Systemic Risk and Security Management

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Abstract The aim of this paper is to develop a decision-theoretic approach to security management of uncertain multi-agent systems. Security is defined as the ability to deal with intentional and unintentional threats generated by agents. The main concern of the paper is the protection of public goods from these threats allowing explicit treatment of inherent uncertainties and robust security management solutions. The paper shows that robust solutions can be properly designed by new stochastic optimization tools applicable for multicriteria problems with uncertain probability distributions and multivariate extreme events.

1 Introduction

Standard risk management deals with threats generated by exogenous events. Typically, such situations allow to separate risk assessment from risk management. Repetitive observations are used to characterize risk by a probability distribution that can be used in risk management. Statistical decision theory, expected utility theory and more general stochastic optimization (STO) theory provide common approaches for this purpose.

Security management includes threats generated (intentionally or unintentionally) by intelligent agents. Obvious examples are threats to public goods and homeland security from terrorists (Ezell and von Winterfeldt 2009). Less evident examples are floods which are often triggered by rains, hurricanes, and earthquakes in combination with inappropriate land use planning, maintenance of flood protection systems and behavior of various agents. The construction of levees, dikes, and dams which may break on average, say, once in 100 years, create an illusion of safety

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and in the absence of proper regulations developments close to these constructions may create catastrophic floods of high consequences.

Other examples include social, financial, economic, energy, food and water security issues. Water and food security deals with the robust functioning of complex multi-agent water and food supply networks. Threats associated with such systems depend on decisions of different agents. For example, an increase of bio-fuel production may change market prices, induce threats of environmental degradation, destabilize supplies of food and water, and disturb economic developments.

These examples illustrate threats that cannot be characterized by a single probability distribution. Inherent uncertainties of related decision problems with the lack and even absence of repetitive observations restrict exact evaluations and predictions. The main issue in this case is the design of robust solutions. Although exact evaluations are impossible, the preference structure among feasible alternatives provides a stable basis for relative ranking of them in order to find solutions robust with respect to all potential scenarios of uncertainties. As we know, the heavier parcel can be easily found without exact measuring of the weight.

The goal of this paper is to develop a decision-theoretic approach to security management. It shows that robustness of solutions in security management can be achieved by developing new stochastic optimization tools for models with uncertain multi-dimensional probability distributions which may implicitly depend on decisions. The common approach, using the concept of two-stage Stackelberg game is built on strong assumptions of perfect information about preference structures of agents which lead to unstable solutions and discontinuous models even with respect to slight variations of initial data in linear criteria functions. Our proposed decision-theoretic approach explicitly deals with uncertainties. It does not destroy convexities but still preserves the two-stage structure of the Stackelberg "leader-follower" decisions.

In order to develop robust approaches, Sects. 2, 3, and 4 analyze similarities and fundamental differences between frequent standard risks, multivariate multi-agent catastrophic risks generated by natural disasters with the lack and even absence of repetitive observations, and risks generated by intelligent agents.

In the case of standard risks, the term "robust" was introduced in statistics (Huber 1981) in connections with irrelevant "bad" observations (outliers) which ruin the standard mean values, least square analysis, regression and variance/covariance analysis. Section 2 shows, that switching from quadratic (least square) smooth optimization principles in statistics to non-smooth stochastic minimax optimization principles leads to robust statistical decisions. This idea is generalized in the following sections.

In general decision problems (Sect. 3) under inherent uncertainty the robustness of decisions is achieved by a proper representation of uncertainty, adequate sets of feasible decisions and performance indicators allowing to characterize main socio-economic, technological, environmental concerns and security requirements. This leads to specific STO problems. In particular, a key issue is the singularity of robust solutions with respect to low-probability extreme events.