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Possible topics for PhD project within risk analysis and game theory

1. Several players with different attitudes towards risk interact with each other in static and dynamic (over time) situations. These can be theoretically analyzed with prescriptive and descriptive analysis tools and investigated empirically. Just like mathematics, probability theory, and operational analysis are the most natural analysis tools in the engineering disciplines, game theory is a natural analysis tool when the behavioral dimension is involved. Game theory gained an important Nobel prize in economics in 1994, represents today the main core of microeconomics, and has found its place within most disciplines where the behavioral dimension is involved, for example biology, economics, evolutionary theory, finance, international relations, law, mathematical sociology, political science. The following 18 game theorists have received the Nobel Prize: Samuelson 1970, Arrow 1972, Harsanyi 1994, Nash 1994, Selten 1994, Lucas 1995, Vickrey 1996, Aumann 2005, Schelling 2005, Hurwicz 2007, Machine 2007, Myerson 2007, Roth 2012, Shapley 2012, Tirole 2014, Hart 2016, Holmstrom 2016, Thaler 2017. Game theory requires at least two players, that at least one player can choose at least two strategies, and that each player receives a payoff given the combinations of strategies chosen by all players. Operational analysis can be characterized as a game by an actor against "dead nature." The four most common games are the prisoner's dilemma, chicken, battle of the sexes, and insurance games. The payoff or utility function is assumed to be arbitrarily general e.g. regarding subjectivity and specified attitude towards risk.
2. Quantitative analysis tools within economics, political science, and mathematical sociology can be used for analyzing the behavioral dimension in risk, safety, security, and resilience research. These tools can be used to analyze and find empirical support for stakeholder attitudes towards risk, the types of interaction that occur and may occur between individuals or groups of individuals who unilaterally choose incompatible strategies under uncertainty and incomplete information about environmental parameters, payoffs, beliefs, and preferences. The collective consequences of individual strategies can be explored. It is possible to analyze which strategies are optimal for triggering or curbing crises and conflicts. At the collective or societal level, it is possible to analyze, prescriptively and descriptively, how principles or guidelines can be designed to create incentives for profit-seeking and/or safety-seeking and/or security-seeking individuals to act in harmony with self-interest, collective interests, and/or societal safety and security.
3. Players’ attitudes towards risk: Strategically interacting actors at different levels, e.g. at the individual, group, organizational and societal levels, are involved in accidents, disasters, crises, emergencies, accidents, hazards, and devastations, where phenomena related to reliability, risk, safety, security, uncertainty, and vulnerability are relevant. An actor can be stereotypically characterized as risk-seeking, risk-neutral, risk-averse. Theoretical and empirical work by e.g. Kahneman and Tversky (1979) show e.g. that an actor instead of following classical probability theory operates with a value function which is concave for gains, convex for losses, and typically steeper for losses than for gains. Theories of this kind, as well as the assessment of empirical support, emerges and evolves frequently in today's international research literature. It is important that Norway gains insight and contributes to the development of this literature.
4. Complex systems contain both the technical and human dimension. The engineering disciplines have a long tradition of developing understanding of the technical dimension, such as reliability analysis, probabilistic risk analysis, etc. In addition, the essential behavioral dimension should be incorporated. A model can be developed where the technical system is influenced by decisions and actions, which in turn are influenced by management and organizational factors, where Bayesian probability theory is used in the analysis. A principal-agent model can be developed where each component of a system is an agent-machine system. The principal maximizes system reliability given three conditions that impose constraints and incur costs. 1. Divergent views/requirements from different stakeholders (interest groups, bodies with decision-making authority, etc.). 2. Incentive systems for agents maximizing utility. 3. Expenditure on the operation and maintenance of technical components. These models can be further developed, empirical support can be given, and alternative models can be developed. The key is to achieve explanatory power according to conventional scientific criteria.
