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Immersive Face Validation: A new Validation Technique for Agent-based Simulation

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***Abstract*—Agent-based simulation is very popular for its ability to approximate real life problems in an efficient way. To assure that the developed model is sufficienlty correct, validation needs to be performed. This contribution proposes a new approach to validate agent-based simulation models. To this end, a novel face validation technique is presented that enables systematic plausibility checks by a human expert immersed in a fine grain virtual reality environment that is the exact representation of the simulated multiagent model. It turns out that Immersive Face Validation, is a technically feasible process which offers great insight into the behaviour context of individual agents.**

I. Introduction

AGENT-BASED simulation is a highly attractive simulation paradigm with great potential of developing a great variety of real world representations. However, as the problems we try to solve using modelling and simulation tend to become more complex, the need to certify their accuracy is significantly evident. Only when the model is sufficiently valid it can be used to make decisions regarding the actual real system. The degree to which a model forms an accurate approximation of the intended system can be determined via a process called *validation*. Therefore, *validity* is one of the most important properties of a simulation model particularly because it certifies that the developed model is the "right" model [1].

Validation covers an essential part in the life cycle of every simulation model. Nevertheless, not all validation techniques are appropriate for all simulation models and there are cases in which particular approaches are required. Especially for models based on the multiagent system metaphor, several particularities; starting with the level of detail until the missing micro-, macro-level link, indicate the need of creating new validation techniques able to assure the plausibility of the agent-based simulation's outcome [2]. If in this context we consider the lack of empirical data to initiate statistical validation, it is eventual for our focus to lie on *Face Validation*. This type of validation is based on the implicit estimates and intuition of human experts or stakeholders and it can result in a powerful tool which can be applied from early simulation phases and alongside. In this contribution, we propose *Immersive Face Validation*; a new validation technique which enables the systematic use of human evaluators participating (or even interacting) in the simulated situation in real-time. The domain-expert, immersed in a Virtual Reality (VR) world that is an exact representation of the simulated model, will have the opportunity to check the simulation's dynamics on the agent level through a natural within perspective (agent's point of view). Hence s/he can then detect and consequently evaluate regular or irregular behaviour derived from the theoretic basis of the real system. This validation technique is not emerging as a stand-alone method for certifying the model's validity but it should be rather seen as an additional tool in the overall validation process.

The use of VR is not incidental. In the field of agent-based modelling, there are particular cases where visualisation offers a great means for communicating, identifying and understanding the behaviour of a model. In macro simulations where only one observation point is possible, it is very difficult to make any assessment on the micro-level. Due to this issue, we invest on the use of VR visualisation as it can better describe behavioural details on the agent level. Furthermore, the variety of possible interactions is clearly much higher and appropriate for immersive face validation as well. Of course, this new evaluation process overcomes the restricting top-down perspective (bird's eye view) yet it does not reject it from the life cycle of the simulation model as the later provides an abstraction layer that is not apparent in the detailed VR world.

To realise this technique in a system, a key idea is that this functionality should be cheap to setup, applicable to a wide variety of multiagent models and finally available on demand. The later one is very important as not all agent-based simulation models are applicable for immersive face validation. Therefore such a functionality should come as an add-on to the simulation that is used only when necessary, but still can be switched off for the deployment or other test simulation runs.

In the following, we will first present background work on the field. In Section III we are going to discuss the overall validation framework, including its functionality. Then in Section IV we show how such a technique can be realised in a feasible system. Finally, shortly after a discussion of related work, the paper ends with a summary and an outlook to our planned future steps.

II. Background Work

The role of validation in modelling and simulation is unquestionable. There exist a wealth of literature investigating procedures and techniques for assessing the credibility of different applications in the domain of modelling and simulation such as [1] and [3] as well as specifically on agent-based simulation [4]. Balci in [1] analyses 45 techniques (VV&T), ranging from informal to very formal, for validating and evaluating a model while in [5] he defines 20 rules to guide a practitioner in conducting credibility checks in a simulation model.

