# VISUALIZATION TECHNIQUES FOR SIMULATION MODELS IN VIRTUAL REALITY

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**ABSTRACT**
The aim of this paper is to merge simulation modelling and virtual reality technologies more deeply together. There are lot of platforms in field of simulation modelling which provide acceptable three dimensional capabilities and more flexible visualization properties to ease the understanding of the results of simulation model. However virtual and augmented reality technologies must be considered as well, because their development in last decade is strongly considerable and could improve perception. To hand the results or the process of simulation model to people, students or trainees in easy understandable and interactive way could be a great challenge. Thereby the researcher team of Virtual and Augmented Reality laboratory of Vidzeme University of Applied sciences develop new methods for basic 3D data depiction in virtual and augmented environment. Petri nets based modelling and notation could be appropriate and most comparable to functional block diagrams and parallel processes which are organized in scenarios of virtual reality systems. If transformation between these two technologies could be achieved, then successful approbation in different scenarios could open new possibilities in education and wide use of simulation modelling.

Keywords: virtual reality, augmented reality, Petri Nets, NetLogo, simulation modelling, visualization

## 1. INTRODUCTION

The history of necessity to merge real and virtual environment is longstanding, however definitions are formulated just in last decades. If the first approaches of mixing real and virtual appeared in cinematography in 1950s, then definition appeared only in 1997 by Azuma. History facts are summarized by Kent [2011], and the first entry devoted to cinematographer Morton Heiling, who created Sensorama simulator in 1957, this simulator was patented and provided visuals, sound, vibrations and smell. The AR term appeared only in 1990 by Tom Caudell whose work was related to aircraft maintenance works. Azuma's definition [1997] in 1997 prescribed AR as combination of real and virtual worlds in 3D with real-time interaction capabilities. Despite this definition, most of nowadays AR applications still offer real worlds augmentation with two dimensional data. Most of applications from Google Play and Apple's App Store for Android and iPhoneOS based smartphones and tablets provide two dimensional information. For example, text or image based descriptions or instructions, navigation arrows and instructions, or poorly interactive marker solutions with 3D object integration. Rapid growth of mobile devices usage and also technological leap of supported features makes professionals to think over new solutions in different economic sectors. Modern mobile and entertainment AR systems use one or more of the following tracking technologies: digital cameras and/or optical sensors (Nintendo Wii, Sony PlayStation Move, Microsoft Kinect), accelerometers, GPS, gyroscopes, solid state compasses, RFID and wireless sensors. These technologies offer varying levels of accuracy and precision. By Kent's literature analysis [2011] most important is the position and orientation of the user's head. Tracking the user's hand(s) or handheld input device can provide 6DoF interaction technique. In Furht's turn [2011] performance is relevant consideration. In spite of rapid advances in industry of mobile devices, their computing platform for real time imaging applications is still rather limited if done using cell phone's platform. As a result, many applications send data to a remote computer that does the computation and sends the result back to the mobile device, but this approach is not well adapted to AR due to limited bandwidth. Nevertheless, considering the rapid development in mobile devices computing power, it can be considered feasible to develop real-time AR applications locally processed. This Furht's conclusion [2011] confirmed a choice for AR pilot product use the tablet PC with camera and already integrated sensors. More immersive solution with Vuzix AR HMD will be developed after development of theoretical model and working portable tablet solution. The usefulness of mobile devices use is also affirmed by Lee [2009]. Mobile computing devices have been widely deployed to customers; the interest in mobile AR is increasing. As the need for mobility is growing, computing devices shrink in size and gain acceptance beyond an audience of tech-savvy specialists. With the help of enhanced computing power, small devices have sufficient computational capability to process complex visual computations. For example, a cell phone with a camera and wide screen can serve as an inexpensive AR device for the general public. Emerging wearable computers are also excellent platforms for enabling AR anywhere users may go.

