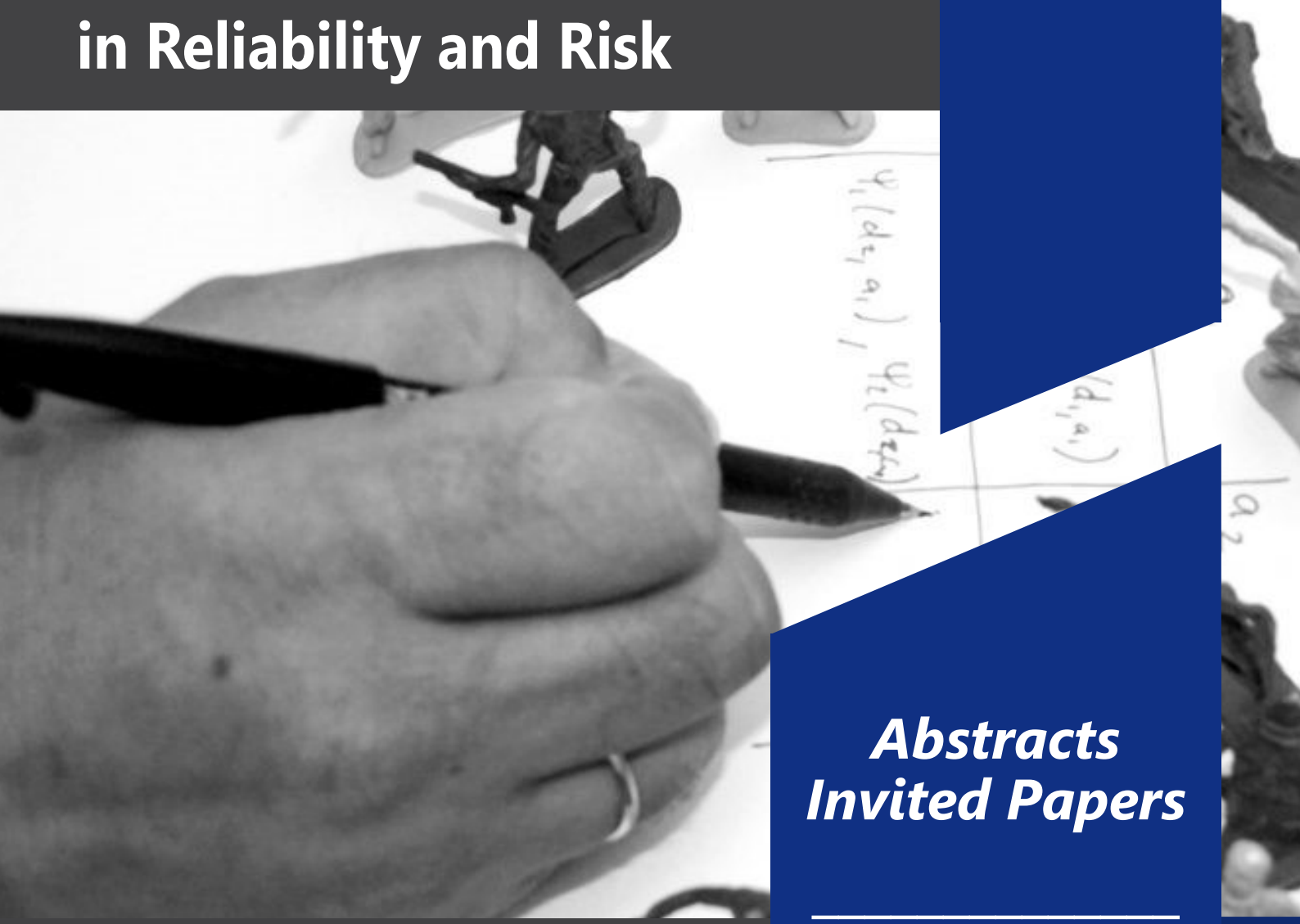
GDRR

Games and Decicions in Reliability and Risk



Abstracts Invited Papers

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ON

GAMES AND DECISIONS IN RISK AND RELIABILITY

GDRR 2017

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Royal Academy of Sciences

Abstracts

Invited Papers

On the Relationship between Safety and Decision Significance

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Risk analysts are often concerned with identifying key safety drivers, i.e., the systems, structures and components(SSCs) that matter the most to safety. The safety categorization of SSCs is risk-informed, i.e. it makes use of the insights gained from a probabilistic safety assessment(PSA) model. Once a PSA model is developed, analysts use it to assess the consequences of the failures or success of given SSCs. Several importance measures are built on these scenarios[1].

These success/failure scenarios play a central role in all phases of the risk analysis of a complex system. However, their information contributes differently in different phases of the decision making process. In a post-implementation setting, while in a pre-implementation one, he needs to decide whether to accept or not a given design. Hence, the decision maker should be interested also in the decision significance of an SSC.

This then opens the question of whether an SSC can be both decision significant and safety significant. Answering this question has a clear risk-management implication: A risk manager would have a better way to allocate resources, if she/he could focus on the decision significant SSCs and be reassured that these remain safety significant.

Herein, we investigate under which conditions we are reassured that an SSC which is decision significant remains safety significant. The answer to this question requires a series of non-trivial steps. The first is to establish relationships among traditional risk importance measures and the Decision Worth[2]. In fact, traditional importance measures are used to determine the safety significance of SSCs[3]. The Decision Worth is a value of information-based importance measure that allows to obtain insights about the decision significance of an SSC. The second is the introduction of the class of θ–importance measures as the class of importance measures whose ranking is invariant in a pre and post-decision setting. The third step is to address the conditions under which traditional importance measures become θ–importance measures.

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Combining failure and self-correcting processes in seismic risk analysis

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Two widely known features of the earthquake generation process are the following:
- earthquakes tend to occur in clusters, sometimes, but not only, referred to as swarms, foreshocks and aftershocks activity;
- the fault rupture that generates an earthquake decreases the amount of strain present at the location along the fault where rupture occurs.

Two different classes of models – self-exciting and self-correcting models – correspond respectively to the two features and have been widely studied separately in the literature.