Several tools and methodologies are developed proposing different ways of validating multiagent simulations. Klügl in [2] proposes a process for validating agent-based simulation models which combines face validation, sensitivity analysis, calibration and statistical validation. Niazi et al. propose at [6] a validation and verification tool for agent-based simulation models for a wide variety of models. In this tool a multiagent overlay is created on top of the actual simulation model. The agents populating this overlay have as main task to monitor the simulation's run based on predefined constraints which when violated are logged. JAT [7] tests the behaviour of the individual agents in a simulation by using "mock agents" which communicate through messages with the agents of the real simulation. The evaluation is then based on the replies actual replies which are compared to expected responses.

Due to its nature, immersive face validation relies on natural human intelligence and therefore the engagement of experts for plausibility checking is crucial. Human involvement is similarly a core subject in other areas related to agent-based simulation as well. A characteristic example lies in the paradigm of participatory simulation (PS) [8]. In a PS, multiple humans (i.e., expert, stakeholder or non-expert) are intended to control individual agents in an agent-based simulation by diving into some virtual space. Then based both on observation and on the actual operating history a more realistic behaviour model can be created. Role-playing games (RPG) [9] are also present in participatory processes. In such types of simulation, roles are allocated with defined rules. Experts or stakeholders are then enabled to interactively participate in the design process through computer-based role-playing games, interacting with the individual agents and other users in the environment, access as well as exchange information so as to finally formalise the agents' behaviour. Very often autonomous agents are introduced in games being able to learn complex behaviour via interaction with the participant experts/stakeholders.

Nevertheless, immersion in virtual reality has also a broad field of application. We may find immersive scenarios for training or educational purposes [10], for evaluation of intelligent virtual characters [11] till the measurement of "presence" as validation technique in crowd simulation [12]. In this context, multiagent simulations with a spatial environmental model pose a significant importance in our work as not all simulation models are appropriate for performing immersive face validation. Therefore pedestrian simulation and crowd simulation are somehow interesting fields to explore. Although dealing with the same subject, pedestrian and crowd simulation form two distinctive research communities. In crowd simulation the realism and plausibility of the pedestrian behaviour illustrating a particular layout is in the focus of attention. The individual virtual character and its potential interaction with an observer or an immersed human is focused on produced flows while densities are forming the output of a simulation run. On the other hand, the outcome of pedestrian simulation is used for detecting bottlenecks, optimizing layouts, etc. while the individual and its movement is relevant if realistic trajectories are produced [13].

III. Validation Framework

In the validation process proposed by Klügl [2] at least three methodological elements are identified with respect to face validation: (1) animation assessment, (2) output assessment and (3) immersive assessment. The third element, *immersive assessment* in the face validation process is basically the starting point of this work as it can be seen as prior to the immersive face validation technique.

In this section the immersive face validation framework is described. It begins with the prerequisite that a runnable model is developed which means that standard debugging for uncovering errors is already performed from the modeller and output data is produced for the first time in the simulation's life cycle. Immersive face validation does not seem meaningful in earlier stages where the model is not conceptually valid enough. A common 2D visualisation on the macro level seems always attractive in early phases and therefore we do not exclude it from the preliminary validation steps. Fig. 1, illustrates the general frame of the simulation's life cycle focused on our proposal for this new validation technique. In the following sections we are going to analyse the overall process in the context of modelling cycle as well as the validation procedure itself.

A. Overall Process

Once the simulation model is conceptually valid, the modeller has the opportunity to enable plausibility checks in the agent-level as well. At this point, the immersive face validation itself has to be set up.

1) Validation Setup: Since the beginning of this paper we considered that this validation technique should be available/used only when necessary. The actual visual outcome would correspond to a detailed visualisation interface that comes as an add-on to the intended simulation. It is essential for the modeller of a multiagent simulation to be able to focus on the model development and avoid the complexity of how to deal with setting up an immersive visualisation. The ideal case would be to establish a connection between the simulation and the visualisation interface using minor configurations. The connected systems would then automatically generate the 3D representation of the virtual world from the simulation output, while they would enable an immersive movement of the human observer in the simulation without the need for further adaptation.