## 2. PROBLEM AREA AND GLOBAL PRACTICE IN CONTENTS VISUALIZATION

Today, image processing and computer vision technologies have been progressed to a stage that allows us to infer the 3D information of the world directly from the images. Because of the success of these technologies, more and more vision-based AR applications are emerged. Augmented reality refers to the combination of virtual objects and real-world environment, so that users can experience a realistic illusion when using the interactive virtual object to explore the real-world environment (Kan et al., 2011). Several technologies and approaches of augmented reality implementations are available today. These technologies can be divided in two basic groups: marker-based systems and marker-less systems. Kan et al. [2011] explains marker-based systems by use of specific marker for 3D tracking and positioning. This marker is employed to identify the corresponding virtual object that is to be placed in the real-world environment. When the marker is used as a tracking target, it has to be registered in the system in advance, as well as the virtual objects it associates with. However, since the registered information is independent for different AR systems, markers used in one system may not be applied in another system, unless an additional registration procedure is applied. For that reason in effective way RFID technologies could be used. Ginters et al. [2011] introduced *AR-RFID* low cost visualization solution for logistics. To visualize the items in the storehouse which must be moved to assembly bay the *AR-RFID* solution is used ensuring additional possibilities of checking. That allows reducing the amount of potential errors and diminishing possible losses. RFID scanner reads the component code and 3D model of the item is visualized on the screen. *AR-RFID* by Ginters et al. [2011] eliminates the problem of generating an equally stable and recognizable fiducial marker, because single marker is used only for tracking, not to recognize the 3D model. This makes it possible to use single marker with the highest stability. To identify the 3D model, an identification code, which is read from the RFID tag, is used. The 3D model is found using the identification code and displayed on the screen of the tablet PC. As well considerable marker-based version is described by Kan et al. [2011] how traditional fiducial markers are replaced by QR codes, allowing to use AR in public domain systems. The QR code can be easily generated by any user and the AR system can track it no matter what the information it embedded. Thanks to *FullHD* video cameras and increase of computing performance, it is easier to pull down traditional marker restrictions, Seac02 company offers in its authoring platform LinceoVR to use self-taken photos as markers, providing limitless object-marker alignment options also solving the problem with fiducial marker hiding, which sometimes influences immersion level, if it is visible.

The second AR technologies group is based on marker-less solutions, meaning that marker-less pose trackers mostly rely on natural feature points which are visible in the users environment. Four requirements are summarized by Herling and Broll [2011] to allow accurate pose determination from natural points. These requirements are as follows: fast computation time, robustness with respect to changing lighting conditions and image blurring, robustness against observation from different viewing angles, scale invariance or changing viewing distance. Numerous feature detectors have been proposed providing different properties concerning detection robustness or detection speed. Herling and Broll [2011] divides exiting detectors in two classes: corner detectors spotting corner-like feature, blob detectors not spotting unique corner positions but image regions covering blob-like structures with a certain size.

If nowadays visualization technologies get more and more advanced and realistic in different environments, then also importance of visualized contents must be considered as well. It is coming more and more difficult to construct intelligent environment with highly intelligent contents. Despite complex scenario trees and operation matrixes, simulation modelling is a key to a truly intellectual and realistic content of the virtual environment. Lots of nowadays simulations modelling tools already evaluate three dimensional graphics to visualize results of the model and to make them more perceivable also to unprofessional auditory.