Models that try to capture both these diametrically opposed features should reconcile contrasting trends. The simplest solution would be to mix stochastic models of the two classes: trigger and strain-release models(Schoenberg and Bolt, 2000); in this way, since it is unknown who belongs to what (which events are triggered and which trigger), each event is meant to be generated by both models and the normalized estimate of the conditional intensities $\lambda_i/(\lambda_1 + \lambda_2), i = 1,2$, indicates the percentage of events belonging to each class. The large difference between the scales, at which the triggering and strain-release mechanisms appear to operate, may be a misleading element. To overcome this issue we can assume that the different behaviours correspond to different phases of the seismic activity and the dynamics of their activation times is driven by an unobserved pure jump Markov process; in this perspective a seismic sequence can be considered as a realization of a series of three marked point processes: Poisson, stress release and trigger models(Varini, 2005, Varini and Rotondi, 2006). The comparison on simulated datasets shows that about 70% of the events are correctly classified but the model is hardly able to fit the abrupt changes of state.

This leads to think that it is more reasonable to assume that the different behavioural trends(models) are superimposed rather than consecutive. In this perspective we consider a sequence of strong earthquakes$\{t_i, M_i\}, i = 1, \dots, n$, where t_i indicates the occurrence time and M_i the magnitude. Among these events we distinguish the leaders, main shocks with higher magnitude (exceeding a fixed threshold), from the subordinates, with lower magnitude. The leaders follow a stress release model; conditioned on their occurrence, the remaining events constitute a set of ordered times of minor ruptures occurring in the time interval between two consecutive leader-events. In other words, the events of I level(leader) match the elastic rebound theory, while the events of II level(subordinates) depend on the previous ones and take charge of the other trends. They are modelled by a failure process that allows bathtub-shaped hazard function. In particular, we have examined the generalized Weibull distributions, a large family that contains distributions with different bathtub-shaped hazard as well as the standard Weibull distribution (Lai, Springer, 2014). The model is applied to data from an Italian seismogenic source and the results of Bayesian inference are shown.

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A Bayesian network model for probabilistic safety assessment of highways and conventional roads

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Royal Academy of Engineering

A Bayesian network model reproducing all elements encountered when travelling along a highway or road, such as speed limit signs, terrain, infrastructure, roundabouts, light signals, curves, tunnels, viaducts, intersections and any other safety relevant elements is presented. The driver's attention, one of the main causes of accidents because of its relation to human error, is specially taken into account. Closed formulas for the conditional probability tables are obtained. A partitioning technique, based on the conditional independence property, allows us to reduce drastically the CPU time required, which becomes linear in the number of variables instead of the nonlinear character of alternative methods. Some real examples of applications are provided to show the usefulness of the proposed methodology for probabilistic safety assessment of highways or conventional roads.

Optimization Problems and Games involving Robust Risk Measures

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Many classical problems in Finance, Insurance, Risk Management, Marketing, etc., are modelled by means of Optimization Problems or Games. Interesting examples are, among others, Pricing, Optimal Investment, Optimal Reinsurance, the Newsvendor Problem, etc. Furthermore, the incorporation of ambiguity is becoming more and more important when these problems are studied, since the estimation of the real probabilities frequently incorporates measurement errors which may provoke significant distortions in the provided solutions.

In this presentation we will propose new methods generating proper sets of priors in ambiguous frameworks. These sets of priors will be suitable to extend classical theory about risk analysis, generating the coherent and expectation bounded robust risk measures. They will be represented by means of sub-gradient linked methods, which will allow us to give practical and mathematically tractable tools to optimize them and find their equilibriums in games.

Some practical applications involve heavy tailed risk with unbounded (robust) expectation. For instance, the valuation of some insurance contracts linked to earthquakes, hurricanes, etc. Classical risk measures does not make sense for them because they become infinity, and their implications in Risk Analysis and Optimization.

Numerical experiments and practical applications will be presented.

Likelihood-ratio equivalent classification problems and principled re-balancing techniques

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The use of Bregman divergences as surrogate costs when training discriminative classification machines permits to estimate posterior class probabilities. On the other hand, in binary problems, the Bayesian formulation shows an one-to-one correspondence between the class-1 posterior probability and the likelihood ratio, assuming that the cost policy and prior probabilities are given. So, the Bregman-trained machines also provide estimates of the likelihood ratio, and, consequently, it is possible to obtain a classifier for any other cost policy and prior probabilities. This fact serves to define the likelihood-ratio equivalent classification problems.

According to the above, when dealing with an imbalanced dataset, it is possible to construct and solve a likelihood-ratio equivalent problem which does not suffer the imbalance effects, and to obtain directly a solution for the imbalanced case by means of processing the output of the machine which solves that equivalent problem, the only practical limitation being the quality of the Bregman estimates.

In this work, we formally present and discuss the likelihood-ratio equivalence and its use as a "stricto sensu" re-balance technique. We also review some further applications of the equivalence concept, such as how to employ it in binary representation ensembles for multi-class problems and in designing diversity-based classifier ensembles, as well as some extensions, such as dealing with example-sensitive cost classification tasks.

Optimal Sequential Drilling for Hydrocarbon Field Development Planning

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We present a novel approach for planning the development of hydrocarbon fields, taking into account the sequential nature of well drilling decisions and the possibility to react to future information. In a dynamic fashion, we want to optimally decide where to drill each well conditional on every possible piece of information that could be obtained from previous wells. We formulate this sequential drilling optimization problem as a POMDP, and propose an algorithm to search for an optimal drilling policy. We show that our new approach leads to better results compared to the current standard in the oil and gas (O&G) industry.

Crisis communication and rumor management using social media during disasters

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Social media has been more and more used by government and nongovernment organizations, and private citizens for crisis communication during disasters. However, few research has studied the users' behavior when facing rumors and debunking information. In this research, we first study the effectiveness of crisis communication and how re-tweet and mention could help improve crisis information impression. Millions of tweets posted during Hurricane Sandy in 2012 are collected and analyzed. Content analysis shows that time-gap between original time and re-tweet time is power law distributed and 75 percent of re-tweet occurs within 1.5 hours. On average, one re-tweet could contribute 7,637 second impressions. The second impression consists of only 12% of total impressions, which means that the information distribution heavily depends on first-level followers. We find that although 67% of re-tweets occur within 1 hour, which is efficient for information distribution, the average time is 27 hours, implying that there are some users who re-tweet long after the original tweet posting.

