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A DYNAMIC BAYESIAN MODEL OF COVID-19 PROGRESSION

Plenary
Wednesday 17th November 2021, 8:40 - 9:20am

ABSTRACT

SARS-CoV-2, giving rise to the disease named COVID-19, emerged in late 2019 and rapidly developed into a global pandemic. COVID-19 has a fatality rate estimated at approximately ten times that of seasonal influenza and with open questions around possible long-term consequences. Vaccines have helped immensely, but COVID-19 has had and continues to have a profound impact globally, with close to 5 million reported deaths to date, along with broad impacts on health services, non-COVID patients, the economy and society more generally.

Early on in the pandemic, our group turned its focus to using our existing infectious disease modelling approaches to create models of COVID-19 that could support clinical decision making, understanding and research. Through expert workshops and 1-on-1 interviews, we developed several expert Bayesian network (BN) structures for different facets of the disease. Using these expert BN structures as a knowledge base, we developed an applied dynamic BN (called the "progression" model) for assessing progression in hospital and ICU settings. The progression model provides an overview of the functioning of key body systems, particularly the respiratory, cardiac, vascular and immune systems, and how COVID-19 and various risk factors can affect their normal functioning.

Access to data to support our modelling initially proved surprisingly slow and difficult given the urgent global context. However, the progression model has now been parameterised with data from the LEOSS (Lean European Open Survey on SARS-CoV-2) initiative as well as COVID-19 data from the ISARIC (International Severe Acute Respiratory and Emerging Infection Consortium) initiative facilitated via the IDDO (Infectious Diseases Data Observatory) group. We have benchmarked the performance of the IDDO parameterised progression model against purely predictive (non-explanatory) Naive Bayes (NB) models. The two approaches have comparable performance for simple cases, ensuring confidence that the progression model can provide good predictive performance while additionally supplying the explainability that is so critical in clinical settings. A decision support interface has been provided for the progression model in the form of an interactive calculator. Both the model and its interface are nearing evaluation in an applied setting. We hope this will soon lead to a system capable of supporting decision making around the prognosis of COVID-19 and potentially similar diseases in a transparent, justifiable and intuitive manner.

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PREDICTING BUSHFIRE RISKS TO PEOPLE AND PROPERTY IN VICTORIA USING BAYESIAN NETWORK ANALYSIS

Environmental Session I
Wednesday 17th November 2021, 9:35 - 9:55am

ABSTRACT

Accounting for multiple changing systems in environmental decision making is challenging and requires balancing several competing priorities. In fire risk, one approach which is increasingly used to capture uncertainty within multiple systems and to prioritise management efforts is Bayesian Network analysis. Here, we have used Bayesian Network analysis to understand the interactions between ignition likelihood, containment probability, fire behaviour, fire weather and subsequent risk to people and property. We developed, populated and tested a Bayesian Network (BN) which classifies conditional probability values for variables influencing each of these systems. We then apply this BN to a case study region in Victoria to predict house and life loss values for 3066 locations under conditions capturing the top ten worst ranked weather days. We use Phoenix fire behaviour simulations and landscape scale raster data to populate the parent nodes for each ignition and extract the expected values for predicted nodes under different weather scenarios and varying levels of suppression. We found values predicted by the BN broadly matched the spatial patterns of risk produced in Phoenix i.e., areas where risk was highest and lowest in terms of fire area and house loss aligned. However, the values themselves for each node vary between approaches since the BN considers the influence of ignition likelihood and containment probability on risk estimates. The BN is also able to capture uncertainty around the values presented from across the top ten Phoenix simulations, so the recorded values represent the likely outcome for each node given the range of potential weather conditions in those top ten scenarios. We show that BNs can be a useful management tool for estimating fire risks across a range of weather scenarios and locations while still considering ignition likelihood and suppression effectiveness.

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CARBON FLUXES IN FORESTS

Environmental Session I
Wednesday 17th November 2021, 9:55 – 10:15am

ABSTRACT

Carbon is key ecosystem service in many forests that is subject to change by climate and management practices, such as harvesting and fire. We developed a carbon model that responds to fire regime features that can be applied over landscapes. Combining the model with a fire regime tool, we assessed 100-year fluxes in carbon in response to climate and forest management.

