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The Gap of Current Agent Based Simulation Modeling Practices and Feasibility of a Generic Agent Based Simulation Model

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Abstract

Agent-based modeling had been revolving to be established approach in modeling simulation systems which are used to understand and predict certain real-life scenarios in specific domains. Past researches which are domain-specific caused repetitive building of new models from scratch and restrict replication and reuse because of limitation of models' description. This paper presents a review of gaps between domain-specific agent-based simulation modeling and the recent practices of agent-based modeling that has focused in building generic agent-based simulation models motivations to gage the gap. The paper also presents the motivation from the recent practices that led to the implementation of a new research.

Keywords

Agent-based modeling, domain specific simulation modeling, generic agent-based simulation model, simulation model.

1. Introduction

Simulation had been a renowned approach for learning, understanding and formulating prediction in a wide range of areas especially, social science, economy and business, security systems as well as traffic and transportations [1, 2]. There had been a long discoveries of different techniques of modeling simulation such as cellular automata, discrete event simulation, object-oriented simulation and agent-based simulation.

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Agent-based modeling and simulation, namely ABMS, has been a widely used approach in the area of modeling simulation and seen as a better alternative from the traditional simulation modeling approaches [3].

Unlike other traditional simulation modeling approaches, ABMS adopts the concept of adaptive and autonomous simulation system [4]. ABMS is capable to model real life scenarios to the best similarity because of the components in the model namely, agents, interact with each other as well as inherit human-like cognitive properties such as behaviours and norms where real life does have. Hence, ABMS is always chosen for modeling of simulations in vast range of fields, ranging from business, economics, infrastructure, social science and military to the field of biology [5].

However, the implementation of ABMS is mostly domain-specific, where most of the models are not opened for public, due to propriety issue [3, 6]. This caused different simulation models for different domains to have different languages and definitions, running on different standards and procedures. The results from the simulations are very unlikely to have tested and verified because of the diversity [6, 7]. Due to the existing limitations, it was suggested that future research efforts for ABMS should aim at "building bridges" between specific domain results [6]. That enables researchers to achieve more general and shared understanding to effectively study, explain and predict the overall complex real life scenario instead of specific scenarios.

In order to understand and predict the overall complex real life scenarios instead of only specific domains, generic models have to be produced in order to cope extensive parameters for simulations of different specific domains [8, 9]. In Section 2 of this paper, reviews of current research efforts of developing generic simulation models for higher-level domains is going to be laid out in detail. The gap of current agent-based simulation research works are discussed in detail within Section 2 as well, to understand the motivations and contributions of the research work that is going to be proposed and discussed in Section 3 and 4.

2. The Gap and Emergence of Related Research Works

Past research works of ABMS had been vastly produced, yet most of them are well known to have certain limitations that could have been gaged. The following sub sections in Section 2, discuss the major limitations found and mostly addressed in current researches for enhancement of the agent-based simulation model. The initiatives taken by the current research works to apprehend the limitations is discussed in the sub section as well to understand the feasibility of the motivation and insights for the proposed research work.

2.1 Limitations of Past Research Works

There were four major limitations that had been always found to be emphasized worthy to take note of towards enhancing agent-based simulation systems. The limitations will be discussed thoroughly in the following sub sections.

2.1.1 Limited and Vast Diversity of System's Definition

ABMS developed in the past researches had shown to be particularly solving on a single specific area of research [8, 10]. Due to the fact that the ABMS were developed individually and most are due to ad-hoc specific reason, the specifications or definitions used in the various ABMS were also different from one another [11]. On top of that, most of the ABMS researches are developed where specifications of the models were not released to public, mostly because of propriety issues [2, 3]. Therefore, with such diversified definitions and limited information on existing systems, new researches need to be done from scratch with yet another set of different definitions for the system's specifications. Apart from having to start from scratch, new researchers that need to refer to the existing ABMS to understand more about ABMS face challenges to do so because of the limited or diversified system specifications released. The diversified information of different ABMS caused not only challenges on understanding the different available ABMS, but also caused further challenge in results testing [7, 10].