5. Financial risk: Financial crises reveal the necessity of analyzing the strategic interaction between various players such as countries, central banks, banks, firms, households, and financial inter-governmental organizations, supplementing the abundance of econometric analysis and time series analysis within finance. Each player has a strategy set, with strategies such as setting interest rates, lending, borrowing, producing, consuming, investing, importing, exporting, defaulting, and penalizing default. Markets for goods, debt, and capital are subject to shocks and contagion through time, caused by and impacting players.
6. Information security: The information revolution has introduced new technologies, and changed the way firms, organizations and individuals in the private and public domain interact and conduct business. Cyber security has moved to center stage. Exchange of information and economic transactions increasingly take place via digital electronic activities focused primarily on the interconnectivity obtained via the Internet. One critical part of this interconnectivity is the way organizations integrate their accounting and financial management systems with Internet based applications. Another part is how firms store and transfer information they seek to keep confidential. Organizations on the one hand seek efficient transfer of information, data, and transactions, but on the other hand seek to do this in a secure manner. Gains can be made by intruders breaking through safeguards, violating confidentiality, and unlawfully appropriating information, data, and assets. The field of information security develops at an amazing speed. The mechanisms need to be understood. Firms compete with each other and with external intruders such as hackers over their assets. In this new environment each firm needs to determine the optimal investment in security technology, and the optimal amount of information about security breaches and other events to share with other firms, and public and private information agencies of various kinds. Similarly, the objectives of the intruders need to be understood. Examples of objectives are financial gain, political gain, leisure activities, a desire for challenges, and a desire for causing destruction. Intruders can be profiled psychologically. There are income effects for intruders, and interdependence and substitution effects between firms. These phenomena can be studied from economic, political, psychological, sociological, and technological viewpoints. There is a need for theoretical development, combined with generation and application of empirics. Examples of key words are Technology, Infrastructure, Vulnerabilities, Threats, Risks, Accidental, Incidental, Computer Attack, Cyber Incident, Network Vulnerabilities, Technical Solutions, Forensics, Incident Analysis, Intelligence Analysis, Criminological Approaches, Tracing and Tracking Methodologies, Behavioral Research, Psychology Profiling, Resilience Management, Procedures, Policies, Organizational Management, Cooperation, Global Phenomenon. Examples of agencies which in recent years have improved their collection and to some extent systematic categorization of empirics, e.g. related to cyber incidents, are various statistics bureaus, CERT, CERIAS, the Centre for Information Security, the Norwegian National Authority for the Investigation and Prosecution of Economic and Environmental Crime, the Financial Supervisory Authority of Norway, the UK National Hi-Tech Crime Unit, the UK Home Office, the UK Asset Recovery Agency, the UK Serious Organised Crime Agency, the Securities and Exchange Commission, the FBI, Interpol/Europol, Symantec, various organizations (Statoil, Shell, SR-Bank, Ibas, etc.), Honeynet, and empirics can be compiled by questionnaires, interviews, and other research methods.
7. Strategic interaction and societal safety: Strategically interacting agents are involved in accidents, catastrophes, crises, disasters, emergencies, hazards, where phenomena related to reliability, risk, safety, security, uncertainty, vulnerability are involved. At the individual level actors’ attitude towards risk needs to be understood, and what kind of interaction occurs between individuals or groups of individuals who choose strategies under uncertainty and incomplete information about surroundings, utilities, beliefs, and preferences. The collective implications of individual strategies also need to be understood, and what strategies can be chosen to trigger or dampen crises and conflicts. At the collective or societal level premises or pre-conditions can be laid to create incentives for individuals to behave compatibly with individual and societal safety.
8. Terrorism: Terrorism is a typical phenomenon involving at least two players, one seeking to create or produce terror, and one seeking to prevent terror. The probability of a terrorism event, and the consequences if it occurs, depend on a plethora of factors such as the preferences and beliefs of the players, their competence, available resources, and resource allocation. For example, resource allocation for the defender has to be made between potential targets and across time, between prevention, addressing the terrorism event if it unfolds, and remedying the consequences; and between terrorism and non-terrorism. Resource allocation for the attacker may consist of determining where, when, how, and how fiercely to attack. Multiple players usually face a collective action challenge regarding who shall incur the costs of combating and producing terrorism.
