Policy Brief #2: Modeling the Impact of Intervention Policies for Disease Prediction

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Introduction

Infectious disease modeling is crucial for effectively managing response efforts during epidemics. However, traditional compartmental epidemic models (e.g., SEIR models) face limitations in capturing the complex dynamics that underlie intervention deployment in real-world populations. In response to these limitations, more computationally advanced methods like agent-based modeling, microscopic epidemic models, and multi-agent artificial intelligence methods have emerged as powerful tools for modeling infectious disease interventions at both the individual and population level.

This workshop was convened to discuss best practices for modeling the impact of intervention policies that are often enacted in response to infectious disease outbreaks. In particular, participants aimed to identify state-of-the-art methods for optimizing the allocation of these interventions. Various policy measures and practical applications were proposed to improve intervention strategies, increase public awareness, and enable the robust evaluation of common tools such as contact tracing.

Using AI and Multiagent Systems for Resource Allocation During Epidemics

In public health settings, AI and multiagent systems, like the Restless Multi-Armed Bandits (RMABs) model, have great potential for optimizing the sequential allocation of limited resources or interventions. For example, in India, the RMAB model has demonstrated significant improvements in health message uptake in maternal and child care programs by sequentially identifying beneficiaries who would gain the most benefit from few available interventions [1].

During the workshop, participants discussed the potential of multiagent systems in supporting resource allocation in hospital settings—such as labor allocation, emergency room triage, and bed allocation—during public health emergencies. Participants also addressed ethical concerns regarding the use of multiagent systems for resource allocation, such as the use of automated calls to improve health message uptake. In particular, they emphasized the importance of developing fair, just, and equitable implementation guidelines when utilizing multiagent systems—and AI more broadly—in the allocation of life-saving resources during a public health crisis.

Policymakers play a significant role in shaping the guidelines that govern the use of AI in public health emergencies. Therefore, it is essential to foster collaborations between policymakers, AI researchers, and public health experts to ensure responsible and effective utilization of AI technologies. By promoting research on AI and multiagent systems in public health and incorporating insights from policymakers, AI models that prioritize fairness can be developed.

Advancing Multi-Region Epidemic Models for Improving Pandemic Interventions

The integration of game theory approaches into traditional multi-region SEIR models offers a promising modeling technique for public health policies that may be issued by neighboring decision-makers during an infectious disease crisis. These models help us more accurately simulate outbreak intervention policies by actively demonstrating how policies implemented by individual, region-specific policymakers can impact the spread of infectious diseases beyond their own region.

Effective collaboration and coordination among policymakers from neighboring regions is crucial for achieving optimal and mutually beneficial interventions. During the workshop, participants discussed empirical evidence derived from a recent multi-region, game-theoretic SEIR model that showcased the need for policymakers to recognize the potential for cross-regional disease transmission. Findings from this model and others like it highlight the significance of cross-regional decision-making during infectious disease crises. By employing game-theoretic approaches to capture interactions across neighboring decision-makers, this modeling technique provides valuable insights into how region-specific policies can work in tandem to mitigate—or exacerbate—the spread of disease.

Modeling Human Behavior and Evaluating Government Actions with Microscopic Models

Microscopic agent-based models facilitate simulations at the individual level, providing numerous advantages such as simulating and learning human behavior and effectively assessing policies for decision-makers. During the workshop, ongoing work on the development of a microscopic model that scales to millions of agents was highlighted due to its potential utility in analyzing the impact of government-sponsored policies at the state or country level.

More specifically, the workshop discussion centered on using microscopic models to evaluate various government actions that were taken during the COVID-19 pandemic. Participants stressed the significance of integrating intervention policies—like stay-at-home orders and contact tracing—into microscopic models to gauge their effectiveness. To effectively integrate these intervention policies in the future, it will be crucial to design behavior models that take into account human conduct in different facilities such as households, workplaces, hospitals, and schools.

Furthermore, participants considered the potential of these models to guide decision-making at the local level, such as identifying communities in need of additional resources or locations where specific interventions may prove more effective. The conversation then addressed the limitations of microscopic models, including extensive data requirements and validation challenges. Finally, workshop attendees explored potential future directions within the context of building microscopic models, particularly in the context of intervention-related decision-making. One such direction involves making such models more interpretable for policymakers, even if doing so results in marginal reductions in performance, as it is often preferable to have models that can be readily understood and validated by decision-makers. Other directions include modeling human adaptation processes as human responses evolve through various stages of an infectious disease crisis due to increased knowledge.

References

[1] A. Mate, L. Madaan, A. Taneja, N. Madhiwalla, S. Verma, G. Singh, A. Hegde, P. Varakantham and M. Tambe. “Field Study in Deploying Restless Multi-Armed Bandits: Assisting Non-Profits in Improving Maternal and Child Health” in *Proceedings of the AAAI Conference on Artificial Intelligence.* 2022