2.1.2 Inadequacy of Customization

Most of the specific domain ABMS does not allow further customization to the model because of the objective of the research. This caused limitation of the ABMS application even in the same domain that the ABMS were developed for. The fixed modeling of the ABMS limit the model from coping with different scenarios within the same domain because of the dynamic environment of the domain [2, 9]. This caused more specific models to be developed in order to manage different uncertainties when different scenarios arise in which might cause simulation results to be faulty because of the limitations. Because of the nature of fixed model, extensibility issue will be the further problem due to the lack of options for customization.

2.1.3 Inflexibility of Reuse and Replication

ABMS developed in the past researches implied limitation of reuse because of the propriety issues for releasing the model for public which also caused no further extension could be done to the research [1, 7, 8]. A system's reusability is important for it enables new researchers to be able to develop new similar system based on the existing verified systems' specification instead of building new system's from scratch. A system's ability to be replicated on the other hand, enables the system's simulation results to be invalidated, which is a crucial step to confirm the reliability of the simulation results produced. With the lack of reusability and replication in the research objectives, many individual ABMS were developed, however, few are being applied and tested [2, 3].

2.1.4 Lack of Result Validation and Verification

When there are limited means of reuse or replication, the model and the simulation results for the specific ABMS could be vulnerable to fault for reuse and replication are approaches for system verification and validation. However, validation and verification of ABMS had always been the area neglected in the past researches although validation and verification is an important process to verify the correctness of the simulation model and the reliability of the simulation results [1, 7, 12].

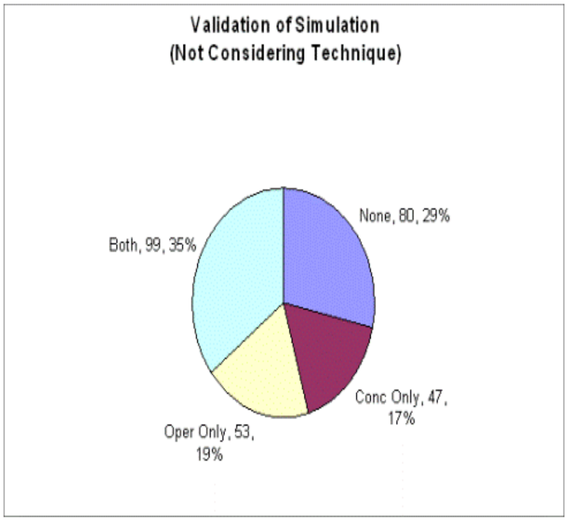

Figure 1: A survey done [3] for practice of validation of agent-based simulation systems, disregarding techniques used

In the survey [3], it was concluded that the practice of having the simulation systems validated was very alarming, as only 35% out of the total surveyed, reported full validation. Therefore, the recent research directions in ABMS had switched tremendously and aimed at solving the listed issues.

2.2 On-going enhancements

Recent research found in the area of ABMS had been found to be flowing to the direction to be generic in order to have better understanding in the overall domain [6]. There are also research works with different initiatives of apprehending the major limitations discussed in Section 2.1 such as extensibility, reusability and ability to be replicated as well. Research work [11] laid out a good foundation of building generic simulation models by the suggestion of a general workflow for integrative simulation.

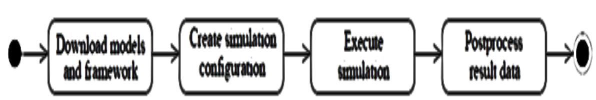

Figure 2: A generic workflow for integrative simulation [11]

Apart from the foundation of building generic simulation models, there are different initiatives that the current research works aimed to resolve different limitations discussed in the above sections.

2.2.1 Openness and Transparent Framework Design

Recent research works done relatively [7, 8, 10, 11, 13] bore the same research objectives of having the framework or model design and implementation opened to public. This enables different individuals to access and study the models for reference purposes, where new researchers could have a better entry to study and understand ABMS.