Second, we investigate four cases of rumor responding and corresponding debunking behaviors of Twitter users during Hurricane Sandy in 2012 and Boston Marathon bombings in 2013. We find that for users who were misinformed and reacted by posting tweet(s), they could respond to this rumor by: spreading (~86%), seeking confirmation (~9%), or doubting (~10%). Given rumor spreading users were debunked, they would respond by: deleting rumor tweets (~10%), clarifying rumor information with a new tweet (~19%), or doing nothing (~78%). We conclude that Twitter users would perform poorly in rumor detection and rush to rumor spreading; the majority of rumor spreading users would not take further actions on Twitter to fix the rumor spreading behaviors. In addition, posting a tweet asking confirmation to rumor information is an efficient way for information navigation during disasters on Twitter since confirming tweets are responded more and faster than those non-confirming tweets. Regression analysis is conducted to study whether verification, follower count, account age, status count, favorites count, and friends count would impact the combating decisions of rumor spreading users when they are debunked by accurate anti-rumor information. We find that the follower count and status count are the two most significant impacting factors on a user's responding behaviors.

Finally, we discuss the optimal debunking strategies dealing with potential rumor information, and the corresponding consequences on the downstream information sharing. We also use simulation to study the impact of different network information flow structure. This research provides some novel insights on crisis communication and rumor management using social media during disasters.

High-dimensional copulas for solving unbalanced classification problems in industrial risk mitigation

Nicolas BOUSQUET
Ingénieur-chercheur expert
Chef du projet MATIS

Environmental risks that can typically affect highly-protected production plants are due to lacks of water, floods, clogging from plants or animals, among others. Those events are scarce and unfortunately, in many situations there is no clear understanding of the physical reasons for which a particular phenomenon is an outlier or not.

The expert knowledge on those events expresses only by choosing covariates, assumed to reflect a piece of true information about the regular phenomemon (e.g., a tide within an estuary), and assuming that the outlier is ? explained ? by the same physics, for objective reasons. The lack of knowledge and the need for industrial mitigation can lead to build a pronostic mechanism (computing for instance a probability of occurrence) based on the statistical classification of feared and non-feared events. In such unbalanced situations, usual learning methods (SVM, random forests, etc.) provide a result which remains biased because of the very low number of feared events, and very simple empirical techniques (Parzen ratio) can do as well as these more elaborated approaches. Nonetheless, several techniques can be used to improve the ROC curve featuring a classification algorithm. The incorporation of expert information can be adressed by using high-dimensional copulas, which can outperform the results of other methods. An governing example highlights the benefits of this approach, that consider the massive clogging problem of French and English production plants.

Societal Risk and Decision Analyses and the Political Process

Simon French
Warwick University

Decision analysis based on subjective expected utility has been with us for at least half a century; risk analysis similarly. Over that time they have developed from a theories of rationally dealing with uncertain events and risks to a practical tool for individuals, small groups and ‘unitary’ organisations, helping them them towards sound decision making. Decision and risk analytic tools have also shown its worth in the context of stakeholder engagement and public participation. The time is right for them be more widely used across government, but to achieve that it may be necessary recognise more clearly that political processes may need replace expected utility or expected loss.

Guidelines for aggregation of cyber-risk in large institutions

Ketil Stolen, Atle Refsdal
SINTEF

Aggregation of risk internally and across business- and organizational structures is important and a prerequisite for risk-based decision support. Good aggregation methods [approaches, procedures etc.] should provide an overall risk picture that is sufficiently correct and easy to comprehend. Successfully establishing and implementing such methods is difficult. We have studied this problem in collaboration with four Norwegian companies working within banking, IT-support and petroleum. Focusing on cyber-risk, in this talk we present our findings and suggest guidelines for risk aggregation.

Risk Analysis and Decision Theory: A Bridge

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The triplet-based risk analysis of Kaplan and Garrick (1981) is the keystone of operational risk analysis. This paper performs a sharp embedding of the elements of this framework into the one of formal decision theory, which is mainly concerned with the methodological and modelling issuesof decision making. The aim of this exercise is twofold: on the one hand, it gives operational risk analysis a direct access to the rich toolbox that decision theory has developed, in the last decades, in order to deal with complex layers of uncertainty; on the other, it exposes decision theory to the challenges of operational risk analysis, thus providing it with broader scope and new stimuli.

The survival signature for system reliability: recent developments

Frank Coolen
Durham University

The survival signature, introduced by Frank Coolen and Tahani Coolen-Maturi in 2012, generalizes Samaniego's signature for systems with multiple types of components. It is a summary of the system structure function in case components of the same type have exchangeable failure times, and as such it is suitable for a range of inferences involving the system failure time.

This presentation will consist of an introductory overview of the survival signature, followed

by a range of recent further results. These will include consideration of component important measures, probabilistic structure functions, resilience due to the ability to move components in the system around, and efficient simulation methods based only on the survival signature.

Modeling extreme events

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Extreme value theory finds wide applications in areas such as environmental science, financial strategy of risk management and biomedical data processing. For example, one of the main decisions to be made in operational hydrology is to estimate design floods for safety purposes, considering floods. Other example could be organizing efficient fire fighting capacity and resource management. In all of them, correct quantification of risk of extreme values are needed.

There exits in the scientific literature several ways to address the statistical study of extremes events, one of them is through the use of the Extreme Value Theory (EVT). In particular, considering only the maximum of the data in a block (season, year…) the well-known Generalized Extreme Value Distributions is obtained.

In this presentation, a hierarchical Bayesian model including in several steps, spatial and time trends is considered. At a first level, or data level, it is supposed that the observed noisy data depend on an unknown or latent process plus several data parameters. At a second level, you have the process level, where it is proposed a model for the latent process through a conditional probability. At the third level a statistical distribution model for the data and process parameters is introduced. The Bayesian paradigm offers coherent tools to quantify the prior knowledge of experts, if you have any. In other case, noninformative priors for the involved parameters can be used.

To approximate the posterior distribution for each model a MCMC algorithm is proposed, specifically a Gibbs sampling with same Metropolis-Hastings steps. Once the posterior distribution is obtained, an assessment of the models is carried out. Two different methods are considered: the Deviance Information Criterium and the posterior predictive assessment.

These ideas are illustrated with a rainfall example considering several observatories and including spatial and time trends.

