Agent-Based Microsimulation (ABµS) Modeling: Revisiting the Micro Perspective

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**Microsimulation models (MSMs)** fall under a category of computerized analytical simulation models that can perform highly detailed analysis of activities. Introduced in the late 1950s by Guy Orcutt, MSMs are suitable to model interactions between the design and implementation of policies and individual decision making units. Frequently, MSMs involve the generation of data on social or economic units (e.g., persons, households, or firms) drawn from survey-based microdata. MSMs enable us to examine the impact of policy changes on individual decision units, and this micro-level focus distinguishes them from other modeling paradigms. In contrast, **agent-based models (ABMs)** and cellular automata (CA) became increasingly popular as modeling approaches in the social sciences because of their ability to directly model individual entities and their interactions.

Although both MSMs and ABMs have been successfully used in the recent past to model complex social (and other types of) systems, there are significant variations of emphasis between the two approaches. MSMs, having a strong applied policy focus, usually are not suitable to model the behaviors of individuals, interactions between individuals, heterogeneous populations, learning, emergence, or other types of adaptive features, etc., for which ABMs are usually better suited. In addition, in many simulation studies, the analysis of spatial and temporal dimensions bears special importance. Since geography usually has an important impact on human activities, often modeling the social system with its local context seems important and necessary. Thus, new paradigms have also been proposed that integrate the power of **geographic information systems (GISs)** with ABMs. It has also been argued that in recent hybrid models, a GIS can provide a bridge to link MSMs and ABMs.

In order to combine the best features of MSMs and ABMs, several studies have attempted to use hybrid, unified approaches that can offer a synthesis of the three paradigms. Such approaches may deliver higher potential in the advance of the simulation and modeling methodology. In this paper, we formally establish the notion of a hybrid, unified approach which we call **agent-based microsimulation**. To distinguish it from agent-based modeling & simulation, ABMS, we denote it by ABµS, where the “µ” stands for the “micro” prefix. Extending an earlier study that integrates an ABM of malaria epidemiology with a GIS, we argue that detailed analysis of the micro perspective can offer additional capabilities and benefits that are often overlooked by traditional ABMs.
The proposed ABµS methodology is applied to model malaria, which is one of the oldest and deadliest infectious diseases in humans, transmitted by female mosquitoes of the genus *Anopheles*. Unfortunately, most malaria ABMs, despite modeling individual agents and their interactions, still simulate a macro system. Although they possess the ability to explore a multitude of new insights by tracking each individual agent, almost none takes any advantage of it, and most focus on the aggregate behavior of agents. The outputs from these models are thus mostly restricted to the macro-level impacts on the system, such as time series plots that depict the proportional changes of various disease parameters (e.g., incidence, prevalence, entomological inoculation rate (EIR), etc.). Thus, the powerful insights that can be explored by modeling and simulating the actions and interactions of the smaller scale units (agents) are often overlooked.

In addition to the macro-level analysis, the ABµS methodology will permit to analyze the micro perspective in the local geographical context for a selected region. Many well-conceived field-based studies of malaria have shown that due to the complex nature of the disease, vector control interventions such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS) may have subtle impacts on the mosquito and human populations. Traditional macro-level outputs of ABMs are often inadequate to capture these. However, ABµS permits the modeling of these features, as illustrated below with two examples drawn from the literature.

- **Community effect of ITNs:**
  Studies from various parts of Africa showed that with sufficient coverage of ITNs, there is an overall suppression of the mosquito population, resulting in a mass community effect of the insecticide that reduces malaria transmission. With the micro-level focus of ABµS, modeling and analysis of such secondary, subtle effects can be easily performed.

- **Policy formulation with limited resources:**
  While simulating the impact of an intervention on a population, often the resources appear to be limited. For example, in a densely populated area with limited number of bednets, traditional ABMs may not be suitable to devise the best resource allocation plan. In such cases, ABµS can simulate and quantitatively analyze the best allocation and use of the limited resources, thus assisting in future policy formulation and decision making by public health officials.

**Future Work**

The current work is in progress. We plan to apply the proposed ABµS methodology to specific geographic regions where the disease is endemic, and different levels of transmission occur throughout the year.