9. Power, conflict, and risk: Power and conflict are pervasive in all interaction and are usually analyzed as political and economic phenomena. The relationships of power and conflict to reliability, risk, safety, security, uncertainty, and vulnerability need to be understood. Power, conflict, and risk play a role at all levels of organization for strategically interacting agents involved in accidents, catastrophes, crises, disasters, emergencies, hazards.
10. Probabilistic Risk Analysis and Game Theory: The behavioral dimension matters in Probabilistic Risk Analysis since players throughout a system incur costs to increase system reliability interpreted as a public good. Individual strategies at the subsystem level generally conflict with collective desires at the system level. Game theory, the natural tool to analyze individual-collective conflicts that affect risk, has been integrated into Probabilistic Risk Analysis by Hausken (2002). Conflicts arise in series, parallel, and summation systems over which player(s) prefer(s) to incur the cost of risk reduction. Frequently, the series, parallel, and summation systems correspond to the four most common games in game theory, i.e., the coordination game, the battle of the sexes and the chicken game, and prisoner's dilemma, respectively. The following three further developments to the merger of Probabilistic Risk Analysis and basic game theory can be made.
    1. One-shot play can be substituted with repeated play. Common equilibrium concepts are sequential equilibrium and trembling-hand perfect equilibrium, with subsequent equilibrium refinements. Repeating a game finitely many times gives the same one-shot solution in every round, due to the argument of backward recursion. For infinitely repeated games, the Folk Theorem is especially famous. It states that "any individually rational payoff [i.e., utility] vector of a one-shot game of complete information can arise in a perfect equilibrium of the infinitely repeated game if players are sufficiently patient." Applied to the prisoner's dilemma, mutual cooperation can be sustained as an equilibrium in the infinitely repeated game if the discount factor is sufficiently close to one. An alternative is Axelrod's (2006) tit-for-tat strategy, which may also sustain cooperation through time.
    2. Complete information can be substituted with incomplete information, successfully formalized in the Harsanyi doctrine (Harsanyi, 1967), which lets each player form a subjective probability distribution over the alternative possibilities, or types, of incomplete information for the other players (This superseded earlier infinite recursions of the kind "If I think that you think that I think ...."). A player's type is thus his characteristics of psychological, physical, or other nature. Examples of types are a player's ability to work (which may be high or low), his competence, his ability to handle risk diligently, his discounting of the future, his threshold level for fatigue, and his reservation price (when buying or selling an asset). Incomplete information can be symmetric or asymmetric across players, e.g., one-sided, two-sided, or n-sided.
    3. The utility to each player can in accordance with principal-agent theory be supplemented with a utility to a manager (principal) which allocates compensation to each player (agent) which incurs maintenance or capital costs for each unit. The principal's strategy set is the range of possibilities for paying the agents and incurring unit costs. The principal maximizes his utility under the constraint that each agent that works for him is maximizing at the same time. Informational issues usually play a role, a typical example being that agents are fully informed and the principal incompletely informed. Hausken (1996, pp. 21-29) considers a simple principal-agent problem with adverse selection, where a risk-neutral, incompletely informed principal assigns probabilities to two possible types (high versus low cost of production) for a risk-averse agent which is fully informed. The principal maximizes utility and obtains a second-best solution while the high-cost agent type is held down to his individual rationality constraint (participation constraint), where the incentive compatibility constraint of the low-cost agent type is binding.) The conventional economic theory of the firm, ignoring technical characteristics, defines property rights and designs incentive systems to address types of misbehavior such as free-riding, moral hazard, and adverse selection. The further potential is to develop a theory of the firm comprising a system with multiple units equipped with both behavioral and technical characteristics, in addition to one or several principals. Clever principals are aware of internal conflicts and address the public good incentive question by structuring utilities such that agents have a reason to cooperate across tasks. The principal can be conceived as a (detached) decision maker maximizing according to multiple attributes as specified by the preferences of multiple stakeholders.

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