial prototype, the set of usable criteria would be fixed, but eventually the user would be able to choose some number of criteria from a list.

Simulations

Surdu, Haines, and Pooch describe the requirements for operationally focused simulations [19]. Operationally focused simulations are those specifically designed for the mission operational environment. Fishwick, et al., [23] and Blais and Garrabrants [24] have identified the benefits that can be gained from using simulation to support planning. A variety of simulations are needed to support this system, ranging from high to low resolution. For instance, the level of resolution required for the Planner would be less than the level required for the Execution Monitors. Time or system resource constraints may dictate that Planners and EMs be able to select the simulation with the appropriate resolution to provide "good enough" answers "fast enough." It is likely that these simulations will need to be designed specifically for this system.

This methodology does not rely on any particular simulations. Any simulation used to support Anticipatory Planning has to provide a Planned State after an action is taken, the list of preconditions required for that action, and the confidence of achieving that Planned State. It must also be able to accept as inputs a state from the Plan Description.

All but the simplest simulations should consider terrain effects. Terrain representation is necessary for event resolution, route and travel time determination, and fuel or other resource consumption determination. A minimal representation would include elevation and GO / SLOW-GO / NO-GO [17] depiction of the terrain. The terrain fidelity can be as high as permissible for efficiency and timeliness.

The simulation should be flexible and sophisticated enough to handle decomposable events. Multiple levels of resolution will allow APSS to adapt to time and system resource constraints. For instance, the Planner might ask the simulation to resolve a company breach operation. If the Planner requires more detail, the system should be able to individually resolve the support force engagement, the breach force execution, and the assault force. Similarly, the system should be able to resolve a battalion versus company event as four companies versus one company, four companies versus three platoons, or twelve platoons versus three platoons.

CONCLUSION

The current definition of Information Operations (IO) should be expanded to include three parts: offensive operations, defensive operations, and information efficacy. The Anticipatory Planning Support System (APSS) described in this paper addresses this third (new) aspect of IO by providing a sophisticated decision support system for the planning and execution of operations. The Anticipatory Planning process accounts for the chaotic nature of warfare in which possibilities appear and disappear. With the advent of information age technologies and by melding IO and conventional operations, U.S. military planners will have the capability to plan faster and better and stay inside the enemy decision cycle. In this way, rather than two disparate operations, with one possibly in support of the other, they would be part of a single operation.

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