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BAYESIAN NETWORKS FOR MODELLING INUNDATION: PILOT STUDY FROM NEW ZEALAND

Environmental Session I
Wednesday 17th November 2021, 10:15 – 10:35am

ABSTRACT

Climate change-induced sea level rise and changes in weather patterns are going to increase the probability of coastal inundation in the future. Colleagues from GNS Science and Waikato Regional Council undertook a pilot project to trial Bayesian Networks (BNs) as alternative to the use of multiple, computationally-intensive process-based models to assess the likelihood of inundation and/or flooding. The pilot study focuses on the Kauaeranga Spillway, which is located on State Highway 25, just south of the town Thames at the southwestern end of the Coromandel Peninsula in New Zealand's North Island. When large rainfall events cause the Kauaeranga River to flood, it can have a major effect on Thames and the adjacent areas. The Kauaeranga Spillway mitigates the risk but, when in use, closes the access the Thames and interrupts essential service, including access to the regional hospital. The Kauaeranga Spillway was in use 13 times in the past 30 years, and modifications have been made to it over this time.

Every time the New Zealand weather service issues an intense rain warning, the Waikato Regional Council is on alert, and staff needs are on stand-by in case the road requires closure. For the pilot study, we focused on the likelihood of the Kauaeranga Spillway operating within the six hours following a weather warning.

We present a prototype model describing the likelihood of the operation of the Kauaeranga Spillway, given the intensity and amount of rain received over the last 120 hours and ensuing river height and flow rate. The information derived from the model is intended to assist stakeholders in planning infrastructure development and maintenance, earlier warning systems and better communication of imminent road closures.

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APPLICATION OF BAYESIAN NETWORK MODELS TO WICKED CLIMATE-HEALTH PROBLEMS

Environmental Session I
Wednesday 17th November 2021, 10:35 – 10:55am

ABSTRACT

Projected warming and other changes in the climate system will impact on communities and health systems through multiple interrelated causal pathways increasing the burden of many climate-sensitive health risks. Exposure to climate hazards will affect communities and health systems in varying degrees resulting in differential health outcomes depending on exposure, vulnerability and health system resilience. Protecting vulnerable communities requires first an understanding of the complexity of the multiple influencing biophysical, socio-economic and socio-cultural factors that put communities at risk, otherwise known as “wicked problems”. We explore the utility of Bayesian Network (BN) models in unpacking impacting factors and intervention options for wicked climate change and health problems, using a case study of climate change and malaria transmission risk to demonstrate how BNs can be used to provide a robust understanding the complex interrelationships underlying wicked climate change and health problems. We demonstrate how BNs can be used to model hierarchical relationships in epidemiological studies and health impacts where there are many inter-related pathways of causality and the suitability for BN’s to improve decision-making process in public health systems particularly in situations where cause-effect relationships are critical in informing decision outcomes. BNs have several advantages over other models as they: i) express probabilistic distributions and thus can handle uncertainty; ii) incorporate a variety of data from different sources; iii) incorporate qualitative expert judgements to fill data gaps; iv) are dynamic and can integrate new or updated data; v) allow visualisation of important variables and drivers in the system and their associated cause-effect relationships, vi) are built through participatory processes, therefore stakeholders opinions and priorities can be integrated from the onset and vii) are suited to decision-making; involving policy-makers in modelling potential impacts of interventions may lead

PROBABILISTIC ASSESSMENT OF COASTAL INUNDATION IN THE PACIFIC

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Environmental Session II
Wednesday 17th November 2021, 11:15- 11:35am

ABSTRACT

Inundation events caused by the compounding of sea-level rise with extreme wave events pose a significant threat to low-lying atoll communities in the Pacific. However, estimating the probability of these inundation events remains difficult due to data sparsity, poorly constrained wave climate projections, and limited modelling/computing capability in the Pacific. Furthermore, there is significant spread in sea-level rise projections. Here, we develop a spatially explicit dynamic Bayesian network (BN) model framework focusing on modelling the wave run-up component of water level at atoll islet shorelines. We use Tarawa, Kiribati, as a case study location with data from 1993 to 2019. We develop the model using reef profile metrics, historical mean sea-level and tidal data, and wind-wave hindcasts. We develop two network structures, one for the lagoon side and another for the ocean side of the islets, to capture the different processes that occur on each side. Each node in the network is discretised using k-means clustering, and expectation-maximisation is used to define the conditional probabilities tables. We compare the model posterior distributions to hindcasts and find that the BN model is skillful at estimating the wave run-up component of water level along the coastline of Tarawa. Tests on data from cyclone events suggest that the dynamic network can detect increases in water level caused by increased wave energy during these significant weather events. These results suggest that this tool has potential application as a framework for assessing the wave run-up component of water level at other atoll islands.