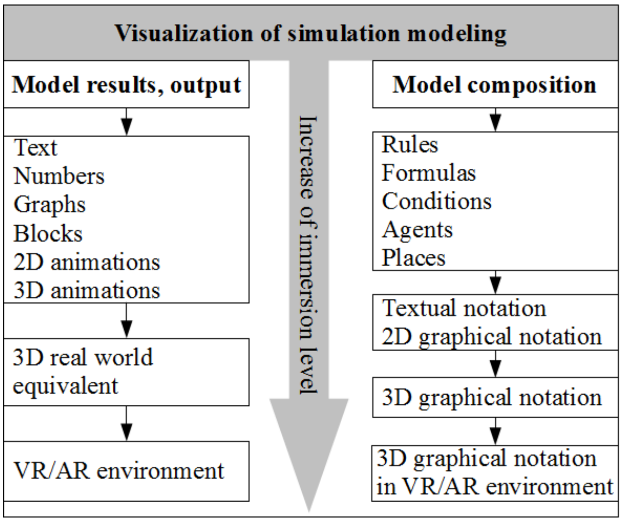


Figure 1: Visualization domains for simulation modelling

In figure 1 virtual and augmented reality is presented as even more immersive environment comparing to typically animated 2D and 3D objects. Thus brings the idea to next step not only to visualize results of the simulation model but also make more immersive the composition process of simulation models (see fig. 1) with 3D graphical notation carried out in VR/AR environment. In this paper NetLogo and Petri nets experience is used to analyse theoretical aspects and chances in usage of VRAR technologies in field of simulation modelling.

## 3. CHARACTER RECOGNITION IN VR/AR ENVIRONMENT

As the test platform TemPerMod simulation model will be used. The model TemPerMod is created in the NetLogo environment. NetLogo is a multi-agent programmable modelling environment for simulating natural and social phenomena. The agent-based model TemPerMod consists from three levels, where first level is that the specialist could change corresponding attributes to every temperament type. That is, he or she can adjust such attributes: figure, colour and activity from predefined list. As depicted in top of figure 2, the modelling desktop has the form of a square and it is divided in four frames. In each frame has equal amount of the agents, which have the same form and colour. At the beginning and the end of simulation session applicant has to answer some questions, which are provided using a popup. This type of simulation is very useful for identifying person's temperament, because it takes less time than executing a long traditional type test. Results from the NetLogo model "TemPerMod" is matching person's temperament type better than results from traditional tests (Lauberte, Ginters and Cirulis, 2010).

In bottom of figure 2 is depicted future evaluation of model which will improve test results and solve problems with users' patience during the test. For interactive final questions data glove or motion recognition for object selection will be used. Depending on runtime conditions Vuzix head mounted display can be used in virtual reality (VR) mode or in augmented reality (AR) mode. If surrounding is too disturbing then VR mode with predefined virtual environments can be loaded, otherwise AR mode can be more entertaining and immersive but effect on test results in both modes needs to be analysed.

For present TemPerMod model during the modelling session every type of agents (geometrical objects) moves with different speed of motion and step by step they eventually bounce into inner quadrant. There they take a random spot and stop till beginning of next cycle. The length of the modelling session is over 100 cycles, where one cycle continues eight to ten seconds. Agents change shape, colour, behaviour and position in every cycle. During the modelling session also ten phrases in written form are announced. The phrases change on screen at every tenth cycle. Full modelling session takes approximately 20 minutes. At the start and at the end of modelling session, applicant is prompted some questions and is asked to input some information about himself, but the end of modelling session applicant has to answer to questions about preferred agents, colour, activity and phrase on the screen (Lauberte, Ginters and Cirulis, 2010).

