Adaptive control techniques can help manage pests more effectively

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As population growth, greater food consumption, competition for land use, and climate change pose challenges to world food production, managing loss of crop due to pests and weeds becomes increasingly important. While chemical pesticides offer effective means for control, potential loss of crop yield is still significant, as is cost. Global potential loss from pests has been estimated to be between 50% and 80% of yield based on crop type.

In a paper published last week in the *SIAM Journal on Applied Mathematics*, authors Chris Guiver et al propose adaptive control techniques to model pest dynamics and management as a control system.

Mathematics has been used to model pest control in other studies. Most of the prevailing approaches rely on deterministic or stochastic optimal control tools, where a management or intervention strategy is used to accomplish a desired behavior and minimize cost. There are pitfalls to these approaches, most notable of which is the capability to handle the uncertainty in pest dynamics due to the interaction of novel species and environments.

"Modeling for the purposes of pest management is inherently uncertain," says Stuart Townley, co-author and principle investigator on the project. "Vital rates of pests, such as birth and growth rate, and fertility, are highly sensitive to uncertain and stochastic environmental conditions, while data are often limited; so detailed models to guide decision making are unlikely to be available. Relying on tools from optimal control which require this level of detail could result in poor or fragile performance."

Adaptive control, on the other hand, works around the uncertainty because it does not need prior information about uncertain parameters.

"Our study's primary insight is that, given the uncertainty surrounding models for pests, design of pest management strategies faces two approaches: either develop better models so that optimal controls can be more effective, or adopt design approaches that tolerate the likely level of uncertainty to be faced," says author Brigitte Tenhumberg.

The authors adopt the latter approach by using adaptive control techniques. The input, state, and output in the control system are represented by pest control, the pest population, and some measure of the population respectively. The goal of the control system then, is to eradicate or lower the pest population by determining an input which stabilizes the model, driving state variables to zero.

The advantage of adaptive control is that it achieves state stability with minimal knowledge of the system to be controlled, and is simple to compute. The system does not seek to update the dynamic model over time by inferring or estimating parameters. The management strategy, in turn, changes over time in response to how the measured variable changes.

The downside of adaptive controllers is that the additional robustness needed to model uncertainty concedes a loss in optimality.

As author Markus Mueller explains, "The trade-off between robustness and optimality is pivotal in all areas where management or control decisions are made. Management actions can steer closer to optimal decisions when reliable models are available. However, when models are poor, as is the case with pests, actions need to be more cautious and robust. It is at this end of decision making where adaptive control is especially appealing and offers significant advantages compared to other optimal or robust control approaches."

The uncertainty in models necessitates approaches that must be both robust and capable of quantifying the level of uncertainty they can handle.

"In applications, the compromise between robustness and optimality also has economic considerations," adds Guiver. "Optimality may reduce implementation costs, but is susceptible to costly failure; while robustness would have higher implementation costs, it compensates for these potential failures and consequent losses."

Future work from the group includes adaptive deployment of biocontrol agents in order to reduce chemical pesticide usage. This would involve modeling the dynamics of the biocontrol agents in addition to that of pests. Modeling of the spatial distribution of pests will also be incorporated.

"So far, our work has focused on the temporal aspects of pests with abundance changing in time. Clearly, pest abundance has a spatial dimension and this needs to be addressed as well when designing pest management strategies," says author Richard Rebarber. "Here, pest management would seek to reduce, or contain, both the spread of a pest and its abundance. Since using pesticides can have unwelcome consequences, we are also exploring the use of adaptive feedback control in the design of pest management strategies based around bio-control (also known as natural enemies, or pest-predators)."

"Pest management is one of the key factors in addressing the challenge of food security for a burgeoning world population with an increasing per-capita demand," says author Brigitte Tenhumberg. "Addressing food security undoubtedly requires a holistic approach, drawing upon input from policy makers and stakeholders, as well as theoretical insights from academia. Our contribution is to seek approaches to reducing crop losses to pests by applying less pesticide more effectively."

More information: Chris Guiver et al. Simple Adaptive Control for Positive Linear Systems with Applications to Pest Management, *SIAM Journal on Applied Mathematics* (2016). DOI: 10.1137/140996926

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