UNDERSTANDING POLICY INSTRUMENT INTERACTIONS FOR ADOPTION OF ECO-FRIENDLY FARMING PRACTICES ON THE GREAT BARRIER REEF

Environmental Session II
Wednesday 17th November 2021, 11:35 – 11:55am

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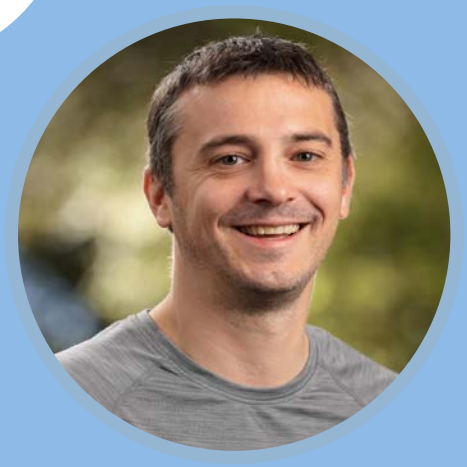
ABSTRACT

Water quality on Australia's Great Barrier Reef has declined in the past century, with agricultural runoff from adjacent catchments in Queensland playing a large role. governments have therefore encouraged the adoption of environmentally friendly agricultural practices to reduce these impacts. Current policy instruments include regulation of farming practices, offering financial incentives through grants or credit schemes, and providing information and assistance to farmers via either community-based social marketing or specialised agricultural knowledge support programs (extension programs). Although there is some understanding of the effectiveness of individual instruments, there is no over-arching framework of how the instruments interact with each other, and how they are affected by the characteristics of the population, the farming practice, and the instrument itself. The social influences that come into play when farmers make complex management decisions are also rarely considered. We applied a participatory modelling approach combining expert knowledge from legal, economic and social sciences. These perspectives were integrated to create a cross-disciplinary Bayesian network that explores the effect of different policy combinations on the adoption of sustainable farming practices in the Great Barrier Reef catchment. A range of stakeholders including practitioners, academics and staff from the Office of the Great Barrier Reef (OGBR) were engaged at several key stages of the design process, including the conceptual modelling stage, and during model validation through scenario analysis. The development of a model to address complex behavioral responses to policy mixes applied in diverse contexts (industries, farming populations and practices) using an interdisciplinary approach and strong stakeholder engagement has proven to be a pivotal first step in improving our understanding how policy instruments can help facilitate practice adoption.



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A BAYESIAN NETWORK BASED-TOOL TO ASSESS UNWANTED IMPACT OF BIOLOGICAL CONTROL AGENTS

Environmental Session II
Wednesday 17th November 2021, 11:55am – 12:15pm

ABSTRACT

BAIPA, for "Biocontrol Adverse Impact Probability Assessment", is a new probabilistic tool based on a Bayesian network model that assesses the potential unwanted impact of organisms released in biological control programmes on non-target species. An example of application of the tool will be presented, integrating information on the potential of an insect parasitoid used in biological control to: (1) disperse in new habitats (given its current presence in habitats occupied by the target species, a weevil, and its ability to spread); (2) interact with non-target species (given the spatial and temporal match of the parasitoid and native, potentially endangered, weevils); and eventually (3) negatively impact the populations of the non-target species (given the rates and outcome of direct attacks by the parasitoid on these native weevils). BAIPA provides an improvement to current qualitative or semi-quantitative methods based on single point numerical estimates to quantify individual risk components. It aims be incorporated into a structured decision-making framework to support national regulatory authorities, such as the Environmental Protection Authority in New Zealand, in their decision-making to release BCAs.

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INTEGRATION OF BAYESIAN NETWORK AND MULTI-OBJECTIVE OPTIMISATION FOR FORCE STRUCTURE DESIGN

Defence & Industry Session
Thursday 18th November 2021, 9:40 – 10:00am

ABSTRACT

Within operational Defence force structure models, interactions among the components (Defence element, force package, operational effect and mission) are defined by logical or physical links which complicate the evaluation of the dependability of these force structure models. In addition, the different operational scenarios and threats provide a challenge to decision makers (DMs) in determining the value of proposed force structures. This study integrates Bayesian network (BN) and multi-objective evolutionary algorithms (MOEA) to present an interactive analysis tool for evaluating and optimising the operational impact of different force structures using DMs' preferences. BN is employed to establish a qualitative and quantitative representation of the relations among the variables of the force structure model, which is named as the Bayesian reasoning value model (BRVM), while MOEA manages the combinatorial nature of the number of contributing capabilities/forces available and to help the DMs to avoid any arbitrary selection of sub-optimum force structures. The proposed methodology provides modelling and data collection structures that assist in making explicit the force structures, scenario parameters, and DMs' preferences, as well as providing a tool for automating/documenting some of the time-consuming evaluation processes.