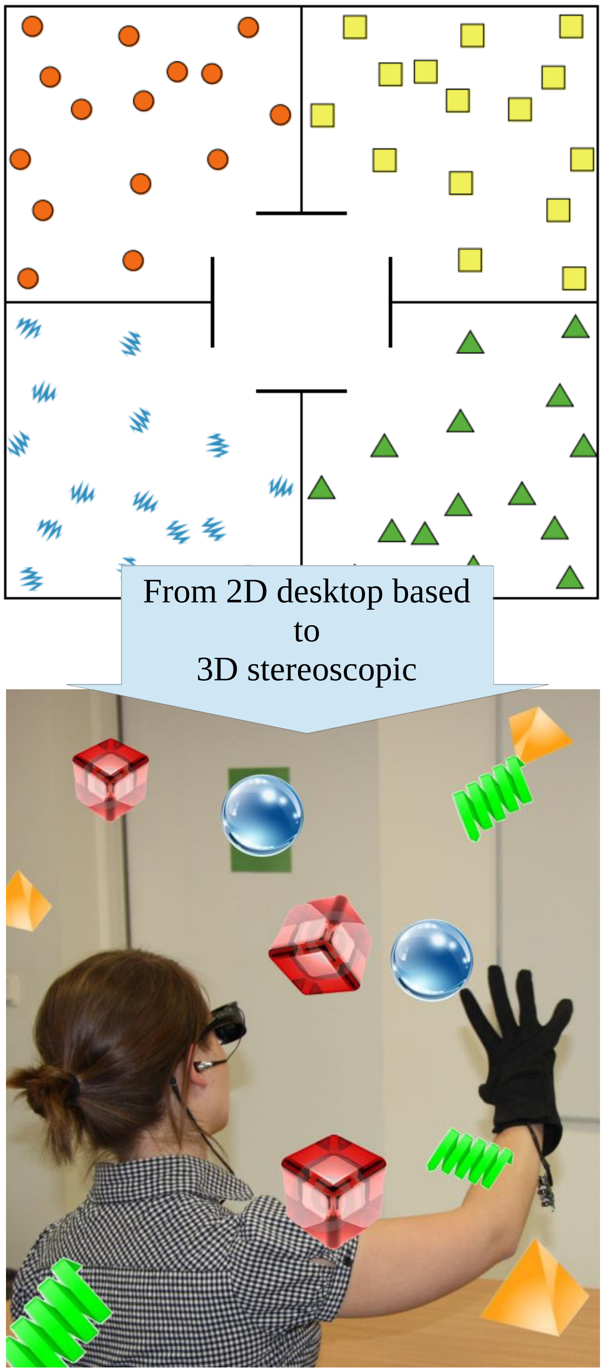


Figure 2: TemPerMod in 3D augmented and stereoscopic environment

To achieve working environment in this paper Virtools VR/AR platform is considered as effective platform which integrates support for many VR/AR devices. As depicted in figure 3 estimated flowchart data from NetLogo environment should be collected by development of TemPerMod procedure converter software module for Virtools platform. Also NetLogo exports can be used to collect data in temporary files during simulation runtime. Depending on variables used in TemPerMod and users FOV (field of view) 3D space is constructed in form of global and local coordinate system. Then comes 3D object generation phase where count, size and random location is defined. Colour is assigned with glass type shaders or typical colour codes or predefined coloured textures can be used. When the virtual world is designed the simulation must be run for predefined amount of time. 3D objects transforms, rotates in provided space and changes their colour during predefined phases. Such hypothesis is also considered that in VR/AR environment the necessary simulation time can be decreased to get the successful results.

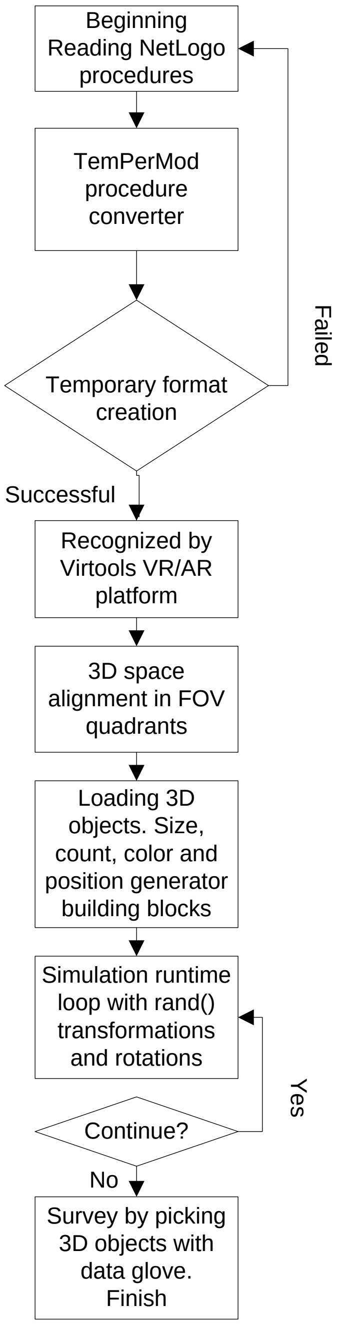


Figure 3: Flowchart for 3D stereoscopic TemPerMod

The final survey form is improved with interaction with 3D objects and audial questions and voice recognition for answer analysis.
The following section will introduce visualization for Petri nets which are also used in simulation modelling.

