Rapid Asset Allocation for Dynamic TACAIR Decision Support

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ABSTRACT

This work addresses a decision support system that can be used for effectively re-tasking TACAIR assets under a variety of constraints. Analysis of the common operational picture provides augmented situational awareness. Automatic risk analysis keeps the user aware of current and planned risk levels to blue force assets. Options for reacting to changes in the battlefield environment are generated using an evolutionary search algorithm.

Categories and Subject Descriptors

I.2.8 [**Computing Methodologies**]: Artificial Intelligence – *problem solving, control methods and search.*

J.7 [**Computer Applications**]: Computers in Other Systems – *military and command and control.*

General Terms

Algorithms.

Keywords

Decision Support, Evolutionary Search Algorithm, Asset Allocation, Situation Awareness.

1. INTRODUCTION

TACAIR command and control systems must consider a multitude of targeting and environmental conditions for dynamically allocating assets. The capability of these systems to prosecute Time-Critical Targets (TCTs) and Time-Sensitive Targets (TSTs) will be greatly enhanced by the introduction of automated decision aids that assist in compressing the kill chain timeline. The need for automated tools that support the dynamic targeting decision process and the requisite information that they require is discussed in [1, 2].

Prosecuting TSTs and TCTs poses many challenges currently alleviated by excess deployment of resources. Recent contingencies have been typified by planning unassigned missions in the event that targets of opportunity arise. Besides the cost of utilizing an abundance of assets, there is an additional cost of the manpower required to support this type of dynamic planning environment. As the number of the assets and objectives increases, a tasking authority can be overwhelmed with a combinatorial number of assignment possibilities when reallocating the new mission set.

To support the compression of the strike kill-chain timeline, automated tools must augment the distributed decision making processes that exist within the Air Operations Center (AOC). Automated tools should support the well defined components of the re-planning process and provide re-tasking options, but should ultimately leave the final decision making responsibility to the tasking authority. Candidate components for automation within the decision support spectrum include COP analysis, routing, route deconfliction, risk assessment, asset allocation and option generation, METOC analysis, and collateral damage estimation.

This work addresses a decision support system that can be used for effectively re-tasking TACAIR assets under a variety of constraints. This suite of software tools merges the existing mission plan with the EnOB and entity state information to provide augmented situational awareness. This information supports the automated generation of re-tasking options that uses an Evolutionary Search Algorithm. This algorithm allocates Attack assets to targets and Suppression of Enemy Air Defense (SEAD) assets to threats.

2. SITUATION AWARENESS

The cornerstone of rapid retargeting resides in assessing the Common Operational Picture (COP). To achieve this, a tool called SIREN (Sensors, Intelligence, ROE, and Environment Network) has been developed to pull together large amounts of both static and dynamic data from disparate sources.

SIREN obtains its dynamic data from providers linked to external systems. Currently these include providers for the Track Manager Server (TMS) used by GCCS-M and a Link-16, with development underway for an XTCF provider. SIREN also incorporates threat lay-down information via an Enemy Order of Battle (EnOB) provider.

The static information is obtained from several different services. A mission plan service makes available the most recent mission plan submitted to the system. Capabilities and Performance (CnP) data for the entities being tracked is available through the CnP service. The effectiveness service determines the effectiveness of a given weapon against a given target or a given SEAD asset against an enemy threat system. WinJMEMs is being integrated to support the weapon effectiveness service.

SIREN constantly monitors the environment and assesses changes to that environment (e.g. emerging threats or pop-up

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targets). SIREN uses a tool called the Risk Assessment and Validation Engine (RAVE) to monitor and update risk levels to the blue force air entities in the COP. RAVE uses advanced kill-chain analysis of the threat systems in the COP to compute these risk levels. SIREN allows the user to specify and monitor a prioritized list of targets. SIREN identifies entities that appear in the COP and notifies the user of potential matches to the user-specified target list.

