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INCORPORATING KNOWLEDGE DISCOVERY TECHNOLOGY IN MICRO-DYNAMIC ANALYSIS METHOD

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ABSTRACT

An agent-based modelling approach is powerful in modelling individual behaviors and social interactions to investigate the resulted social phenomena. Yet this advancement in modelling poses challenges in the analysis process, which is often complicated due to the large volume of simulation logs generated, and the combined effects of input factors. In this paper, we propose a revised micro-dynamic analysis method by adopting a knowledge discovery technology to identify influential combinations of factors causing a target phenomenon and to improve the interpretability of results. We apply this method to the simulation logs generated from an agent-based model which investigated the impacts of group-based learning on cooperative behaviors. It is demonstrated that the method can examine thoroughly the combined effects of input variables from both micro- and meso- perspectives simultaneously not depending on modelers' analysis skills, and imply policies from a different perspective apart from the original analysis.

1 INTRODUCTION

Complementing traditional social research methods, an agent-based modelling and simulation approach is powerful in modelling individual behaviors and social interactions to investigate the resulted emergent social phenomena of interests. Yet this advancement in modelling poses challenges in the analysis process, which is often complicated due to the large volume of simulation logs generated, and the combined effects of input variables (Pereda et al. 2017). Some micro-dynamics analysis methods have been proposed to face this challenge. Yamane et al. (2018) proposed a systematic method to facilitate the analysis process by generating causes of a target phenomenon from the perspective of agent behaviors. Yamada et al. (2020) further improved the method by eliminating "small" and "simple" causes. However, this stream of methods still leaves some problems to be tackled: 1) the interpretability of causes should be improved to make the analysis process more transparent; and 2) a thorough examination of combined effects of input factors is necessary to strengthen the explanation of model behaviors and results.

2 METHOD

We adopt a knowledge discovery technology utilizing an efficient pattern mining algorithm (Iwashita et al. 2020) in the micro-dynamic analysis to tackle above problems. Different from the original micro-dynamics analysis (Yamane et al. 2018), which evaluated the similarity between agents with certain behaviors and various combinations of clustered agents, this technology leverages a fast enumeration algorithm to search over all combinations of input variables, and yield knowledge in an easy-to-interpret format. This new method can eliminate the ambiguity in results' interpretation caused by the similarity among agent clusters in Yamane et al. (2018)'s work, and meanwhile evaluate thoroughly the combined effects of input variables,

i.e., agent attributes and environmental factors, on the target phenomenon. The procedures of the proposed method are illustrated in the following Figure 1.

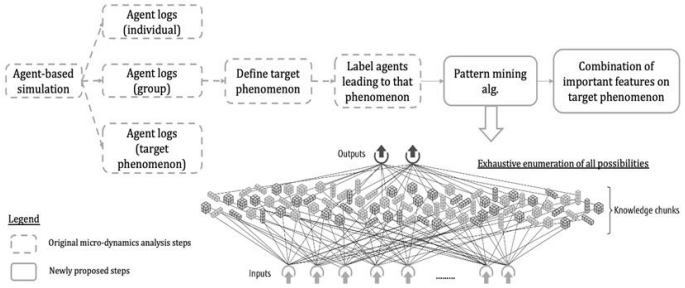

Figure 1: Procedures of the proposed method – A revised micro-dynamic analysis method.

3 APPLICATION

We applied the above method to an agent-based model (Chang and Deguchi 2021), which investigated the impact of group-based learning on agents' behaviors towards public goods contribution. Agents' initial abilities to contribute are varied and will be improved by a group-based learning process. Because of the various scenarios experimented, the original analysis heavily relied on the modelers' preferences and skills. In this method, we first randomly selected logs from different simulation runs across all scenarios. We then coded and categorized group dynamics (average contribution rate per group, group size, etc.), scenarios (different learning rate, etc.) and individual attributes (learning ability, etc.) as input. We lastly implemented the knowledge discovery technology to automatically extract knowledge chunks of a high impact on the contribution behaviors, i.e., the most influential combination of group dynamics and individual attributes, through an efficient search over all possible combinations.

The outcome shows similar results that agents residing in small groups composed by competent agents are more likely to contribute, but implies a different set of policies from a social influence perspective rather than from the conventional pay-off structure one. It recommends that the influence of those agents initially having a higher ability to contribute should be leveraged to prompt the contribution behaviors of others.

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REFERENCES

Yamane, S., H. Yamada, K. Ohori, H. Anai, S. Sakai, K. Takahashi, and J. Ouchi. 2018. "Systematic Analysis of Micro Dynamics in Agent Based Simulation". In *Proceedings of the 2018 Winter Simulation Conference*, edited by M. Rabe, A. Juan, N. Mustafee, A. Skoogh, S. Jain, and B. Johansson, 4214–4215. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Yamada, H., S. Yamane, K. Ohori, T. Kato, and S. Takahashi. 2020. "A Method for Micro-dynamics Analysis based on Causal Structure of Agent-based Simulation". In *Proceedings of the 2020 Winter Simulation Conference*, edited by K.-H. Bae, B. Feng, S. Kim, S. Lazarova-Molnar, Z. Zheng, T. Roeder, and R. Thiesing, 313-324. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Iwashita, H., T. Takagi, H. Suzuki, K. Goto, K. Ohori, and H. Arimura. 2020. "Efficient Constrained Pattern Mining Using Dynamic Item Ordering for Explainable Classification". In *arXiv:2004.08015 [cs.DB]*, accessed 10th September 2021.

Pereda, M., J. I. Santos, and J. M. Galán. 2017. "A Brief Introduction to the Use of Machine Learning Techniques in the Analysis of Agent-Based Models". In *Advances in Management Engineering, Lecture Notes in Management and Industrial Engineering*, edited by C. Hernández, 179-186, Springer, Cham.

Chang, S., H. Deguchi. 2021. "Group-Based Learning and Group Composition on the Provision of Public Goods: Incorporating Agent-Based Simulation and Gaming". In *Simulation Gaming Through Times and Disciplines. ISAGA 2019, Lecture Notes in Computer Science*, edited by M. Wardaszko, S. Meijer, H. Lukosch, H. Kanegae, W.C. Kriz, and M. Grzybowska-Brzezińska, 11988: 127-138. Springer, Cham.