## 4. PETRI NETS IMPLEMENTATION IN VR/AR ENVIRONMENT

Petri nets provide a mathematically defined approach to specification, project, analysis, and verification, performance assessment for systems of parallel and distributed processes. They offer not only accurate semantics and a theoretical foundation but also a graphic form that facilitates the understanding of information and management flow within the same formalism. Petri nets are also utilised in various applications because of the intuitively attractive graphic form in the depiction of different diagrams. Data transmission networks and other communications networks – from telecommunications to internet-based services – are characterised by distributed operation and form systems with concurrent components (WoPeD Petri Nets, 2012).

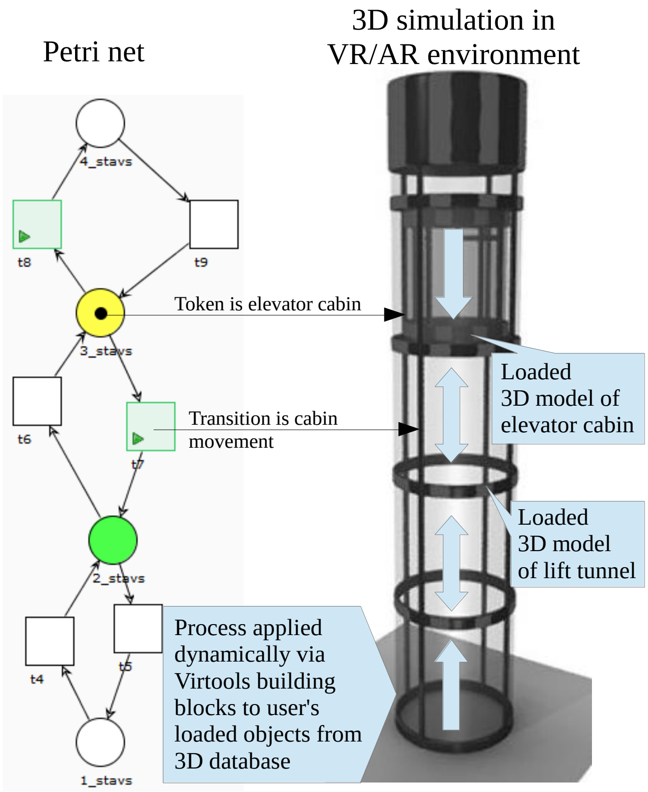


Figure 4: Elevator Petri net look in VR/AR environment

In VR/AR laboratory Petri nets were used to model the operating framework of the method, which is based on dynamic selection of device sets during the training process, using the trainee's individual personality type as the foundation. Petri net algorithm was developed for the enhanced training method and for the location of the most suitable devices, as well as suitability index matrices of devices and device sets, based on which the selection of devices takes place (Cirulis, 2011).

The author used Petri net modelling to explore the nature of the method so that it could be implemented in a real, existing VR/AR authoring platform. There is a possibility of also using UML (Unified Modelling Language), yet UML notation describes aspects of the programming system (from requirements to implementation) from various points of view, whereas Petri nets are fundamentally intended for modelling dynamic system behaviour, but they are also to some extent comparable to UML state and activity diagrams.

In this case classical Petri net for elevator operation is used to explain the idea of result depiction in VR/AR environment (see figure 4). As summarized by Kindler [2004] there are several solutions and tools which provide visualization for Petri net structures. Tool ExSpect uses the concept of dashboards in order to visualize the dynamic behaviour of a system in a way that is familiar to the experts in the application area. Mimic library of Design/CPN allows a Design/CPN simulation to manipulate graphical objects, and the user can interact with the simulation via these graphical elements. GenGED tool for visualizing Petri nets based on graph transformations and their animations. PEP is one of the first Petri Net tools that came up with a 3D visualization of Petri net models where SimPep triggers animations in a VRML model while simulating the underlying Petri net (Kindler, 2004). Kindler successfully visualized Petri net of toy train system in 3D. Lots of principles offered by Kindler for behaviour animation and geometry functions will be used in VR/AR approach for Petri nets (see figure 5). Instead of Petri net kernel, XML and VRML models WoPeD tool's source code is used to develop daemon process for data delivery from token game to Virtools. WoPeD's coverability graph is also exported to prepare matrix of 3D objects' values for determined scenario. These values include information on 3D objects' sizes, scaling, transformations and rotations. For Virtools platform two building blocks are developed by SDK to achieve functionality of data receive from daemon process and adjustment of 3D objects behaviour values which are necessary during the simulation session. As this is the very beginning of the project, more detailed workflows will be presented after development of this approach.