We assume that every agent in the simulation has a direct corresponding character in the virtual 3D world and that every

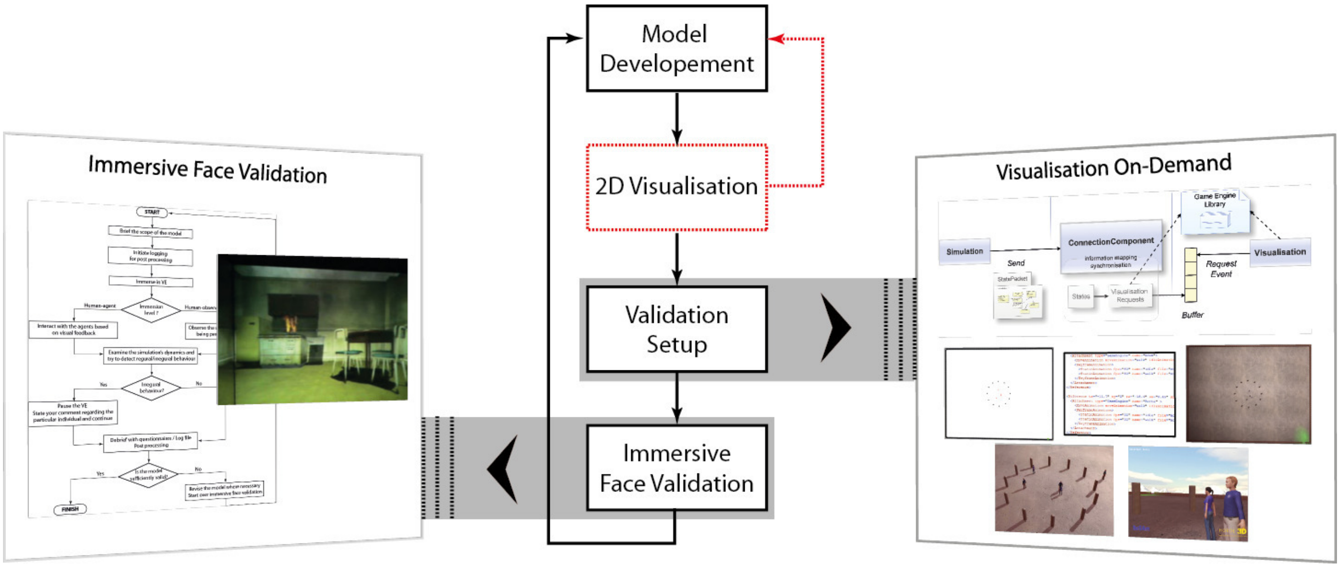

Fig. 1. Graphical illustration of the precesses involved in for enabling Immersive Face Validation in the life cycle of an agent-based simulation model.

activity is visualised in a realistic way. Then in the final stage, the human expert, immersed in a virtual environment (VE) will have to convey and understand the internal structure of the model.

2) Immersive Face Validation: Depending on the level of immersion, we identify two types of participation:

- *human-observer* where the evaluator is immersed in the virtual space and the only ability he/she has is to observe and evaluate the simulation's dynamics. In the best case his presence in the virtual world would be sensed by the individual agents and treated similarly to an obstacle.
- *human-agent* where the evaluator is given the ability to interact with the individuals. This would lead to interaction agent-to-agent.

A core question here refers to what information can be accessed based on the immersion level. In both cases, the individuals' behaviour is visible. What happens though with the reasoning level data? Is it possible to gain such intuition? In the case where only observation is available, clearly we cannot make any assessment on the reasoning level. Contrarily, based on the second alternative where the evaluator participates interactively with the individuals we can certainly access both behavioural and structural (agent's reasoning) information. The critical point here is how efficiently such interaction can be.

