Designing Optimal Aviation Baggage Screening Strategies Using Evolutionary Algorithms

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ABSTRACT

Various mathematical methods and metaheuristic approaches have been developed in the past to address optimization problems related to aviation security. One such problem deals with a key component of an aviation security system, baggage and passenger screening devices. The decision process to determine which devices to procure by aviation and security officials, and how and where to deploy them can be quite challenging. In this study, two evolutionary algorithms are developed to obtain optimal baggage screening strategies, which minimize the expected annual total cost. Here, the expected annual cost function is composed of the purchasing and operating costs, as well as the costs associated to false alarms and false clears. A baggage screening strategy consists of various hierarchical levels of security screening devices through which a checked bag may pass through. A solution to the aviation baggage screening problem entails the number and type of devices to be installed at each hierarchical level. Solutions obtained from a comparison of a Genetic and a Memetic algorithm are presented. In addition, to illustrate the performance of both algorithms, different computational experiments utilizing the developed algorithms are also presented.

Keywords: Aviation Security, Baggage Screening, Evolutionary Algorithms, Genetic Algorithms, Memetic Algorithms

INTRODUCTION

The threat of terrorism against commercial aviation has received much attention in past years and due to security concerns, airport screening procedures have gone through significant improvements to ensure passenger safety. In 1996, the crash of Trans World Airlines Flight 800 (TWA 800) led to the creation of the White House Commission on Aviation Safety and Security (CASS). The CASS recommended the deployment and use of new screening technologies and equipment as well as the development of uniform performance standards
Congress also passed the Federal Aviation Reauthorization Act of 1996 and the Omnibus Consolidated Appropriations Act of 1997 and over the four years prior to 2000, the congress provided the Federal Aviation Administration (FAA) with $1 billion for security and almost one-third of this funding was for the purchase and deployment of security equipment (Coughlin et al., 2002). Aviation security has been improved by the deployment of Explosive Detection Systems, and the implementation of Passenger-Baggage Matching and Automated Passenger Profiling. Additionally, an important increase in aviation security was due to the improvements in baggage screening, the Transportation Security Administration (TSA) has focused in baggage screener training and the success of new procedures in identifying potential threats.

In 1999, the Computer-Aided Passenger Prescreening System (CAPPS) was implemented to increase airport security. CAPPS attempts to identify potential terrorists through the use of profiles so that security personnel can focus the bulk of their attention on high-risk individuals. The passengers who were classified as not posing a security risk were labeled as nonselectees, while those who could not be cleared were labeled as selectees (O’Harrow, 2002). Some researchers have mentioned that implementing CAPPS is not sufficient to warrant the security of an airport and have indicated that airports using CAPPS to select passengers for increased scrutiny are less secure compared with airports using systems that randomly select passengers for thorough inspection. For instance, Chakrabarti and Strauss (2002) developed an algorithm called Carnival Booth that demonstrated how a terrorist could defeat the CAPPS system by using a combination of statistical analysis and computer simulation. In their paper, they evaluated the efficacy of Carnival Booth and illustrated that CAPPS is an ineffective security measure.

After the terrorist attacks on September 11, 2001, aviation security moved in the direction of uniform screening with the enactment into law of the 100% checked baggage screening mandate, which eliminated the distinction between selectees and nonselectees. The TSA revisited selective screening policies through the development of the Computer-Assisted Passenger Prescreening System II (CAPPS II), a refinement of CAPPS. However, on July 14, 2004, the TSA announced that due to privacy concerns CAPPS II would not be implemented. Moreover, aviation security experts have suggested that it is more effective to perform a more intense scrutiny of passengers perceived as “greater security risks” than increasing the screening intensity for all passengers, given that 100% checked baggage screening is not cost-effective, and suggested that creating multiple levels of security for screening passengers may be more effective than treating all passengers the same (Poole & Passantino, 2003). Later, Barnett (2004) suggested that CAPPS II may only improve aviation security under a particular set of circumstances and recommended that CAPPS II be transitioned from security centerpiece to one of many components in future aviation security strategies. Martonosi and Barnett (2006) used a mathematical model to explore the antiterrorist effectiveness of airport passenger prescreening systems and noted that CAPPS II may not substantially improve aviation security if the prescreening procedures for each type of passenger are not effective. Recently, Weiss (2011) developed along with MITRE Corporation the Dynamic Airport Security Model. The model, a fast-time desktop simulation, accepts the airport layout, security procedures and threat vectors (path-weapon combinations) as inputs and models the performance of the airport’s defense against those threat vectors.

**Notation**

- $S$: Expected number of bags screened bags per year;
- $C_{FC}$: Cost of a false clear;
- $r_T$: Probability of a treat;
- $r_{FA}$: False alarm probability rate;
- $r_{FC}$: False clear probability rate;
- $C_{FA}$: Cost of a false alarm;
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