By development of 3D visualization for Petri net with technologies mentioned above, it gives varies of ways and looks to run the simulation. Virtual reality gives opportunity of immersion, e.g. instead of watching 3D simulation on a monitor you can be in the virtual elevator cabin and see the world from other perspective. This brings us to a reverse approach by which the token game is driven by actions in virtual world. In elevator case the VR participant presses buttons in cabin and the model professional receives information through a model (figure 5). In the beginning it could be easy and interactive way for editing exiting models rather than for development of new ones.

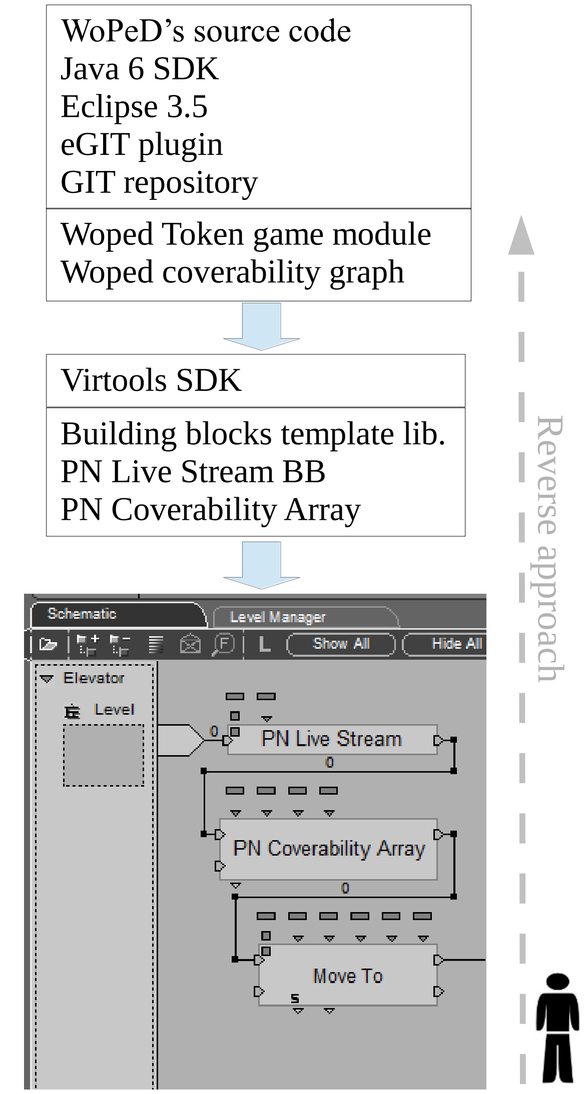

Figure 5: Technological approach for Petri net VR/AR visualization

## 5. CONCLUSIONS

Logics of visualization for different simulation modelling tools are different but technical realization and tools can be similar. As VR/AR platforms are complicated and contain plenty of other tools, then best and cost effective way is to use VR/AR platform with software module development capabilities. By provision of VR/AR environment for simulation models also non experts of the field can perceive information in understandable way. In these paper ideas and possible realization ways were introduced for NetLogo simulation model and Petri net model.

Interesting aspect was brought also in figure 1 and figure 5 offering simulation in interactive way by use of VR/AR technologies. 3D graphical notation for Petri nets was introduced by Dance already in 2001. Also reverse approach of simulation modelling or simulation model editing must be seriously considered in future research. Dance [2001] also confirms that it is more effective and easier way to convey the structure of a physical object in 3D space using 3D objects than it is to do so with a 2D symbolic representation, or, a text description, or, a mathematical representation.

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