It is our belief that adding high-level interaction to the abstract model would expand the overall complexity. By high level interaction we refer to natural language. There is plenty of work related to this tasks such as [14] or [15] however apart from the technical problems of using syntax, such an attempt would require natural language parsing, semantic interpretation of notions so that in case the observer would ask to an agent "Where is the nearest exit?" in an evacuation scenario, an understandable answer should be expected. Due to these issues at the current validation procedure we will only place our focus on strictly visual and/or haptic feedback.

B. Procedure

Let us assume that the model is ready for immersive validation and the relevant component (visualisation on demand) is turned on. The overall immersive face validation procedure as depicted in Fig. 2 begins with a short description of the scope of the model. The evaluator needs to be aware of the experimental conditions under which s/he is supposed to validate the simulation model. Then logging is initiated so as to capture all actions of the human expert in the VE and facilitate post processing. The type of immersion should be defined as well. As described in Section III-A2, the level of immersion defines the level of participation in the simulated model. Nevertheless, one of the most important contributions here is that we introduce a meta-level interaction. To be more specific, while the evaluator focuses on the system's dynamics, s/he has to pause the immersive visualisation and place comments regarding the behaviour of the particular individuals in real-time (a real-time behaviour debugging). Such direct functionality clearly promotes interactivity and precise better communication of the validation's outcome. After completing one full simulation run, the evaluator should describe the overall comments briefly in a post processing activity and reply on model-specific questionnaires. If the final decision over the models validity is positive (i.e., the model is determined as sufficiently valid) then the overall process terminates. Contrarily, in case there exist in context behaviour abnormalities, the model has to be revised and immersive face validation starts over again.