Managing epidemic risk by early identification of infected individuals in contact networks

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and
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Models of infectious diseases are commonly used to investigate the dynamics of disease spread and to evaluate the efficacy of different intervention strategies [1]. Mathematical models of infectious diseases capture system dynamics by introducing a small number of compartments, corresponding to disease states, and the system evolves as individuals move from one compartment to another, for example from the susceptible (S) to the infected (I) state. For mathematical tractability, these models typically assume perfect mixing, i.e., any individual may come into contact with any other. This unrealistic assumption is relaxed in network epidemiology by introducing a contact network, which specifies the structure of interactions and determines who may transmit the disease to whom in the population. The network perspective makes it possible to better investigate risk of disease spread on different network topologies and to consider different types of interventions and decisions.
We consider the problem of inferring the source node of an epidemic in an SI process with unknown infectivity. We assume the network structure to be known, and the data consist of a list of infected nodes observed at a small number of time points. We tackle this problem using Approximate Bayesian Computation (ABC) [2], which is a novel Bayesian inference technique for complex models, where the likelihood function either does not exist in closed form or is computationally infeasible. ABC allows the inference to be carried our jointly on the two unknowns, disease infectivity and the location of the seed node within the network. We study the problem first on regular lattices and then consider more complex and realistic network structures. Even though the posterior distribution is too complex to study analytically, our approach makes it possible to take a fully Bayesian approach, and we provide not only point estimates but also credible intervals for the quantities of interest.

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Joint work with Ritabrata Dutta (InterDisciplinary Institute of Data Science, Università della Svizzera italiana, USI, Lugano) and JP Onnela (Department of Biostatistics, Harvard T.H. Chan School of Public Health, Harvard University)

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To Better Manage Risks in Multi-Period New Product Development — Select Riskier Projects

Janne Kettunen, Shivraj Kanungo

We consider multi-period new product development(NPD) where the decision maker(DM) chooses, periodically, which development projects to fund from the pool of available projects. We show that the availability of new development projects in future periods, which the initiated projects can be switched for, has major implications for what projects are optimal to select the thereby for the portfolio value and risk. Furthermore, we show that a risk-averse NPD portfolio selection approach(i.e., selecting low risk low value projects every period) implies higher risk than a risk-neutral selection approach(i.e., selecting high value high risk projects every period). We name this phenomenon the risk aversion paradox and show it to be commonly present in multi-period NPD portfolio selection problems. To overcome the paradox, we propose a forward looking NPD selection framework. Finally, we show that the risk-averse DM can reduce the risk further by employing a less risk-averse selection approach.

Keywords: New product development, project portfolio, optimization

Bayesian Robustness for Fault Tree Analysis

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Fault tree analysis (FTA) is often used to evaluate risk in large, safety critical systems but has limitations due to its static structure. Bayesian approaches have been proposed as a superior alternative to it, however, this involves prior elicitation, which is not straightforward. A large amount of data is required to correctly update a mis-specified prior and such data may not be available for many complex, safety critical systems. Therefore, there is a need to develop a Bayesian robustness approach for FTA which can quantify the effects of prior mis-specification on the posterior analysis.

Here, we propose the first Bayesian robustness approach specifically developed for FTA. We not only prove a few important mathematical properties of this approach, but also develop easy to use Monte Carlo sampling algorithms to implement this approach on any given fault tree with AND and/or OR gates. We then implement this Bayesian robustness approach on two real life examples: a spacecraft re-entry example and a feeding control system example. We illustrate how minor mis-specification of priors for each of the elementary events can

snowball into a significant distortion to the prior of the top event and therefore into the posterior analysis too.

Keywords: Fault tree analysis, prior elicitation, distorted band of priors, Bayesian robustness, Bayesian networks.

Modeling repairable systems by virtual aging

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Repairable systems subject to minimal, perfect or imperfect repairs upon each failure are modeled by presenting virtual aging concept. Virtual aging is developed by using marked point processes, (T_1, Z_1), $(T_2, Z_2), \dots, (T_n, Z_n)$ where T_i's are failure times and Z_i's are types of repair choices. The marks of this marked point process, i.e. repair actions, are assumed to be unknown and unobservable so modeled as latent variables. According to the dependence structure of the latent variables various models are developed. For the statistical analysis of these models, Bayesian framework is presented and as an illustration this method is applied to train door failure data of 40 underground trains.

Directed Expected Utility Networks

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A variety of statistical graphical models have been defined to represent the conditional independences underlying a random vector of interest. These are then used to guide fast and distributed inferential routines that exploit this graphical representation. Similarly, many different graphs embedding various types of preferential independences, as for example conditional utility independence and generalized additive independence, have more recently started to appear. One of the few available models that aim at contemporaneously depict probabilistic dependence, the form of the utility function and the structure of the underlying decision space is the influence diagram. However, influence diagrams are almost exclusively designed to work when the utility can be assumed to factorize additively. In this work we introduce a new graphical model, called a directed expected utility network, whose edges depict both probabilistic and utility conditional independences. These embed a very flexible class of utility models, much larger than those usually conceived in standard influence

diagrams. Our graphical representation, and various transformations of the original graph into a tree structure, are then used to guide fast routines for the computation of a decision problem's expected utilities that generalize those usually utilized in standard influence diagrams' evaluations under much more restrictive conditions. We illustrate our methodology by constructing a directed expected utility network to support decision makers in the domain of household food security.

M. Leonelli & J.Q. Smith, Directed Expected Utility Network, Decision Analysis 14(2) (to appear).

A New Graphical approach to Bayesian Games

Peter Thwaites (University of Leeds)