2.2.2 Customizable and Extensible ABMS

Relative research works [7, 8, 9, 10, 11] were found to aim at producing customizable frameworks and models to allow other researchers to have access to the database to add in different models to further customize or extend the model. This enables the ABMS framework to be able to be more dynamic in application as it is able to be customized or extended to simulate different domains according to different models that had been added in by other researchers. For instance, the ABMS research documented by Bagneris [7] had already been extended by Coleman and Nazif [14] to test different business strategies in the same domain of online business.

2.2.3 Flexible for Reuse and Replication

Recent research works [7, 8, 9, 10, 11, 13] aimed at resolving issues of inflexibility of reuse and replication in the past researches. This had enabled different researchers to be able to reuse the same generic model to simulate different scenarios of same domain [14, 15, 16, 17, 18, 19]. This had also benefited much to the verification of reliability of the simulation results for the ABMS, as the results were able to be replicated.

3. The Proposed Conceptual Generic Simulation Model

As the direction of ABMS is moving into studying, explaining and predicting general or higher level of real life scenarios of different domains as described in Section 2, insights were gained from the reviews of the current research works to initialize the conceptual design of a cross-domain generic ABS model.

As found in literature, ABMS previously had been mostly domain-specifically developed with vast diversity of model designs and definitions which caused further limitations in ABMS. Thus a well-defined generic ABMS model is crucial to address to the limitations. It is also worthy of noting that even for the current practices of generic ABMS frameworks are not well documented in general with one language, as each of the generic models are in different domains and the standard method of documentation was not followed [20]. Hence, most of the recent research works, although aimed to resolve the standardization in model's designs and definitions but the accomplishments are limited.

Apart from speaking the common rules and standardized definitions and modeling, the model needs to be developed customizable as well. In order for the model to be further reused and replicated, the models and components within the framework need to be able to be customized in order to meet the requirements of different domains that use the generic ABS model for simulation. As the existing generic ABS model that were generic to one specific domain, made adjustable to accommodate different specific requirements of different components from the same domain, proposed generic ABS model that aims to accommodate cross-domain simulation need to have a model that can be customized to accommodate different domain requirements. Thus, a conceptual generic ABS model is constructed with the motivation of filling the gap of the current research works. The conceptual model will be drafted and discussed thoroughly within this section, Section 3, as well as Section 4 within this paper.

Based on the limitations found in the past research works and resolutions in the recent research works, the gaps being found are not entirely addressed or resolved. Hence, with the motivation of addressing filling the gaps found and towards building a better model, a generic agent-based simulation model is constructed. The model will be having an open-source extensible and customizable initiative. It will also be enabled for simulation of data from different sources, for validation and replication processes, which also for generic purposes. The model also aims for an adjustable generic concept, which does not only accommodate simulation of sub-domains under the same vast domain, but made adjustable to accommodate different domains.

The overall concept of the functions for generic agent-based simulation model as described in the section above is illustrated in Figure 3.