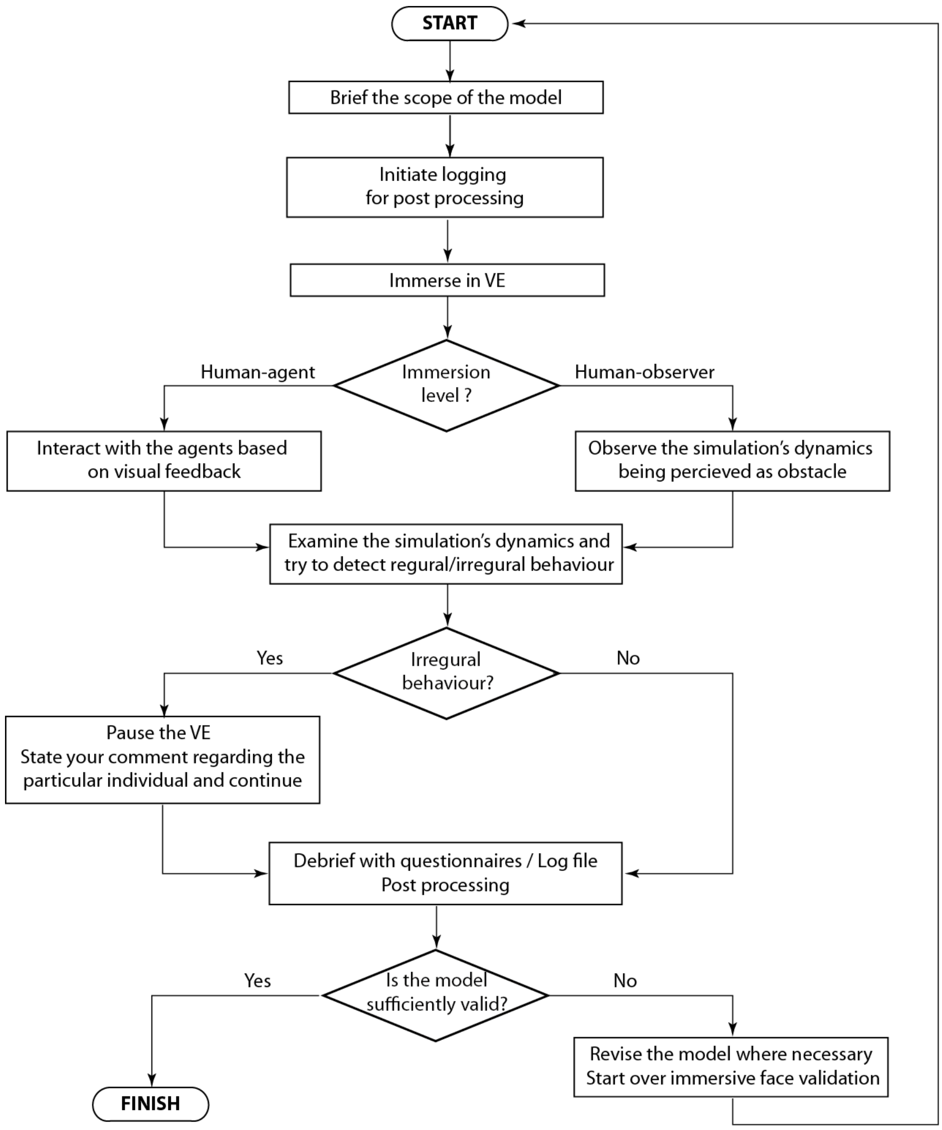

Fig. 2. Diagrammatic illustration of the overall proposed validation process.

IV. Towards the Realisation of Immersive Face Validation

Since the new validation framework is defined, the consequent step is dealing with how to realise such functionality into a valid system. Our objective is to create a multiagent simulation framework in which a modeller is enabled to build a 3D virtual world based on the simulation model's dynamics. This additional visualisation should come with minimum cost taken that the modeller's focus is on creating valid simulation models and not on diving into the development of fine grain visualisations.

From a technical point of view, the final solution for such a system must provide an easy-to-use and fast way of generating a 3D visualisation on demand (we already explained that not all simulation models are appropriate for immersive face validation). We can identify three basic requirements:

- A modeller shall be enabled to add the immersive visualisation to the multiagent simulation model with minimal additional effort.
- The visualisation's output should be realistic so as to allow validation assessments on the micro-level.
- The overall solution should be as generic as possible and applicable to a wide range of models.

Building an additional visualisation upon the simulation model is not a trivial task as there are several inherent conceptual and technical challenges. However, based on our previous work, we are confident enough to claim that such a system is technically possible. In [16] we presented conceptual challenges and investigated different architectures for realising such a particular system. Oriented towards the problem of on-demand interfacing agent-based simulations with virtual reality we focused on how to deal with the inherent granularity discrepancies and on how to handle and relate information between the two systems. In [17] we proposed an initial framework which provides a generic way for mapping the information which describes the state and context of a simulated agent to its 3D counterpart in the virtual reality system. Our basic assumption is that the simulation should not depend on the 3D visualisation therefore using a 3D simulation platform or directly embedding the simulation into a 3D environment with all the necessary visualisation overhead does not seem meaningful. Central task is to find an efficient way to connect connect agent-based simulation to a VR system.

To gound our work, we developed a prototype using SeSAm[1]; a general modelling and simulation platform and the Horde3D[2] GameEngine. The simulation's dynamics are then projected on a CAVE-based immersive virtual environment [18] where a human was immersed in the human-observer immersion level. An export function for SeSAm was also developed that generates a complete description of the VR scene out of the simulated situation in XML format (i.e., scene graph). The agents' behaviour is programmed using activity graphs which facilitate the connection to animation combinations due to the already structured behaviour program. SeSAm has the overall control of the model's behaviour transferring information to the game engine. A buffered socket communication using a string-based protocol offers a solution to the synchronisation problem given that the simulation runs faster than the VR system. The data communicated contain information related to both the entities populating the simulated world but the environment as well. In every update information regarding each relevant entity's position, orientation and activity with tags already connected to animations. Similarly, information about the environment states changes or other events (e.g., creation or removal of agents), are also sent by the simulation platform. Several experiments where performed in different application scenarios such as a 2D evacuation scenario and a 3D boids example with variant number of individuals [17]. The overall outcome was very positive yet there are still several challenges to overcome before proceeding to the evaluation of the immersive face validation as validation technique.

V. Related Work

In this section we are going to present a comparative view of our proposed validation framework to other related work.

