Available online at www.sciencedirect.com

ScienceDirect

IFAC Papers Online CONFERENCE PAPER ARCHIVE

IFAC-PapersOnLine 48-3 (2015) 008–013

Threat Evaluation Using Analytic Network Process

Seckin UNVER *.Tuncay GURBUZ **

**Industrial Engineering Department, Galatasaray University, Istanbul, TURKEY(sunver@gsu.edu.tr, unverseckin@gmail.com).*

*** Industrial Engineering Department, Galatasaray University, Çırağan cad. No.36 34349 Ortaköy Istanbul, TURKEY (e-mail: tuncaygurbuz09@gmail.com, tgurbuz@gsu.edu.tr).*

This research has been financially supported by Galatasaray University Research Fund.

Abstract: In this study, our objective is to apply the Saaty's well-known multi criteria decision making method, Analytic Network Process (ANP) to Threat Evaluation process and comment on the results. In order to do that, a scenario is created with a number of aircrafts approaching to a defended asset from different directions. Some of them are ignored regarding their intent while others are evaluated and assigned with a target value. By that, obtained values can be used in sequencing or prioritizing the targets in a war environment.

Keywords: Threat assessment, threat evaluation, ANP.

1. INTRODUCTION

Decision-making under stress is a hard task for human beings. It requires strong mental capability and years of experience. Air defense decision-making is a highly complex process and it can only be performed by experienced and skilled experts in the field.

Informally, the purpose of Threat Evaluation "TE" is to rank observed enemy craft according to their threatening behavior with respect to a number of Defended Assets "DA". In theory, it is evident that the TE process provides decision support (which improves command and control as well as situation awareness) and is dedicated to improving the operational tempo of operators.

The motivation behind this study is the need for a decision tool, which takes environmental weapon and threat related-characteristics into account, and suggests an effective course of action for air defense in a complex attack environment. Unlike former studies, which proposed mainly heuristic algorithms for threat evaluation phase, we use The Analytic Network Process "ANP" for calculating threat values of targets.

2. THREAT EVALUATION CONCEPT

During this decision process, there are some elements of surface-to-air defense such as DAs, threat elements and WSs which are needed to be considered according to their attributes:

Defended Assets: In defensive counterair operations, a listing of those assets from the critical asset list prioritized by the Command and Control "C2" center to be defended with the resources available. Thus, some of the DAs have higher priority than the others and need better protection.

Threat Elements: Generally in air defense, threat means all enemy forces attempting to attack or penetrate the friendly air environment. In other words, threats are elements with the intention of damage or injury to the DAs. Threat can be missiles (ballistic, guided. etc.) or aircrafts which drop bombs or fires directly to the ground targets.

Weapon Systems: Weapons such as Anti-aircraft "AA" guns or Surface-to-air missiles "SAM" are used in air defense to eliminate targets.

2.1 Threat Evaluation

TE is a pre-deployment process by which a commander and his staff draw on their encyclopedic knowledge of the enemy, including doctrine, tactics and capabilities, to deduce the nature of the threat they face.

Many methods were studied for assessment of threats. Some of them are Rule-based systems (Harris, 1988)-(Liebhaber, 2000), Bayesian networks (Endsley, 1995)-(Okello and Thorns, 2003)-(Johansson and Falkman, 2008), Neural networks (Jan, 2004)-(Hua and Ke, 2012)-(Azak and Bayrak, 2008), Multi-criteria decision analysis (Qu and He, 2002) and Fuzzy logic (Yawei, 2007)-(Dongfeng et al., 2012).

Three main criteria of the TE process are C*apability* (Hall and Llinas, 2001), *Intent* (Hall and Llinas, 2001) and *Proximity* (Roy et al., 2002).

Capability: It refers to the identification of threat and its ability to destroy or cause damage to the DAs. Radar cross-section, answer to identification friend or foe "IFF" interrogation, etc. can give us information about target's identity. The capability of a target depends on its platform capability whether, for example, it can maneuver fast or is a stealth platform and on the weapons it carries for the mission. Fuel capacity of a target is another parameter that can give us

10.1016/j.ifacol.2015.06.050

information about target's maximum range of operation. Basically, the target must be identified first; then its capability can be inferred.