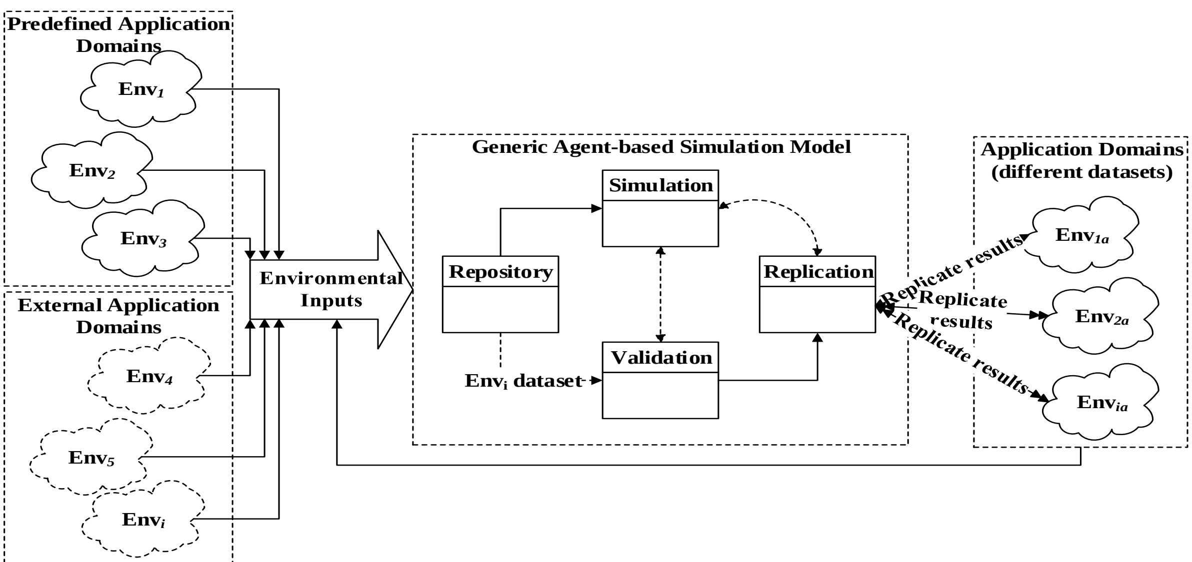

Figure 3: Overall concept of generic agent-based simulation model

The generic agent-based simulation model is conceptually designed to be capable of simulating scenarios of different application domains or environments. However, to make sure of the model to have a certain level of generic nature, more than one application domain in which, this research work chose three predefined environmental inputs (Env_1, Env_2, Env_3) need to be inserted into the model for generic modeling. The simulation model will then process simulation execution and because of the extensive nature of the simulation model, the model is expected to be capable of replicating simulation results of different datasets of similar application domains (Env_{1a}, Env_{2a}, Env_{3a}). Due to the extensive nature of the simulation model to accommodate simulations of more application domains, the model is designed to be capable to integrate different external inputs (Env_4, Env_5, Env_6). The domain specific environmental inputs further customize the simulation model to meet the specific requirements of simulation.

The simulation model consists of 4 main components which are namely the repository, simulation, validation and replication. In order to be generic for simulation of different domains and at the same time, addressing to the gaps of the limitations of agent-based simulation models, the existence of the components are inevitable.
Repository is a crucial component to be in an agent-based simulation model, where inputs from different application domains are stored [8, 10, 11]. Repository component is further illustrated in Figure 4.

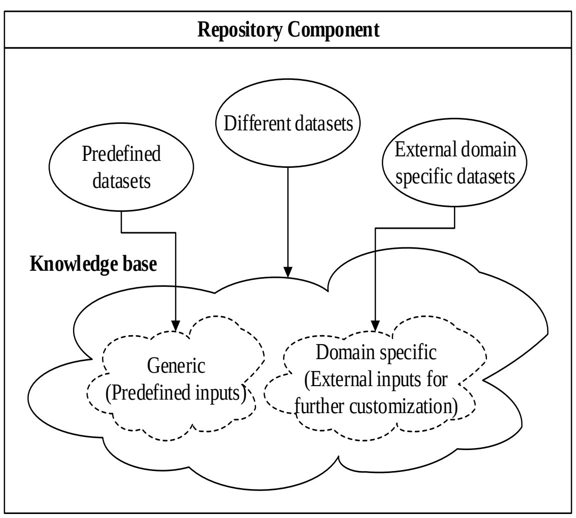

Figure 4: Conceptual repository component of generic agent-based simulation model

In this model, the knowledge base consists of data acquired from more than one domain, in which is set to be three for initial predefinition of the generic simulation model as illustrated in Figure 3. Three different application domains (Env1, Env2, Env3) will be chosen for the case study of three different environments in order to acquire the predefined environmental inputs. The case studies are carefully chosen to accommodate cross-domain simulation which therefore could be generic to a few domains. Apart from initial data acquired, the model is conceptually made customizable through integration of external domain specific environmental inputs into the knowledge base as shown in Figure 3 [7, 11]. External domain specific datasets are contributions of data from other domains that would like to further customize the model to better suit the simulation of the specific application domain. The datasets are integrated and stored into the knowledge base as well so that once the model is further customized and extended, other similar application domains can reuse the extended model without repeating the process of further configurations. The data acquired and stored in knowledge base is then extracted and analyzed to be shifted to simulation component for configuration of simulation execution. The conceptual simulation component is further illustrated in Figure 5.