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VALIDATING A LARGE-SCALE DECISION SUPPORT BAYESIAN NETWORK

Defence & Industry Session
Thursday 18th November 2021, 10:00 - 10:20am

ABSTRACT

Force Structure Plan 2021 was a major event which sought to determine the utility of alternate options regarding the capability portfolio of the Australian Department of Defence. To provide evidence-based decision-support, Defence Science and Technology Group developed a Bayesian reasoning value model to estimate the efficacy of capability portfolio options, relying on opinions from subject matter experts. Validation is a central aspect of the development of models whose main purpose is the provision of decision-support. Successful validation ensures that model structure and outputs reflect the phenomena they emulate, and enable decision makers to trust model outputs and influence their decision-making. This talk introduces the validation framework that was applied to the Bayesian model, focusing on how performing validation at all stages of model construction ultimately gave decision-makers confidence to trust outputs to inform decisions surrounding future investment.

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A COMBINED BAYESIAN NETWORK AND MULTI-CRITERIA DECISION ANALYSIS APPROACH FOR ANALYSING DEFENCE DECISION MAKING PROBLEMS WITH UNCERTAIN CRITERIA AND PREFERENCE WEIGHTS

Defence & Industry Session
Thursday 18th November 2021, 10:30 – 10:50am

ABSTRACT

In this presentation we propose a new combined approach between Bayesian Network, Utility Theory, Analytical Hierarchical Process and Stochastic Multi-criteria Decision Analysis for analysing Defence decision making problems with uncertain criteria and decision makers preference weights.

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DEVELOPING A SUPPRESSION EFFECTIVENESS MODEL TO CALCULATE THE LIKELIHOOD OF BUSHFIRE CONTAINMENT

Defence & Industry Session
Thursday 18th November 2021, 10:50 – 11:10am

ABSTRACT

Victoria's Emergency Management agencies have legislative responsibilities related to Bushfire Management on public and private land. One of the ways in which these responsibilities are discharged are through pre-positioning and dispatch of fire-fighting resources such as aircraft, bulldozers and water carrying vehicles, such as tankers. Currently the type and number of resources dispatched is largely informed by the knowledge and experiences of the dispatching officer. Advancement in technology, data collection and modelling provide us with an opportunity to support decision makers to test, evaluate and optimise their decisions. This project aims to develop a "first attack" suppression model that will assist decision makers to estimate the probability of a bushfire being contained based on different combinations of resources being dispatched to the fire. The model needs to accommodate data gaps around suppression effectiveness and uncertainties related to the initially reported ignition location, landscape dryness and weather conditions. This uncertainty extends to likely suppression effectiveness of different resource combinations.

A Bayesian Network modelling approach was adopted for this project because it allows us to i) capture and communicate uncertainties to the decision-maker; ii) combine data from previous bushfires with elicited expert judgements when faced with knowledge gaps; and readily update the model when new sources of data become available. We conducted a series of online workshops with experts (practitioners and managers) to build and parameterise the model. We first elicited individual conceptual model structures from a group of operational bushfire managers using the BARD software, developed by Monash University. Next, we elicited judgements for a range of variables using the iterative IDEA protocol ('Investigate', 'Discuss', 'Estimate', 'Aggregate'). We are currently further populating the model with aircraft data collected during past bushfire seasons. The Phoenix RapidFire – a bushfire simulator – will be utilised to capture uncertainties associated with bushfire growth. Outputs from the Phoenix RapidFire will be combined with likely construction rates of different fire fighting resources to calculate the probability of successfully suppressing a bushfire under different conditions.

