Environment

Answers to fire management in the machine

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The Horse River Fire was the costliest disaster in Canadian history (Credit: Cplc VanPutten) : MCpl VanPutten

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Big data and clever algorithms can offer new solutions for the management of wildfires.

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On May 1st 2016, with the spring weather unusually warm and dry, two wildfires ignited near the township of Fort McMurray, in Alberta, Canada. One fire started inside the town's boundary; the other started seven kilometres outside town. Air tankers were immediately deployed on the fire that threatened the town, and while it was successfully extinguished, the other fire evaded suppression attempts, jumping the Athabasca River two days later. This fire, named the Horse River fire, ultimately became one of the costliest disasters in Canadian history, leading to the evacuation of the entire population of 80,000 Fort McMurray residents, destroying 2,400 structures, and burning through almost 600,000 hectares by the time it was declared under control some two months later on July 4th.

The Horse River fire illustrated perhaps the two greatest challenges of wildfire management: decision making when information is imperfect and the prioritisation of limited resources. Despite numerous decision-support tools now available to fire managers, tools are still needed that can model the complex – sometimes unintuitive – relationship between fire and the environment in which fires occur; and that can also provide predictions from incomplete and noisy data.

The problem-solving power of artificial intelligence offers promise in this area. AI – and its subset of machine learning algorithms – has considerable potential to improve or complement existing decision-support systems.

A recent review of where machine learning could assist in wildfire science and management found three hundred studies spanning a diverse range of problems. The majority focused on estimating fire risk, detecting fires, mapping forests and other flammable vegetation and mapping burned areas, tasks now made easier by an abundance of high-resolution satellite data and sophisticated weather models.

Other applications included forecasting fire weather, fire risk under climate change, predicting fire ignitions, determining fire risk, predicting fire behaviour, predicting fire effects (for example, forecasting smoke movement), and other questions related to decision making for fire management (for example, allocating resources).

Despite the breadth of wildfire science problems machine learning has been applied to, it has largely been used to answer questions such as "what has happened?" or "what is happening now?".

What needs more work are predictive tools to answer the question: "What is going to happen?". Specifically, when and where are fires going to ignite? Which fires are likely to threaten communities or industry? Which of these fires should be acted on first?

Fire managers need to anticipate actions that might be required days or even weeks later. If additional firefighting resources are needed for large fires, it can take days to bring in more air tankers and helicopters or weeks to arrange for firefighters from other jurisdictions to arrive. The reality of limited firefighting resources combined with extreme fire seasons creates not only a prediction problem, but a prioritisation problem – both occurring in the context of incomplete information.

Predictive tools based on machine learning have potential to greatly aid fire management. Looking at how machine learning has been applied in other areas of the environmental sciences can reveal new opportunities for fire management. For example, already used to expand the coverage of weather stations, machine learning could be used to improve local monitoring of fire danger. It has the potential to improve current weather forecasting systems and extend fire risk forecasting for up to two weeks or even longer, aiding long term planning. Usually, models are developed using computer science in tandem with observations and physics. Machine learning algorithms might be able to replace the parts of the model that represent various physical processes (such as cloud formation or rainfall), improving the accuracy of not only weather forecasts, but predictions of future fire risk under various climate change scenarios. Similar hybrid approaches may also be helpful for predicting the spread of fires, currently based on complex physics-based simulations that are time consuming to run, even on the fastest computers.

Two of the more recently developed machine learning methods show great promise. The first of these, deep learning, uses so-called neural networks to simulate the complex processing of the human brain. Deep learning has been used for a range of visual processing tasks, from automatically tagging cats in social media apps to detecting cancerous growths. It may be useful for predicting fire growth or forecasting fire risk. The second method, reinforcement learning, involves the use of programmed “agents” that learn to maximise some reward. Reinforcement learning can be seen in self-driving cars and financial trading, but may also be useful in developing decision support tools around resource allocation during challenging wildfire seasons.

As immense as the promise of machine learning in fire management is, challenges remain. A data-driven science is only as good as the data it uses. And machine learning needs a lot of data — the collection of which is often compromised by the immediate need to respond to wildfires. For the promise of machine learning to be realised, data collection would need to be fully integrated into the fire management process.

Developing decision support systems for fire management also requires machine learning expertise not generally available within fire management agencies. The development of interpretable models and actionable tools requires closer interaction between the fire management and machine learning communities.

Helpfully, machine learning tools from Google, Microsoft, IBM and others are becoming easier for non-experts to use. However, ease of use is not enough. A cultural shift would be required in fire management for these tools to be adopted. Machine learning is the science of probability – it can't remove uncertainty from decision making, but it can help quantify the uncertainty.

In the coming years, rapid advancements are likely to occur at the intersection of machine learning and wildfire management. Linking these two branches of science could provide new solutions to protect communities and infrastructure.

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