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Old tools, new landscapes: Application of multi-objective evolutionary algorithms to achieve bushfire risk reduction objectives

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Abstract: The risks of bushfires are increasing across Australia due to a changing climate and an expanding urban fringe. Recent experience emphasises that these bushfires can have destructive consequences across a range of values (e.g., built and environmental "assets"). Communities must decide how they can best care for and manage landscapes (e.g., use prescribed burning or other "fuel treatments") in a way that reduces the spread and potential impact of bushfires. However, decision-makers are often challenged by the limited size of management budgets and personnel, which are relatively small in contrast to the size of the landscapes that they care for.

Multi-objective evolutionary algorithms (MOEAs) are flexible optimisation tools that have been widely applied to support decisions across a range of environmental modelling and simulation domains (Maier et al. 2014). MOEAs are highly effective at exploring the abovementioned style of problem, where decision-makers face many potential options (e.g., where to prescribed burn?), a series of constraints (e.g., limited budgets) and one or more different objectives (e.g., risk reduction for a range of assets located throughout a landscape).

Up until recently, however, MOEAs had not been applied to support bushfire risk management decision-making, as the landscape fire simulation models that are typically used to estimate risk-based objectives are computationally expensive, often taking several hours to generate a set of outputs corresponding to a single decision (e.g., proposed set of areas for prescribed burning). Given that MOEAs can require many tens of thousands of decisions to be evaluated, they were considered computationally intractable for informing practical decisions related to bushfire risk management (Miller and Ager 2013).

Recent applications of metamodeling have enabled the risk-based outputs of landscape fire simulation models (e.g., burn probability) to be estimated in a much more computationally efficient manner than before (Radford et al. 2024a; Radford et al. 2024b). These developments in metamodeling have allowed for the first applications of MOEAs to explore bushfire risk management (Radford 2025). Although MOEAs have been broadly applied to other problems relating to environmental modelling and simulation, new guidance must be developed to ensure they are efficiently and effectively applied in this new domain.

We present the detailed formulation of a MOEA application to the problem of bushfire risk management in the Adelaide Hills of South Australia. In particular, the study explores how different potential fuel treatment areas (e.g., prescribed burns) could be combined to form a fuel treatment plan. Potential fuel treatment plans are evaluated in terms of (1) their ability to reduce the likelihood of a bushfire to impact on specific assets, and (2) the area of fuels that would be needed to be treated to achieve that reduction in likelihood. During the MOEA application, genetic algorithm evolutionary operators were used to form new fuel treatment plans through the processes of cross-over and mutation.

Our findings demonstrate that fuel treatment plans developed using MOEAs can out-perform fuel treatment plans developed using existing rules-of-thumb by between 80 and 280%. The MOEA demonstrates that it can adapt to different objectives for bushfire risk management and/or constraints that face the decision-maker. Future work will require additional objectives, such as ecosystem health and natural resources, to be incorporated into the MOEA formulation.

This presentation summarises emerging opportunities, challenges and lessons related to the application of optimisation and metamodeling tools for supporting decisions in bushfire risk management. We invite MODSIM's diverse attendance to share their experiences with MOEAs, landscape fire and metamodeling to help support future applications of MOEAs to bushfire risk management.

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