Many Bayesian games can be readily represented by graphical structures such as MAIDS (Koller & Milch: Multi-agent influence diagrams for representing and solving games, Game Econ Behav 45 2003). But the development of these representations has coincided with concerns expressed regarding the application of Bayesian game theory to real problems. We focus on two of these concerns. Firstly, a player may assume that an opponent is subjective expected utility maximizing (SEUM), but in many real games it is improbable that they can know the exact quantitative form of this opponent's utility function. Secondly, many common Bayesian games have highly asymmetric game trees (Banks, Rios Aliaga & Rios Insua: Adversarial Risk Analysis 2015), and cannot be fully or efficiently represented by an ID (influence diagram). The first concern was considered in Smith 1996 (Plausible Bayesian games, Bayesian Statistics 5), in the context of games with sufficient symmetry to be expressible as IDs. If the game ID is considered to be common knowledge to the players, then they can use the conditional independence/Markov structure of the ID to discover simpler games and simpler optimal decision strategies for playing these games. To address the second concern, we suggest the use of CEGs (Chain Event Graphs). These were introduced in 2008 (Smith & Anderson: Conditional independence and Chain Event Graphs, Artif Intell 172) for the modelling of probabilistic problems exhibiting significant asymmetry. They encode the conditional independence/Markov structure of these problems completely through their topology, and have been successfully used for both causal analysis (Thwaites, Smith & Riccomagno: Causal analysis with Chain Event Graphs, Artif Intell 174 2010; Cowell & Smith: Causal discovery through MAP selection of stratified Chain Event Graphs, Electron J Stat 8 2014) and decision analysis (Thwaites & Smith: A new method for tackling asymmetric decision problems, WUPES'15, extended version accepted by Int J Approx Reason 2017). We show here how causal CEGs can be used to simplify asymmetric games, in a manner analogous to that described for IDs in Smith 1996. The players know the structure of the game, but not the exact forms of other players' utilities. Each player subjectively assigns probabilities to their unknowns, and estimates values of their opponents' utility functions. These latter depend both on chance and the strategies of the players. Our approach is decision-theoretic; our games are sequential, with the players and chance acting alternately. The resultant game is therefore an Extensive Form Bayesian Game with Chance moves. Our

players are SEUM, conditioned on the information available to them each time they make a decision, and hence they are sequentially rational. Our solution technique computes subgame perfect equilibria, and results in a subgame perfect Nash equilibrium (Banks et al 2015). Such games occur in many areas, and we illustrate our ideas with an example from one such area, that in which large constitutional organisations such as governments are at risk from anticonstitutional organisations such as groups trying to radicalise members of the population. The game played here is asymmetric since the different decisions available to the players lead to very different collections of possible futures. We focus here on adversarial games, and our example is expressed as a two-player game. But the techniques described can also be used both for non-adversarial games and also for multi-player games. A more comprehensive description of our work in this area appears in Thwaites & Smith: A graphical method for simplifying Bayesian Games, invited revision for Reliab Eng Syst Safe special issue on Games & decisions in reliability & risk.

Based on joint work with Jim Q. Smith (University of Warwick)

Adversarial classification: An adversarial risk analysis approach

Alberto Redondo, ICMAT-CSIC
Roi Naveiro, ICMAT-CSIC
Atinuke Adebanji, Dept of Mathematics, KNUST

The threats posed by active adversaries with increasingly sophisticated tools with which to evade detection and compromise machine learning algorithms permeate the world of business. This threat is further compounded by the classifier not knowing what type of attack will be made in a broad spectrum of possibilities and when. This marks a move from the standard classification problem to the adversary aware classification problem, usually designated as adversarial classification. Examples are numerous and include fraud detection, spam detection and network monitoring, among many others.

This problem is usually modelled as a game between two players (the classifier and the adversary), in which stringent assumptions are made about the shared set of data and common knowledge. These assumptions make them actually inappropriate for mimicking real life scenarios.

We, therefore, propose an adversarial risk analysis approach to the problem, in which the classifier maximizes her expected utility using a guessed forecast of the actions undertaken by the attacker. This forecast is built by simulating from the random elements in the decision problem faced by the attacker and consequently identifying the random optimal attacks.

We illustrate the methodology with a spam detection problem in which a Naive Bayes classifier is used as a starting point. We discuss various computational issues.

Designing water quality monitoring networks by using a multi-objective artificial bee colony-based optimization approach

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According to the report of the United Nations Environment Programme in 2016, severe pathogen pollution affects around one-third of all river stretches in Latin America, Africa and Asia. The risk of diseases or even death increases when drinking or coming into contact with polluted water. The number of affected people may range into the hundreds of millions on these continents. Among the most vulnerable groups are women and children. Water quality monitoring and assessment is an essential factor in the management of freshwater resources in river basins. Allocation of the water quality monitoring sites is the first and significant step in the design of a water quality network, but it has been traditionally based on intuition, experience and subjective judgement. In the last years some approaches have tried to objectivize station location based on different criteria. In this work, environmental, economic and social planning objectives have been identified and a Multi-Objective Artificial Bee Colony-based optimization algorithm has been proposed in a Geographic Information System framework. The algorithm searches properly all over the solution space to find non-dominated solutions. Specifically, the number of stations is minimized in a range of values at the same time that the detection of lower compliance areas of water quality standards, the affected population and the relative importance of the river stretches are maximized. Data collection is mainly based on the WorldQual model, which estimates pollutant parameters as Biological Oxygen Demand, Faecal Coliform bacteria or Total Dissolved Solids. This approach has been tested on the Great Fish River basin in South Africa (32,396 km^2 of drainage area), showing that the approach performs well and provides insightful and valuable information to the decision maker. A great advantage of the proposed approach is that it can be used to initially locate monitoring stations based only on WorldQual simulated data in river basins where there is no previous monitoring network. Optimizing the computational time is a challenge to address larger river basins with more than 500,000 km^2 of drainage area.

Optimization model for the improvement of energy storage efficiency

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Undoubtedly, energy storage and related technologies are increasingly playing a prominent role in the global energy debate. In recent years, energy storage came at the forefront of mainstream discussions about how to reach a global sustainable energy future. Hence, the motivation of this work stems from the real need in society for electric and thermal energy storage, both in industry and household applications. Energy storage is a major challenge in the long term, but also in the medium and short term. In fact, battery-operated devices are omnipresent in our lifes, and electric vehicles are not a caprice anymore. On the other hand, renewable energy technologies are becoming available for self-consumption , not only for large-scale use, but also for a small-scale one, through decentralized storage.

A lot of research is being carried out regarding energy storage from the point of view of materials science, physics, and engineering. Thus, an heterogeneous set of technologies, including graphene, phase change materials, or bio materials, just to mention some of the cutting-edge ones, are emerging.

An optimization model has been developed to model energy storage systems that allows for considering not only existing technologies, but also emerging or forecasted technologies. The Combined Energy Storage model allows for energy transfer between energy silos regardless of their physical nature, along with other features like obsolescence and availability uncertainty. The new model could provide insights for policy makers and market stakeholders on which technologies have more potencial in order to prioritize funding and/or investments. Upon lessons learned from previous works [1,2], risk managemet measures for this innovative model will be discussed for including in a forthcoming stochastic version of the model.