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QUANTIFYING WILDFIRE RISK ASSOCIATED WITH ELECTRICITY NETWORKS USING BAYESIAN DECISION NETWORKS

Defence & Industry Session
Thursday 18th November 2021, 11:10-11:30am

ABSTRACT

Power distribution networks face several competing challenges, including the regulatory requirement to deliver a reliable, modernised system that can operate under a changing climate. It is therefore important that energy providers consider the impacts of natural events such as bushfires in their risk management planning, and importantly, how networks will adapt in the future to increase the resilience of electricity networks in the context of major and cascading events. Risk-based decision-making aims to quantify the likelihood of an impact occurring, and the consequences of this impact to an ecological system, process, or value.
The aim of the project was to use risk-based approach improve the scientific underpinning for characterising risk from bushfire to the power distribution network. We assessed risk across the extent of the network in two ways, the risk posed by ignitions caused by the electricity network and the risk posed to the network from landscape fires. The approach followed a series of steps; of landscape setting, wildfire simulations, assets (human and environmental) and risk characterisation. In the final step, risk characterisation is undertaken using Bayesian decision networks. Results from this project will support TasNetworks business operations, justifying ongoing commitment and investment to bushfire risk mitigation activities. The ability to predict where the highest risks are from (and to) the network and surrounding assets is important for determining where management actions can be implemented to reduce those vulnerabilities. Overall, areas of the greatest impact were found to be in the region surrounding Hobart in the southeast, and along the northern coast of Tasmania. These regions correlate with areas of urban settlements and higher housing density (and hence powerline density). These areas occur where a complex urban interface exists in a topographically diverse landscape covered with fire prone vegetation.

INITIAL EXPLORATIONS OF MACHINE SELF-LEARNING WITH GENERATIVE ADVERSARIAL BAYESIAN NETWORKS

New developments in Bayesian Network Modelling
Thursday 18th November 2021, 11:55 – 12:15pm

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BN modeling:
https://www.plexuseco.com/The%20Plexus/bbns.htm

Publications:
https://www.plexuseco.com/The%20Plexus/bgmpubs.htm

U.S. Forest Service scientist page:
https://www.fs.fed.us/research/people/profile.php?alias=bmarcot

ABSTRACT

A popular A.I. machine-learning algorithm, known as generative adversarial networks (GANs), is used with neural network programming to improve the accuracy of classification predictions. The GAN ("generator" network) creates hypothetical cases that the predictor ("discriminator" network) incorporates by using machine-learning algorithms to improve its prediction accuracy. Bayesian network (BN) modelling lends well to this framework of the self-learning and self-updating procedures of GANs, but in the Bayesian context. BNs can be used as a generator to create case files of situations for which the network predicts poorly, and can then use machine-learning algorithms such as gradient and expectation maximization to adjust its conditional probability values to improve its predictability. This talk presents an initial framework, with an example, for using the GAN approach in the context of Bayesian network (BN) modelling, here calling it generative adversarial Bayesian networks (GABNs.).

DESIGNING AN EVIDENCE-BASED BAYESIAN NETWORK FOR ESTIMATING THE RISK VERSUS BENEFITS OF THE ASTRAZENECA COVID-19 VACCINE

New developments in Bayesian Network Modelling
Thursday 18th November 2021, 12:15 – 12:35pm

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ABSTRACT

Confusion surrounding safety of the COVID-19 AstraZeneca (AZ) vaccine in relation to fatalities from rare, atypical blood clots (thrombosis and thrombocytopenia syndrome [TTS]) has contributed to increased vaccine hesitancy in Australia. A lack of transparent, unbiased, and well-researched media communication, and an increasing number of scientific studies and data sources presenting findings on only a single piece of the overall puzzle, compounds the issue. A risk-benefit analysis framework is therefore urgently needed to reduce uncertainty for those attempting to make an informed decision regarding the AZ vaccine, by combining and effectively communicating the risks and benefits. This framework must be transparent in its assumptions and cited evidence, be able to incorporate data from a wide range of sources, and be easily updatable to accommodate new evidence and changes in the pandemic landscape, such as new virus variants or vaccines, or changes in the rates of community transmission. Bayesian networks can provide the ideal framework for synthesising the evidence from local and international data, government reports, published literature and expert opinion, into a probabilistic model that is both interactive and transparent. Here, we describe the methods used to design and implement a Bayesian network model collating the best available evidence to compare the risks versus benefits of the AZ vaccine in an Australian context. Expert judgement was used to interpret the available evidence to determine the model structure, relevant variables, data for inclusion and how these data inform the model. The model can be used to generate scenarios comparing the risk of dying from TTS following the AZ vaccine with the risk of dying from COVID-19 or COVID-19-associated blood clots. We also show how the same modelling process can be used to create an equivalent risk-benefit network model for the Pfizer vaccine and the risk of myocarditis.