Applying the MAIA Methodology to Model the Informal E-waste Recycling Sector

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Abstract. Agent-based social simulations aims to model and study complex human interactions. MAIA is an agent-based methodology that addresses different aspects of a social system aiming to guide the developer through out the modeling process. In this paper, we illustrate the use of the MAIA methodology by developing a formal representation of the e-waste recycling sector. This is expected to facilitate a structured simulations aimed at underpinning policy for sustainable development.

Keywords: agent-based modeling,simulation, institutional analysis

1 Introduction

Agent-based simulation is a rapidly developing method both in the social sciences as well as in the engineering sciences [4]. As it can be expected in such developing field, there are currently many approaches with regard to conceptual design, software implementation and outcome analysis that are hard to compare, evaluate and integrate. Especially when the models move away from general and abstract notions towards specific decision support models, more information is required on the assumptions about the agents and the world they inhabit. This requires a shared understanding of concepts, required elements, and framing of the problem at hand [4], towards which we have proposed the MAIA (*M*odeling *A*gents based on *I*nstitutional *A*nalysis) methodology [2]. The core concepts of this framework are inspired by the Institutional Analysis and Development (IAD) framework [5] while the details are added based on an agent-based software methodologies called OperA [1].

¡¡¡¡¡¡¡ .mine The MAIA methodology aims to cover all phases of simulation development, starting from conceptualization and analysis of the system to be modeled, to detailed design as well as semi-automatic implementation and implementation guidelines. The MAIA meta-model covers five difference conceptual structures presented in figure 1. The outcome of the conceptualization phase, is a number of tables representing different concepts of the system such as agents, resources and roles. There are also a number of diagrams illustrating dependency between roles, physical links and social networks. In the detailed design phase of MAIA, more detailed diagrams(e.g. sequence diagrams) are added to refine the outcomes of the conceptualization level. At the implementation level, classes

and methods are suggested that can be used as skeletons for (object-oriented) code development. ======= The MAIA methodology aims to cover all phases of simulation development, starting from conceptualization and analysis of the system to be modeled, to detailed design as well as semi-automatic implementation and implementation guidelines. The MAIS meta-model covers five difference conceptual structures presented in figure 1. The outcome of the conceptualization phase, is a number of tables representing different concepts of the system such as agents, resources and roles. There are also a number of diagrams illustrating dependency between roles, physical links and social networks. In the detailed design phase of MAIA, more detailed diagrams(e.g. sequence diagrams) are added to refine the outcomes of the conceptualization level. At the implementation level, classes and methods are suggested that can be used as skeletons for (object-oriented) code development. ¿¿¿¿¿¿¿ .r693 The benefits of MAIA for

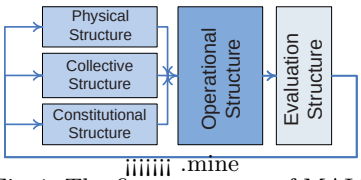

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Fig. 1: The five structures of MAIA

developing agent-based models include:

1. Support of structured analysis and design. The rich set of components both for social and technical concepts give a comprehensive composition of the system.
2. Specific support for social scientists, usually less familiar with programming.
3. Support of the model development cycle including (semi)automatic coding.
4. Knowledge sharing with the domain experts facilitated through the outcomes of MAIA.
5. Suite of tools to support MAIA developers. =======
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In this paper, we briefly introduce MAIA by describing its application to an experiment on how informal institutions, norms and culture could be represented in an agent-based model.

2 Exploring Ewaste Recyling with MAIA

Electronic waste (e-waste), is a growing global problem. A considerable amount of e-waste ends up in developing countries, where the recycling is done mainly

by informal backyard recyclers in an unskilled and harmful way [3]. The aim of this project is to gain awareness on how these recyclers can be influenced to make use of professional recycling plants which reduce current health risks and increase efficiency.

¡¡¡¡¡¡¡ .mine The existing e-waste recycling situation in India was decomposed, designed and implemented using the MAIA framework. In the following, we only explain the five structures of MAIA for the conceptualization phase as applied to the e-waste project to give a general overview of the MAIA concepts. Space limitations make it impossible to give the detailed specification. Full documentation of this case study including tables,diagrams and code is available from the corresponding author. ======= The existing e-waste recycling situation in India was decomposed, designed and implemented using the MAIA framework. In the following, we only explain the five structures of MAIA for the conceptualization phase as applied to the e-waste project some of the conceptualization to give a general overview of the MAIA concepts. Space limitations make it impossible to give the detailed specification. Full documentation of this case study including tables,diagrams and code is available from the corresponding author. ¿¿¿¿¿¿¿ .r693

1. *Physical Structure.* The physical structure is made of three distinct concepts namely resource, location and link. The resources identified include money, old computers, gold and e-scrap. There were no relevant locations and the composition of the resources resulted in a link diagram.

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2. *Constitutional Structure.* The roles the agents take, the groups they form, the objective dependencies of roles and the institutions they follow are defined in this structure. In this case study, 7 roles were identified (e.g. unit boss, segregator, extractor). These roles are internal roles (i.e. agents are defined to take those roles). Other roles (e.g. government) are defined as external entities meaning that there are no agents taking the role and thus the behavior is static without any particular decision making. =======

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The four institutions identified were government registration and safe extraction (formal) and corruption and child employment (informal). Recycling units were defined as a group with resources (e.g. old computers) and roles (unit boss, segregators etc...).

4. *Collective Structure* This structure specifies the *agent* and the *social network*. The worker agent which is the only agent can take different roles: unit boss, segregator, refurbisher and extractor. Each agent has properties(e.g.age and salary), characteristics(e.g. risky) and resources(e.g. money). The *social network* is a

graph where the sender and receiver are agent-role pairs and the link between two nodes gives a general description of the interaction between two pairs.
5. *Operational Structure* The general focus of the operational structure is on the continuous activities of the system such as decision making of the participating agents and the functions that link decisions to outcomes. This structure is divided into two main components, the action situations such as buying products or hiring workers and role enactment agreement which defines how a worker agent would take different roles.
6. *Evaluation Structure* Two matrices are the result of the evaluation structure linking action situations to outcome parameters.

Besides its direct contribution to the e-waste project, this case study has contributed to further understand the implications of MAIA. Among those we can address: the ease of communication with professional refiners who were the domain experts, easier analysis of results and debugging due to the evaluations structure and well documented model with explicit components that may also be reused.

3 Conclusion

This paper introduces MAIA through the application to e-waste recycling. We are applying this methodology to other case studies. MAIA tool suite is currently under construction to support developers.

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