3. OPTION GENERATION

The problem of TACAIR asset allocation has been the focus of recent research. Investigations into optimizing deliberate planning assignments are provided in [3,4] while other work [5,6] has been applied to the dynamic tasking problem. The present work extends the capabilities presented in [6].

For re-planning, the user may submit any number of targets to the system at any time for option generation. These options are generated using an evolutionary search algorithm that allocates Attack assets to targets and SEAD assets to threats. Multiple weapons may be assigned to a single target or threat. Likewise, a single aircraft can prosecute more than one target. The algorithm attempts to maximize effectiveness while minimizing overall mission risk. A persistence objective is introduced to minimize disruption to the deliberately planned missions. The spatial-temporal aspects as well as commander's intent are incorporated into the objective function.

The effectiveness score for an allocation specifies the degree to which all targeting objectives (i.e. desired probabilities of destruction) are achieved. For each target, the effectiveness service is queried to obtain a probability of destruction (P_d) value for each weapon assigned to that target. These individual P_d values are then aggregated into an overall P_d against this target. Using this aggregate value relative to the target's desired P_d, an effectiveness score is determined according to the degree of overkill or underkill. The overall effectiveness score for the entire mission set is calculated by summing the effectiveness scores for each target weighted by the inverse of its priority.

The risk score for an allocation considers the risk to each aircraft from the threat laydown as the aircraft executes its assigned mission. Ideally, RAVE would be used to compute the risk to an aircraft over its entire route. However, RAVE has not yet been fully integrated into the genetic search algorithm so this risk is currently evaluated from an analysis of only those threats in the proximity of the targets to which the aircraft is assigned. The overall risk to each mission is determined by considering the risk to the aircraft the mission contains. A risk score for each mission is evaluated using the mission's risk against a baseline risk threshold, where lower risk is preferred and therefore yields a higher score. The overall risk score for an allocation is calculated by aggregating the risk scores across the missions.

The persistence score is a measure of the change to the overall mission plan. A high persistence score results from minimizing the number of changes to weapon assignments and minimizing the number of additional targets assigned to any mission. The former minimization views persistence from the pilot perspective (i.e. fewer changes to fewer pilots). The latter minimization seeks to select the required weapons for a single target or threat from as few missions as possible.

Other objective components are included for the spatial-temporal aspects of the problem. A distance score is used to keep missions as close as possible to their planned areas of operation. A time-on-target score assures that targets will be prosecuted within their specified time-windows. A recovery score assures that aircraft will reach their recovery points as scheduled. Similar to effectiveness and risk, each of these scores are calculated starting at the aircraft level.

4. RESULTS

The evolutionary search algorithm has been extensively tested on large, realistic problems formulated by subject matter experts. One such test problem consisted of 107 attack assets, and 20 targets producing a search space of 21^{107} possible asset allocation solutions. These solutions, considered sound by subject matter experts, were typically generated in under 20 seconds on a typical desktop PC.

Incorporating dynamic allocation of SEAD assets has been tested on smaller problems in which reasonable solutions can be more easily recognized. The size of these problems has been on the order of 10 targets, 10 threats, 10 attack assets, with 10 SEAD assets. Reasonable solutions to such problems have been generated in one to three seconds.

5. CONCLUSIONS

This work has presented an overview of a decision support system for the rapid re-tasking of TACAIR assets. The system pulls together disparate data in support of automatic option generation for asset allocation. The evolutionary search algorithm implemented presents the user with reasonable solutions for reassigning both attack and SEAD assets in response to changes in the battlefield environment.

The algorithm currently incorporates commanders intent as weightings on the individual (effectiveness, risk, persistence) components in the objective function. Multi-objective optimization techniques are being explored as alternatives to the weighted linear combination to ascertain if this system can yield a broader range of reasonable allocation options.

Future work also includes incorporating the RAVE tool for quantifying route risk as opposed to considering only threats near the targets. METOC analysis, semi-automated collateral damage estimation, auto-routing, and route deconfliction are the subject of ongoing investigation with respect to this effort.

6. ACKNOWLEDGMENTS

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