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Deep Learning for Short-Term Traffic Flow Prediction

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Real-time spatio-temporal measurements of traffic flow speed are available from in-ground loop detectors or GPS probes. Commercial traffic data providers, such as Bing maps, rely on traffic flow data, and machine learning to predict speeds for each road segment. Real-time (15-40 minute) forecasting gives travelers the ability to choose better routes and authorities the ability to manage the transportation system. Deep learning is a form of machine learning which provides good short-term forecasts of traffic flows by exploiting the dependency in the high dimensional set of explanatory variables, we capture the sharp discontinuities in traffic flow that arise in large-scale networks. We provide a variable selection methodology based on sparse models and dropout.

We develop a deep learning model to predict traffic flows. The main contribution is development of an architecture that combines a linear model that is fitted using l_1 regularization and a sequence of tanh layers. The challenge of predicting traffic are the sharp nonlinearities due to transitions between free flow, breakdown, recovery and congestion. We show that deep learning architectures can capture these nonlinear spatio-temporal effects. The first layer identifies spatio-temporal relations among predictors and other layers model nonlinear relations. We illustrate our methodology on road sensor data from Interstate I-55 and predict traffic flows during two special events; a Chicago Bears football game and an extreme snowstorm event. Both cases have sharp traffic flow regime changes, occurring very suddenly, and we show how deep learning provides precise short term traffic flow predictions.

The Possibilistic Reward Methods for the Multi-Armed Bandit Problem

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The multi-armed bandit problem has been at great depth studied in statistics, becoming fundamental in different areas of economics, statistics or artificial intelligence, such as reinforcement learning and evolutionary programming.

Two families of bandit settings can be distinguished. In the first, the distribution of rewards is assumed to belong to a family of probability distributions whereas in the second, the rewards are only assumed to be bounded (say, between 0 and 1), and policies rely directly on the estimates of the expected rewards for each arm.

Almost all the policies or allocation strategies in the literature focus on the first family and

they can be separated, in two distinct approaches: the frequentist view and the Bayesian approach. In the frequentist view, the expected mean rewards corresponding to all arms are considered as unknown deterministic quantities and the aim of the algorithm is to reach the best parameter-dependent performance. In the Bayesian approach, each arm is characterized by a parameter which is endowed with a prior distribution.

In this work, we propose a set of allocation strategies to deal with the multi-armed bandit problem that accounts for the Bayesian perspective, the possibilistic reward methods. First, we use possibilistic reward distributions to model the uncertainty about the expected rewards for arm, derived from a set of infinite confidence intervals nested around the expected value. Depending on the inequity (Chenoff-Hoeffding, Chernoff or Bernstein) used to compute the confidence intervals we have three PR methods with different features.

Next, we use a pignistic probability transformation borrowed from decision theory and the transferable belief model to convert these possibilistic functions into probability distributions following the insufficient reason principle.

Finally, Thompson sampling techniques are used to identify the arm with the higher expected reward and play that arm. For this, we carry out a simulation experiment by sampling from each arm according to their distributions. Finally, the picked arm is pulled/played and a real reward is output. Then, the possibilistic function corresponding to the picked arm is updated and started again.

A numerical study analyses the performance of the proposed methods with respect to other policies in the literature. For this, five scenarios are considered accounting for a Bernoulli distribution with very low success probabilities, success probabilities close to 0.5 and success probabilities close to 0.5 and Gaussian rewards; a truncated Poisson distribution in [0,10]; and a truncated exponential distribution in [0,10].

Playing a chemical plant protection game with distribution free uncertainties

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A common criticism on game theoretic risk analysis of security threats is that it requires quantitative parameters of both the defender and the attacker, whereby the parameters of the attackers especially are difficult to estimate. In the present paper, a game theoretic model for chemical plant protection, able to deal with the defender's distribution-free uncertainties on the attacker's parameters (Interval CPP Game), is proposed. The Interval CPP Game only requires the interval(s) in which the attacker's parameter(s) is (are) located, instead of the exact number of the parameter(s). Two algorithms are developed, namely the Interval Bi-Matrix Game Solver (IBGS) and the Interval CPP Game Solver (ICGS), for solving general bi-matrix games with interval payoff uncertainties and especially for solving interval CPP games, respectively. Both algorithms are based on mixed integer linear programming (MILP). Theoretic analysis as well as a case study show that including the defender's uncertainties on the attacker's parameters would reduce her equilibrium payoff.

Adversarial Risk Analysis for Bi-agent Influence Diagrams

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In his landmark paper, Shachter (1986) proposed extending the computation of optimal decision policies in influence diagrams to the multi-agent case as an important problem. So far, this suggestion has been faced from a (non-cooperative) game theoretic perspective, stemming from Koller and Milch (2003) who introduced Multi- Agent Influence Diagrams (MAIDs) and provided algorithms for finding Nash equilibria in general problems modelled as MAIDs.

A main drawback of such methodology is its underlying common knowledge assumption, criticised in e.g. Raiffa et al. (2002). Most versions of non-cooperative game theory assume that adversaries not only know their own payoffs, preferences, beliefs and possible actions, but also those of their opponents. These common knowledge assumptions allow for a symmetric joint normative analysis in which players maximise their expected utilities, and presume the other players to do the same. Their decisions can then be anticipated by Nash equilibria and related concepts. However, in many contexts, including counter-terrorism or cybersecurity, players will not generally have such knowledge about their opponents.

Adversarial Risk Analysis (ARA) provides a way forward, as common knowledge is not required. In supporting one of the participants (the defender, she), we view her problem as a decision analytic one, but procedures which employ the game theoretic structure, and other information available, are used to estimate the probabilities of the opponent's (the attacker, he) actions. A main motivation for ARA developments arises from security and counter-terrorism analysis. Cases dealing with protection from intelligent threats include preventing ships from piracy risks (Sevillano et al., 2012) or anti-IED defence in routing problems (Wang and Banks, 2011).

These and other applications have been dealt with relatively simple ARA models, with basic sequences of defence and attack movements. Indeed, we can identify a number of templates which may be viewed as basic building blocks for general security risk analysis problems, see Ríos and Ríos Insua (2012). They differ in the way and order in which attack and defence movements take place within the global sequence of decisions and events, as well as in the information revealed.

