Complex events and feedback within and between different levels of aggregation: implications for the development of hybrid SD/ABM simulations

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Combining system dynamics (SD) and agent-based modelling (ABM) has a tremendous potential to model complex systems in various fields. Though the number such hybrid approaches is constantly increasing, some of the fundamental issues are still unanswered and compromise the practical applicability. This paper re-visits the concept of hybrid simulations with a particular focus of combinations of SD and ABM. The desirability and feasibility of hybrid SD/ABM simulations are addressed, including philosophical, theoretical, and methodological considerations. Two key issues that separate SD/ABM from other hybrid simulation approaches are the conceptualisation of feedback across SD and ABM boundaries and inconsistencies with regard to emergent phenomena from the ABM module. A common approach for the interface between SD and ABM is aggregating agents' states, but this does not sufficiently address the complexity of dynamic systems with emergent properties. The implications of this issue are illustrated using the example of the collaborations between universities and industry. Entrepreneurial activities of universities are modelled using system dynamics and multiple universities interact with a set of agents, representing companies and start-ups in innovation ecosystems. Complex events, a collection of interrelated (simple) events, are introduced as a means to deal with emergent behaviour and feedback within and between different levels of aggregation. This has wide implications for combining SD and ABM but also for the study of complex systems in general. A model development process (MDP) for hybrid SD/ABM simulations that incorporates these ideas is provided based on the case study. The MDP is based on conceptualising feedback using causal loop diagrams before any separation between agents and aggregated variables and the operationalisation of complex events. The paper concludes with directions for future research.