Multiple Criteria Optimization and Analysis in the Planning of Effects-Based Operations

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Abstract

Effects-based operations (EBO) is a military concept that approaches the planning of operations from the systems perspective [1]. EBO looks into the final overall outcomes of the direct impacts of actions in a system. Using EBO terminology, the overall outcomes are called effects whose purpose is to fulfill pre-determined higher-level objectives of the operation. The planning problem of EBO is to find an action that causes the desired effects while at the same time causing minimal undesired effects. As a single action in a system can have multiple consequences, a multi-criteria approach is necessary.

We present a new planning process for structuring, analyzing and solving the planning problem of EBO. The process begins with the identification of effects from pre-determined higher level objectives. The boundaries of the system are defined, followed by the construction of a system model. Using the system model, the consequences of each action are identified. The fulfillment of the effects is evaluated with a number of criteria which are constructed by determining where in the system an effect will manifest itself. The values of the criteria given by each action are then calculated by using the system model. Finally, the criteria are used to find a set of efficient actions from which a single action is chosen.

We demonstrate similarities between the EBO planning process and a multi-criteria decision analysis (MCDA) process [6]. An MCDA process begins by identifying a set of alternatives followed by the specification of decision criteria. Next, the consequences of each alternative, i.e., action, are determined. Finally, the preferences of the decision maker are elicited and applied for the evaluation and comparison of the alternatives. Both the EBO planning and MCDA processes first structure the problem and then seek efficient alternatives, i.e., actions with respect to a set of criteria. However, the EBO planning process places greater emphasis on the system perspective. In the EBO planning process, the consequences of the alternatives are identified by utilizing a system model. The system model is also integral to the definition of the criteria and evaluation of the performance of the actions on each criterion. Despite the obvious similarities of the approaches, MCDA methodology has not been applied before in the planning of EBO.

It is also possible to see the planning problem of EBO as a multi-criteria optimization (MCO) problem [3]. In this case, the criteria form the objective functions, the constraints of the optimization problem are determined through the system model, and the possible actions

are represented by the decision variables. Thus, MCO methods can also be utilized for finding efficient actions which makes the planning of EBO a new application area of MCO.

Different approaches have been suggested to the planning of EBO (e.g., [4], [7]). However, the explicit use of multi-criteria approaches has not been considered before. We present how the planning process discussed above can be supported using a multi-criteria influence diagram (MCID) ([2], [5]) which is a graphical representation of a multi-criteria decision making problem under uncertainty. An MCID consists of variables which are represented by nodes and probabilistic dependencies between the variables represented by arcs and formalized using conditional probabilities. Three types of nodes exist in MCIDs: chance nodes, decision nodes, and utility nodes which in the EBO planning process are used to model the system, actions, and criteria, respectively.

The EBO planning process and the utilization of MCIDs are illustrated by an example analysis of a fictitious military mission. There are two actors in the mission representing an attacker and a defender. The attacker conducts two air-to-ground operations against targets which are a part of the military and civilian infrastructure of the defending country. The analysis is conducted from the perspective of the defender. The objective of the analysis is to find a way of allocating the defender's available military resources to protect the possible targets such that the desired effects will be achieved and the undesired effects will be avoided.

The example analysis illustrates the application of MCDA to the planning of EBO. The parallel use of MCDA methods and a system model facilitates the discovery of actions leading to the desired effects. In addition, the philosophy of EBO can be applied to complex planning problems in non-military settings such as in the planning of marketing campaigns [7]. One can easily imagine applications in the area of health care policy as well.

Keywords: Effects-based operations; Military planning; Influence diagrams; Multi-criteria decision analysis

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