Beyond these templates, we consider general adversarial problems between two agents in which we allow for more complex interactions between them, typically sequential and simultaneous movements, spanning across the corresponding planning period. Being our aim to support the defender in her decision making, we need to forecast the attacker's intentions. Assuming that this agent is an expected utility maximiser and taking into account our uncertainty about his probabilities and utilities, we can predict his random optimal decision. We solve general adversarial problems using the MAIDs ability to model complex interactions, taking advantage of the concept of strategic relevance in Koller and Milch (2003), but relaxing the common knowledge assumption through the ARA methodology.

Keywords: Non-cooperative games, Decision analysis, Adversarial risk analysis, Bi- agent influence diagram, Relevance, Critical Infrastructure Protection.

Automating large scale risk and reliability analysis

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We deal here with automating large scale risk and reliability analysis. The problem is motivated by monitoring a large number of internet traffic related me series so as to detect in advance safety and security issues that might lead to important losses to a company. We describe a flexible class of decision support models to support such activities and its implementation.
We shall focus on monitoring continuous me series. For them we use a combination of a DLM, with a trend and a seasonal component, together with an outburst process. We describe how identify and forecast (short and long term) with such model. We then describe how to support relevant reliability and risk decisions based on such models. Finally, we sketch our implementation, including some of the compromises required to facilitate (nearly) real- me safety and security decisions.

A New Approach to Modeling Software Reliability Under Imperfect Debugging

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Software has become a critical part of our day to day life. Timing of release of a software in the market is an important business decision. Delayed release of software results in lost revenue whereas early release can result in marketing a product of inferior quality. Thus reliable statistical estimation of software reliability is essential and integral part of a software development. Imperfect debugging procedure makes the modeling quite complicated. Most of the existing software reliability growth models produce inconsistent estimators. We will review existing methods and their drawbacks. We propose a new class of models for assessing software reliability. The new approach uses a Poisson model for modeling imperfect debugging and a hierarchical model for modeling the debugging process.

Statistical Estimation of Maternal Mortality Risk

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Maternal mortality continues to pose tremendous challenge in Sub-Saharan Africa. The region is one of the most likely place for a woman to die of pregnancy related causes and this is further worsened when there is political conflict. Being the only region that is expected to record a substantial rise in the number of live births over the next two decades (WHO 2015), it is expedient to study the previous incidences of maternal mortality disaggregated to the district level and provide statistical estimates for the risk of occurrence. Ghana with a projected population of *28,489,444 (UN 2017)* and covering a total area of 238,533 km^2 (227,533 km^2 of land and 11,000 km^2 of water (Mundi Index 2014)) is one of the richest and most stable countries in the West Africa region. Nevertheless, it experiences unacceptably high maternal mortality. The maternal mortality ratio in 2015 ranged between 270 and 340 deaths per 100,000 live births (UNICEF 2015). Several reasons are provided for this ranging from poverty, poor maternal education, high prevalence of deliveries by traditional birth attendants/unskilled birth attendants, Obstetric complications, haemorrhage, eclampsia and sepsis to mention a few. Concerted efforts have been geared towards ameliorating maternal healthcare services in Ghana, high coverage of essential interventions does not necessarily imply reduced maternal mortality (Souza 2013). One of the recent intervention being the free maternal healthcare programme introduced in 2012. This study seeks to evaluate the effect of this programme on the risk of maternal mortality between 2012 and 2016. The nationally representative data from the District Health Information Management System (DHIMSII-the reporting platform for health data from Municipal Health Districts to Regional Offices) is used for the statistical analysis and risk estimation. Regional and sectorial disparities in the risk of maternal mortality.

Detection of intra-community VAT fraud through graph theory and machine learning

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The anomaly detection objective has become a very important task in the fields of medicine, security, engineering, risk analysis, etc. The common approach to deal with these situations in the financial field is trying to model the main characteristics of each entity as a multidimensional point. However, as the access to relational data has grown, the number of techniques that allow detecting anomalies in these structures has increased, being possible to determine with certain probability anomalies in a network created with commercial

transactions using the graph theory and machine learning.
This paper focus on creating a decision support system which recognize possible intra-community VAT fraud using the graph theory and machine learning about novelty detection, which are novel in the state of the art. It is also necessary to mention that this strategy can be used to discover big hidden heritages in tax heavens. The fraud according to the European Court of Auditors is billions of euros.
The main point of view over graph theory consists in create a framework to detect and explain the anomalies applying criminology theories. For this purpose, the framework abstracts the details of criminal theories through three main concepts: a) a stochastic process based on discrete time Markov Chains where each node of the graph represents the existence of an anomaly by a set of numerical values regarding local or quasi-local indices, b) the assignment of a ranking based on the Pareto dominance for each entity and c) a textual description which explains the reason why this entity seems fraudulent. This is important because in this field the explanation denotes that an individual is an alleged suspect.
The machine learning approach determines the probability of an entity to form part of an intra-community VAT fraud. For this task, it is used the intrinsic characteristics of an entity provided by the Spanish Tax Agency (AEAT). Since the data is clearly unbalanced because the fraud is an uncommon situation, the techniques used belong to the one-class classification and novelty detection paradigm.
The data used for this project has been provided by the AEAT. The number of commercial relations carried out per year is 157 million of which the number of those that exceed 20.000e is 9 million. The later, from 2010 to 2015, are those that have been used in research. Moreover, the most important characteristics of each 715 thousand companies have been supplied, such as the number of employees, the annual sale volume, the TAX deducted amount, if the company is active in the register of intra-community operators, the reason of the exclusion of this register, etc.