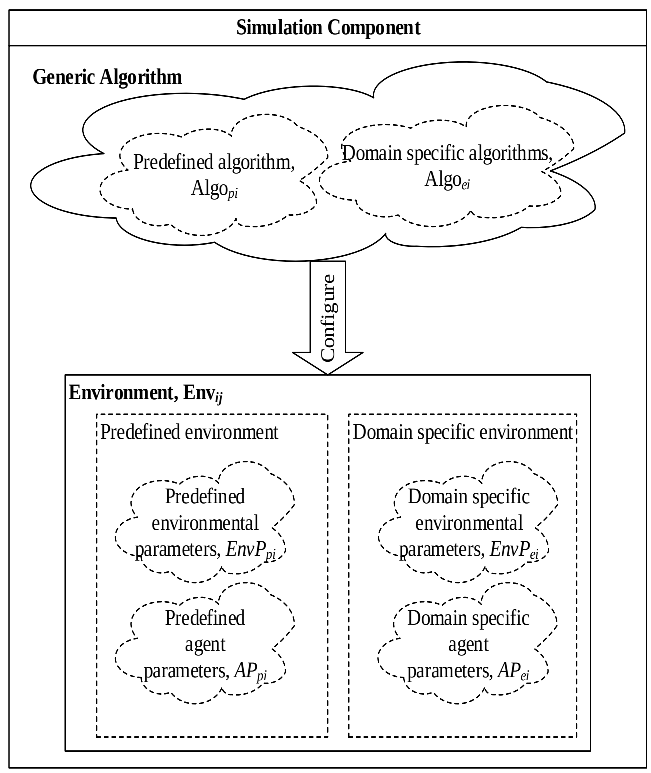

Figure 5: Conceptual simulation component of generic agent-based simulation model

The generic algorithm consists of predefined algorithm for the initial configuration of the simulation execution and domain specific algorithms that enables further configurations. The predefined algorithm is conceptually designed for governance of simulation of three different domains chosen for study. The predefined algorithm, $Algo_{pi}$ governs the simulation execution by configuring parameters of predefined environment, $EnvP_{pi}$ and predefined agents, AP_{pi} accordingly. For instance, the predefined algorithm is defined by the different parameters of each predefined environments and agent that lives in them. Thus, predefined algorithm, $Algo_{pi}$ is denoted using the formula below;

$$Algo_{pi} = \{EnvP_{pi}, AP_{pi}\} \quad (1)$$

where;

$i = \{1, 2, 3, 4, \dots\}$

This imply that the predefined algorithm, $Algo_{pi}$ governs the simulation by configuring different predefined environment, $EnvP_{pi}$ and agent parameters, AP_{pi} in accordance to the predefined data extracted from the repository component.

As the simulation model is conceptually designed to be extensive to accommodate simulation of more domains through further customization, domain specific datasets are extracted and analyzed to generate domain specific algorithms, $Algo_{ei}$. The domain specific algorithms governs the simulation execution through parameters configurations of domain specific environment, $EnvP_{ei}$ and domain specific agents, AP_{ei}, accordingly. For instance, the domain specific algorithm is defined by the different parameters of each domain specific environment and agent that lives in them. Thus, domain specific algorithm, $Algo_{ei}$ is denoted using the formula below;

$$Algo_{ei} = \{EnvP_{ei}, AP_{ei}\} \quad (2)$$

where;

$i = \{1, 2, 3, 4, \dots\}$

This imply that the domain specific algorithm, $Algo_{ei}$ governs the simulation by configuring different domain specific environment, $EnvP_{ei}$ and agent parameters, AP_{ei} in accordance to the domain specific data extracted from the repository component. The domain specific parameters further customize the simulation execution without altering the predefined parameters.