Intent: Unlike capability, intent is a bit more subjective term in TE process. Intent refers to the assumed future behavior of a target. Knowing the intent of a target is essential for an operator to prioritize the processing of a target and to choose suitable tactics and appropriate weapons to engage the target. Target intent is one of the main discriminators for classifying whether a target is friend or foe since a particular type of aircraft may be in service in both forces. For example, typical commercial aircrafts tend to fly with steady speed, constant altitude and in a straight line. If a target maneuvers more than normal indicates more threat than a non-maneuvering target. Other indications of hostile intent may be the use of radar-jamming units or if the target's fire control radar is on.

Proximity: Proximity is a class of parameters that are measuring the target's proximity to the DA. One of the most important parameter to define the distance of target to the DA is the Closest Point of Approach, "CPA". CPA is point where the distance between asset and the direction of velocity of target will be the shortest. CPA can easily be used as a measure of threat level. Targets in far distances can be considered less threatening, while targets in shorter distances indicate more potential threat. Some of the parameters related to the CPA are:

Time to CPA "TCPA": Target's approaching time to the CPA calculated using (1).

$$\text{TCPA}=(\text{distance from CPA})/\text{speed} \quad (1)$$

CPA in Units of Time "CPAIUOT": Means the time it takes the target to hit the DA after arriving the CPA calculated using (2).

$$\text{CPAIUOT}=(\text{distance at CPA})/\text{speed} \quad (2)$$

Time Before Hit "TBH": TBH is an estimate of the time it takes the target to hit or reach the DA calculated using the following:

$$\text{TBH} = \text{TCPA}+\text{CPAIUOT} = (\text{distance from CPA} + \text{distance at CPA})/\text{speed} \quad (3)$$

These calculations are made under the assumption of constant target velocities. This is a reasonable assumption for many platforms and conventional weapons, since they seldom make rapid maneuvers between two track updates (Oxenham, 2003).

2.2 Problem Definition

The main aim of air defense is to defend the assets by using weapons to neutralize the threats. Threats are generally airplanes flying at very high speeds. They send rockets to or drop bombs onto assets. During the engagement period, radars supply information to C2 center on velocity, position and type of threats. C2 center checks the weapon availability, decides on the best engagement strategy and sends engagement orders to weapons. If the weapon accepts the order, it prepares to fire.

In the beginning of the process, we need to determine the intent of the possible threats whether they have hostile intent or they are neutral. Then we may treat them as targets and assign their target values. To do so, some parameters about threats considering their past and present conditions need to be gathered. The parameters are listed below:

Altitude "ALT": Approximate feet above ground or an indication of change (e.g. climbing).
Countermeasures "CM": Using techniques or tools to avoid radar signals, thermal or infrared guided systems.
Heading: Exact compass heading or indication of heading relative to the DA (i.e. opening or closing).
Closest Point of Approach "CPA": Estimated distance that track will pass by own ship if the track and own ship remain on their current courses.
Fire Control Radar "FCR": A system that is used by an attacker to track a target by intense radio beams.
Flight Plan/Airlane: A published or otherwise known commercial air route.
Maneuverability "MNB": Agility of track and maneuver capacity
Maximum Radius of Operation "MRO": Also varies according to platform type and fuel capacity, indicates maximum reach point of track beginning from lift-off.
Origin "ORG": Indicates the country from which the track most likely originated.
Platform Weapons "PW": Armaments on track.
Speed "SPD": Approximate airspeed or an indication of change (e.g. increasing).
Weapon Engagement Range "WER": Varies for the onboard armament, indicates maximum and minimum firing distances.

2.3 Intent Estimation

Usually, intent of a target cannot be observed directly. What can be observed are signs that the enemy is engaged in particular actions or behavior. Therefore, to read the intent of a target, operators get as many clues as possible from different information sources such as radar, IFF-interrogation, intelligence, visual inspection, etc.

Operators generally carry out a number of sequential activities within the overall task. Consider the activities of an operator from "initial detection" to "intent assessment" of a single target. The activities include recognition that the target exists, assessment of the environment in which the target is operating, and assessment of the target behavior within the environment, leading to an assumption about its intentions.
A conclusion about the intent of a target may lead to actions of further investigation or to intercepting and neutralizing the target (Nguyen, 2002).