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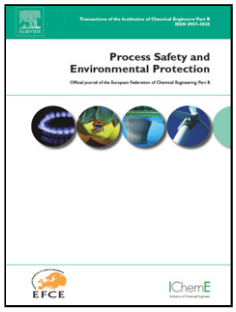

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ACCEPTED MANUSCRIPT

Optimal patrol scheduling of hazardous pipelines using Game theory

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Abstract:

An approach based on game theory is proposed to schedule security patrolling for a pipeline system. The method proposes numbers of patrolling paths according to the risk of security incidents on the pipeline system, in order to allow the patrolling team to covering high-risk segments more than low-risk segments. Patrolling of the pipeline system was modelled mathematically, based on time and distance discretization. The overall approach also examines the presence of security countermeasures on a pipeline system, and their effects on the patrolling schedule. The application of the method is explained by an illustrative case study.

Keywords: Security, Risk assessment, Game Theory, Patroling

1. Introduction:

Nowadays game theory is widely used in the security domain from cyber security to physical security, and for the allocation of limited security resources to scheduling the patrolling in critical infrastructures. The application of game theory to security is well explained by Tambe (2012), and Bier and Azaiez (2009).

Game-theoretic analyses of conflicts require modeling the probable consequences of each choice of strategies by the players and assessing the expected utilities of these probable consequences. According to Tambe (2012), game theory provides a sound mathematical approach for deploying limited security resources to maximize their effectiveness. The Bayesian Stackelberg game is one special class of game theory and has recently been used for security applications (see Tambe (2012)). In this class of game the players may have incomplete information about either the actions or the payoffs representing other players. Incomplete information is modeled by assuming that players can have different types. Thus the players that know their types will outguess each other's type with the probability distribution over possible types of the other player (that is why it is called Bayesian game). This security game is a sequential or extensive form of games in which the defender starts the game as a leader while the followers, defined as different types of attackers, will observe and respond to the leader.

As mentioned before, one of the applications of game theory in the security domain is to schedule patrolling. Patrolling can be defined as an act of traveling within an area in regular intervals so as to secure it against different threats.

Pita et al. (2008) developed a security game for Randomizing schedules for patrolling, checking, or monitoring in an airport surrounding. Their model called ARMOR (Assistant for Randomized Monitoring over Routes) casts this patrolling/monitoring problem as a Bayesian Stackelberg game. ARMOR has been successfully deployed since August 2007 at the Los Angeles International Airport (LAX) to randomize checkpoints on the roadways entering the airport as well as canine patrol routes within the airport terminals.

Tsai et al. (2009) addressed strategic randomization of security resources by a security game. They developed the Intelligent Randomization in Scheduling (IRIS) system, which is a software to schedule the Federal Air Marshals (FAMs) that provide law enforcement aboard U.S. commercial flights. In IRIS, Tsai et al. (2009) model the problem as a Stackelberg game, with FAMS as leaders that commit to a flight coverage schedule, and terrorists as followers that attempt to attack a flight.

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