Thus, the conceptual generic algorithm, $Algo_i$ of the simulation model comprises of predefined algorithm, $Algo_{pi}$ and domain specific algorithm, $Algo_{ei}$. The two entities form the generic algorithm, $Algo_i$ to govern the simulation execution through configuration of the overall environment being simulated Env_i which comprised of predefined environment, $EnvP_{pi}$ and agents, AP_{pi} as well as domain specific environment, $EnvP_{ei}$ and agents, AP_{ei}. Hence, the generic algorithm, $Algo_i$ could be denoted using the formula below;

$$Algo_i \in Env_i \quad (3)$$

where;

$$Env_i = \{EnvP_{pi}, AP_{pi}, EnvP_{ei}, AP_{ei}\} \quad (4)$$

$i = \{1, 2, 3, 4, \dots\}$

Similar to the workflow of integrative simulation in the research work by Hennicker et al. [11]; the simulation configuration in this conceptual model is done by the generic algorithm generated.

The simulation is executed through the implementation of the generic algorithm, $Algo_i$. Simulation results are expected to be acquired after simulation execution. The results acquired will then be shifted to validation component for results validation and verification. The validation component is further drafted in Figure 6.

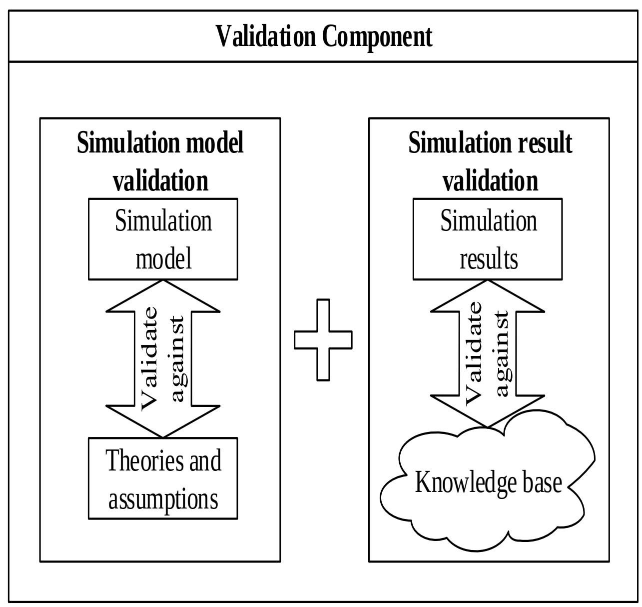

Figure 6: Conceptual validation component of generic agent-based simulation model

As a generic agent-based simulation model, it is inevitable for the simulation model and simulation to be validated and verified before being released for reuse or further customization [3, 7, 21]. Thus, within the validation component, the model and results will be validated to determine the reliability of the simulation result. As suggested in [3]; the model should be validated against theories and assumptions of the real environment and the results are validated against real environment data [8]. If negative result is acquired through the validation and verification process, the flow must return to the repository model for further customization of the simulation execution through amendments of the generic algorithm. However, if positive result is acquired, the generic algorithm is then validated to be able to accommodate a reliable simulation of the specific environment or application domain, Env_i. This also validates the simulation model to be able to proceed for replication of results in replication component, where further validation of robustness of the simulation model is done. The illustration of replication component is in Figure 7.

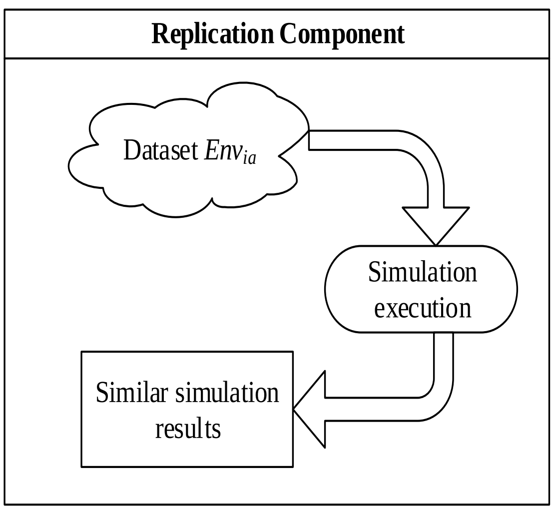

Figure 7: Conceptual replication component of generic agent-based simulation model

Replication defines the ability of simulation model to simulate the same result, given a different dataset of a similar environment [7]. In this research work, the replication component is conceptually designed to be able to replicate the results of the similar environments, Envi with different datasets provided to the model, Envia. With the proven ability of replicating results, the simulation model and simulation results is being further validated of its robustness and reliability. This will imply that the generic agent-based simulation model is practically approved of its generic nature to be used by many and reliable to be used by many as well.