Just tell them how to reduce risk:
Applying protection motivation theory to nudge cyber-secure behaviour

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Human error is often said to be the weakest link in the cybersecurity chain. There are significant challenges, therefore, in ensuring that people are both aware of cybersecurity risks and are able to respond to those risks in a meaningful way. This paper is part of a larger initiative which takes a human centred approach to cybersecurity and explores the contribution of behavioural insights to cybersecurity. The aim is to observe whether changes

in the design of web interfaces (i.e. the choice architecture according to the behavioural economics literature) can seamlessly trigger more secure behaviours.
In this context, this paper presents the results of an online experiment with 2,000 participants in five EU countries (Germany, Sweden, Poland, the UK and Spain) to explore the effect of nudges on security behaviour. Four behavioural measures were collected as participants made purchases in a mock online store.
The nudges tested in the experiment were warning messages inspired by protection motivation theory (PMT). This theory seeks to clarify the cognitive processes which mediate behaviour in the face of a threat. It posits that, when facing a threatening event, people conduct two appraisal processes: one focused on the threat itself and the other on their ability to act against that threat (threat appraisal and coping appraisal, respectively). This will affect their intention to take precautionary action and will result in adaptive or maladaptive behaviours vis-à-vis the threat. In their threat appraisal, people will consider how negative the consequences of the threat are (perceived severity) and the likelihood of the threat materialising in a way that will affect them directly (perceived vulnerability). In their coping appraisal, people will assess whether undertaking a recommended course of action will remove the threat (response efficacy) and also their level of confidence in being able to carry that action out (self-efficacy).
The results of our experiment show that making users aware of the steps they can take to minimise their exposure to risk (i.e. heightening coping appraisal) is effective in generating more secure behaviour. No such evidence was found for highlighting the risks to users of unsecured behaviour (i.e. heightening threat appraisal). This result suggests that the reason users often fail to behave securely is not necessarily because they do not care, or because they are unaware of the risks, but rather because they simply do not know what safe behaviour entails. Giving them specific instructions, and reminding them that it is easy and within their grasp, is therefore an effective way of generating secure behaviour. This clearly has implications for policies that seek to make online transactions safer.

Robust budget optimization under uncertainty in the media industry

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We are faced with the problem of optimizing the allocation of the marketing budget of a firm. The dependence of sales on the investment levels on each possible media channel and other external factors is stochastic, it is not well understood and it is hard to transfer from one product to another. Thus, we must learn this dependence, but the data available is clearly insuf- ficient for such a task, so we must take into account the risk associated with our decisions. We model the dependence using a bayesian approach and perform robust optimization to find the optimal investment strategy for each possible risk preference, without assuming knowledge of the firm's utility function. We present some possible models, their practical implementation, and their application to one real data set.

An Adversarial Risk Analysis Model for Social Emotional Robotics

April Liu
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I shall present an adversarial risk analysis model to support the decision making of an autonomous robot which interacts with other robots and persons and simulates emotions in their interactions. I first describe a(n emotionless) generic ARA model and then incorporate several affective components. I shall finally present potential applications and discuss interactions with other agents.

Implementation of a General Model for Incident Risk Analysis as an Actionable Software Tool

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A thorough application of the risk analysis process is essential for producing a reliable and useful characterisation of risk scenarios. Indeed, simple methods well applied are more acceptable than sophisticated ones poorly applied. This emphasis on the application is even more critical during incident or emergency risk analysis as it will take place in the context of time constraints and lack of information.

Therefore, it is paramount to implement risk analysis models as software tools complemented with procedures for risk elicitation, so analysts will be able to provide a more accurate, consistent, and quick risk analysis.

This paper presents the implementation of a general model for incident risk analysis (GIRA) as a software tool using the R language and software environment. GIRA formalises the incident risk analysis process, including risk evaluation, through an influence diagram. The implementation involves additional models – and their software implementation – that complement GIRA to make it actionable. Specifically, these models are made for eliciting the relevant events of the incident and their likelihood, eliciting the assets and objectives that are valuable to the stakeholders, and quantifying qualitative elicitations.

Fraud detection in electronic payments

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Fraud detection in electronic payments with credit cards is tackled as a supervised learning problem in machine learning. This is a problem with highly imbalanced classes (roughly one fraudulent transaction per 6000 legit) where predictor variables are mostly categorical. The characteristics of this problem: highly imbalanced clases and the existence of categorical variables with many values makes it difficult for standard classification algorithms and calls for *ad hoc* methods to be developed.
Our approach to the problem has been through Bayesian networks and a suitable modification of the random forest algorithm. We will discuss the appropriate metrics for this kind of problems and evaluate the performance of these classification methods.
The optimal level of alarms that the bank should raise is a decision analysis problem that involves not only the expected fraud detection, but also knowledge of the costs associated with raising false positives and the operating costs for investigating alarms.

A random multiattribute utility model with multi-sampling to represent incomparability in pairwise comparisons

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(IBM T. J. Watson Research Center)

When comparing options that are judged on several attributes (e.g., apartments or job positions), some comparisons are more difficult than others. For instance, it is more difficult to choose between two apartments if one is well located but very expensive and the other is affordable but poorly located. When posed with such comparisons that involve a significant attribute conict, it is more likely that decision-makers will expressincomplete preferences if it is allowed, or declare the options indifferent if not. Because of the latter effect, it would be useful to distinguish between “true" indifference and indifference induced by attribute conflict when measuring preferences.
We propose a random utility model to represent the effect of attribute conflict. In this model, attribute weights and marginal utility function parameters are drawn from probability distributions whose parameters represent the DM's preferences. Our model also introduces a threshold to explicitly represent an indifference band. The main novelty in our model, compared to previous probabilistic utility models, is to represent the inconsistency of the decision-maker through multi-sampling: the preferences about a pair of options is derived from several random draws of the probabilistic utility function, which allows to represent inconsistent judgments. When the draws are consistent, i.e., the difference in utility between the two options does not vary too much across draws, it results in strict preference or indifference between the options. When the draws are inconsistent, which typically happens

when there is a high multi-attribute conflict in the comparison, the options are deemed incomparable.
We train and test the model on empirical data of comparisons between apartments differing in terms of location and rent, where expressing incomparability was only allowed for half of the participants. We observe how well the random utility model can predict the expression of incomparability. We compare the proposed model to an additive random model, where the variability in utility across random draws is independent from the options' characteristics.

Approximate Bayesian Computation for Dynamic Queueing Networks

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Important real-world systems such as airport terminals, manufacturing processes and hospitals are modelled with networks of queues. To estimate parameters, restrictive assumptions are placed on these models. For instance, arrival and service distributions are assumed to be time-invariant. Violating this assumption are so-called dynamic queueing networks which are more realistic but do not allow for likelihood-based parameter estimation. A new type of queueing simulation technique, previously described by Ebert et al. (2017), has computational speed-ups of more than two orders of magnitude. We use this queueing simulation scheme with an approximate Bayesian computation (ABC) algorithm to infer parameter distributions in a data-driven manner.

We can then trial different scenarios and compute expected performance measures to provide decision support in the face of uncertainty. For instance, immigration officers at an international airport could plan staffing levels to minimize average waiting times for customers, taking into account likely flight delays.

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