Face validation is very much associated to the use of human experts in the life cycle of agent-based simulation. We have seen in section II the association and use of domain-expert/stakeholders through the paradigms of participatory simulation and role-playing games where domain-experts are participating and interacting in the simulated environment with the purpose of feeding with better input for modelling. Our vision is somehow different in that sense and much more similar to Pelechano et.al [12] as we only aim at evaluating the plausibility of the simulated model. However Pelechano et.al in their work try to evaluate the model's dynamics by measuring the level of "presence" users reached in their immersion to the VE whereas we rely in human expertise, perception and intelligence.

Later developments in microscopic pedestrian simulation produced an increasing need to provide detailed spatial representations in physically simulated 3D worlds, as a method to increase transparency and visibility on generic multiagent simulation platforms such as Repast[3] or MASON[4] which embed Java3D into their simulation platforms. Our approach here is different as we aim at simplifying the modeller's tasks and hide all the increased complexity of handling the 3D visualisation engine. In the early 2000s, the breve[5] platform has been developed. It has been recently extended with the simple programming language "steve" which is comparable to the language used in NetLogo for supporting inexperienced programmers in using the 3D simulation platform. However, besides not really being agent-based, a clear separation between visualisation and model representation seems to be difficult.

The combination of virtual worlds and simulation is also prominent in crowd simulation [19], [20]. Hereby it is important to mention that our main consideration is to provide a solution that doesn't relate in any specific application domain but rather maintains a generic character as much as possible. Several agent architectures have been used with graphic engines or game engines were used as means for combining the reasoning capabilities with 3D representation and visualisation and rich environments [21], [22]. In our case however, the game engine is responsible only for supporting the creation of the virtual reality environment and drive the dynamics of the simulated multiagent model situation.

There are in the literature several middleware solutions such as Pogamut [23], Gamebot [24] or CIGA [25] trying to create an interface for agent-based simulation and virtual reality. From a technical point of view, our proposed framework follow similar principles with the one of Oijen et al. [25], who consider the coupling of the two systems and not their embodiment. Nevertheless their vision is to use/include BDI agents in 3D game engines for building intelligent behaviour and here exactly lies the main difference to our approach. We consider this combined system as a helpful tool to evaluate the model's dynamics. Similarly, Vizzari et al. [26] present in their work a framework for visualising crowd simulations based on interacting situation agents. When compared to our solution, they do not handle the synchronisation issue but they rather reduce the simulation's speed so as to visualise properly the simulation's dynamics and maintain consistency.

VI. Conclusion and Future Work

In this contribution we proposed immersive face validation; a new validation technique for plausibility checks in agent-

[1]SeSAm: http://www.simsesam.de

[2]Horde3D GameEngine: http://hcm-lab.de/projects/GameEngine

[3]Repast: http://repast.sourceforge.net/

[4]MASON: http://cs.gmu.edu/eclab/projects/mason/

[5]breve: www.spiderland.org/

based simulation. We have seen that despite the importance of validation in the life cycle of simulation several issues related to the multiagent system paradigm such as lack of empirical data, limit the range of applicable techniques.

Later we touched the issue of interfacing on-demand an agent-based simulation with a virtual reality system is tackled in a prototype that supports the realisation of our validation process. The current setup though solves only half of the problem as it doesn't consider a higher level of immersion for the evaluator (i.e., human-agent). The overall complexity rises significantly as the behaviour of the human would affect the behaviour of the simulated and visualised agents at a time when the simulation run is actually at a completely different time step. Information flow back to the simulation platform is hereby critical. A descriptive example is the handling of collision avoidance in a boids scenario [27] with a human observer regarded as obstacle. Agents in the simulation may avoid the human observer. Yet how the situation can be affected when a mobile human in the virtual world initiates changes? This question is not answered yet and will be a major task in our future work.

Finally, the actual implementation of the proposed framework is currently in our focus. Testing and evaluation of the deployed system is also an important step in the coming work. The framework is going to be tested in different scenarios (i.e., simulation models) with different numbers of agents/characters.

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