4. Discussion

Every component of the simulation model drafted and discussed in Section 3 is designed with the aim of resolving the different limitations found in the literature of research works in ABMS. The sub-sections below discuss thoroughly of the approaches that the conceptual simulation model used to accommodate resolution of the different limitations.

4.1 Standardized and transparent simulation model definition

The simulation model adopts the open source and standardized documentation and definition of agent-based simulation model namely, ODD Protocol [20]. Open source approach will enable other researchers to be able to easily access and use the generic simulation model. Thorough documentations will enable other users to be able to study and reuse the generic simulation model easily and as well as standardized unambiguous definitions will ease other extensive research efforts to be done on the simulation model.

4.2 Customizable simulation model

The simulation model adopts the idea of extensible or customizable simulation model [9] within repository model. Individual datasets from other research works, namely external sources, can be inserted at the repository component to be analyzed, implemented and simulated in the simulation model itself. This will enable the simulation model to extend it generic nature and further customized to meet the simulation requirements of more different domains, other than the initial predefined environment or application domains.

The generic algorithm, $Algo_i$ and environments, Env_i as well as environment's parameters, p_i are unfixed variables as denoted in equations (1), (2) and (3). This implies that the simulation component is extensive and able to accommodate different configurations from the extracted data from repository component. Thus, the model is able to support further customization for extensive generic research works.

4.3 Validation and verification emphasis

As the simulation model is open for the use of different domains and expected to be able to be extended to the use of other research works, the simulation model need to be validated and verified [3, 7, 21]. The validation component process validation of results through comparing the simulation results for and with the real data acquired. The comparison of simulated results with real-life scenario will determine the reliability of simulated results, which will ensure the reliability of the simulation model to correctly simulate the configured environment.

4.4 Flexible for reuse and replication

While validation of simulated results validates the reliability of simulated results, replication of results determine the robustness of simulation model. Replication as suggested in [7] is a phase that is almost never considered in agent-based modeling and simulation but is great to have, to further validate the robustness of a simulation model. Thus the existence of replication component in this generic simulation model. Replication is about generating similar simulation results for the similar environment or application domain but different dataset; therefore, the process of replication is going bottom up and top down again as illustrated in Figure 3.

A different dataset need to be inserted into repository component, in which, followed by other process and end with validation component, where the simulation result will be compared with the real-life data. If the results are validated to be reliable, the simulation model's robustness is determined, for it accommodate simulation of other datasets as well, instead of the predefined data acquired.

As a conclusion, with the continuation of execution of all the components, the generic simulation model is expected to be able to gage the limitations of lack of extensibility or further customization, validation and verification as well as replication and cross-domain generality.

5. Conclusion and Further Works

This paper presented a review of current researches of ABMS in generic modeling and how the current researches has motivated and influenced the research of developing a generic agent-based simulation model which can be applied across different domains. The research aims at a novel development of generic simulation model to study, explain and hopefully predict scenarios of real-life systems in cross-domains manner. The generic simulation model is expected to address the limitations of ad-hoc and domain-specific model development manner as well as extensibility and customizability of the model to be able to accommodate other domains. The generic agent-based simulation model is also expected to address the validation, replication and reuse gaps of the current practices with validated result reliability and model robustness.

However, the generic agent-based simulation model need to be defined in more details with further refinement of research scopes and objectives with the aim to design a more defined generic simulation model. As the simulation model and results generated need to be carefully documented to enable others to be able to understand and apply the model, for simulation of other domains. Thus, in extensive works for this research, standard documentation of The Overview, Design Concepts and Details (ODD) Protocol should be done.

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