Mechanism-Oriented Agent-Based Modeling for Uncovering Causal Mechanisms in Social Phenomena: The Case of a Pandemic Model

Abstract：
Scientific understanding of social phenomena requires elucidating their causal mechanisms, much like in natural sciences. However, unlike natural systems governed by universal principles, social systems are driven by human behavior and interactions, making controlled experiments difficult and equation-based theories limited in scope. Agent-Based Modeling (ABM) has emerged as a promising method to address these challenges by simulating artificial societies composed of diverse decision-making agents.
To overcome limitations in conventional ABM, we propose a “mechanism-oriented ABM” approach. This methodology adopts an entirely bottom-up structure, deliberately avoiding macro-level assumptions to construct models that faithfully reflect real-world social systems. Models are classified into qualitative and quantitative types, with qualitative reproduction serving as a prerequisite for quantitative modeling. In qualitative modeling, hypotheses about agent behavior and attributes are tested through computer experiments to identify the model structure essential for reproducing observed phenomena. Once identified, the necessity of this structure is analyzed to understand the emergence mechanism within artificial societies.
This approach enables systematic identification of causal mechanisms and is applicable not only to social systems but also to biological and pandemic phenomena. In a pandemic modeling example, the infection and recovery processes were simulated, incorporating medical knowledge about immunity. A key structural insight was that virus excretion is proportional to viral load, reflecting the immune-boosting effect of fever. However, due to individual differences in immunity, some individuals may experience uncontrolled viral replication in the body when the viral replication rate is extremely high. If such individuals move freely, the pandemic persists.
Based on these findings, the study emphasizes two essential strategies for effective pandemic control: (1) individual-level monitoring and behavioral regulation based on body temperature trends, and (2) early isolation of severely infected individuals to curb transmission.