Requirements Model of Sociotechnical Systems Simulator Architecture

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Abstract. To avoid any voluntary decisions it is desirable to examine the possible consequences that can be done by simulation. Unfortunately there is no unified methodology and technology for simulators designing. Above mentioned problem when development of each simulator has to be started from the scratches makes elaboration expensive and cumbersome. The article dealt with the way to joint understanding of simulators designing concept.

Keywords: Heterogeneous and distributed simulation · Agent-based models · Requirements model

1 Introduction

Real sociotechnical (humans and/or nature and technology) system as a target object is heterogeneous, complex, stochastic and also subject of cognition and evolution, which determines heterogeneous, distributed and often incompatible model usage within the same working session. Decision making scenarios are determined by a wide range of relevant factors, whose values are difficult to identify. During the EC FP7 project FP7-ICT-2011-7 FUPOL No. 287119 (2011–2015) "Future Policy Modeling" it was found that there is no unified heterogeneous simulator architecture concept that meets the target object requirements and would be implementable on a web-services-based SOA environment [1–3].

Methodology of further research is based on analysis of different architectures of existing simulators respecting basic requirements of sociotechnical systems.

Provided article is an attempt to define the set of typical requirements, i.e. unified concept of sociotechnical systems simulator architecture.

2 Simulator Technologies Development

Simulator architecture is prescribed by both development of software engineering and social factors which determine tasks complexity, heterogeneity and stochastic content.

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The more accurate and credible modeling result is asked the more complex will be simulator architecture.

The way of architectures development from standalone till distributed and heterogeneous environments was fast. Nowadays simulation becomes a business tool which could be used on the Future Internet as SaaS solution, therefore the requests for universal concept of simulators architecture becomes increasingly topical.

Simulation models are different and must fit to goal system essence. Therefore discrete-event (DEVS), system dynamics (SD), agent-based (ABM) and some other approaches can be used. Even more simulation tools and data exchange protocols and formats are different. The question how to combine together different models is still actual and very important.

In the beginning of the 21st century client-server access was offered introducing SQL query analogues (SimAL/SimQL) [4] and wrapping simulation models.

The proposed solution during 15 years did not gain wide acceptance, because asking for SimQL interface designing and synchronization of all parsing/processing steps was problematic. It looks that simulation tasks are too complex to use approach similar to requesting to databases.

From 2008–2011 the group of scientists tried to design Simulation Highway [5] - common approach and rules to deploy, access, join and exploit the different and heterogeneous simulation models in distributed environment on the Future Internet and Cloud. The choreographies were used instead of centralized distribution of resources.

It was defined that simulation requests address a set of simulation cells organizing highway for appropriate task during the simulation session. Each simulation cell operated as a server and simultaneously as a switch so that various simulation models that are registered to the cell and participated in the decision making task can be connected to the simulation highway of the task.

Unfortunately the attempt was unsuccessful because the highway designing asked for a new specification language, but then the models wrapping or decomposition of already validated models were predefined. One of important reasons of failure also was absence of comprehensive requirements concept which determines the set of necessary functionality of models communication environment. So, the unified concept of heterogeneous simulator architecture still not exists but usually HLA technology is used [6].

3 Requirements Model Design

The architecture of sociotechnical systems consists of logical and physical structures. Logical structure involves guidelines, rules, algorithms etc., which create the requirements model for physical structure implementation. Physical structure is hardware and software served as environment for running the tasks of logical structure (see Fig. 1).

Hence the main is logical structure caused by society (social factor) pressure. One of reasons of previous failures related with simulators universal architecture design was shortage of unified requirements model.

Further let's discuss the architectures of some existing simulators.

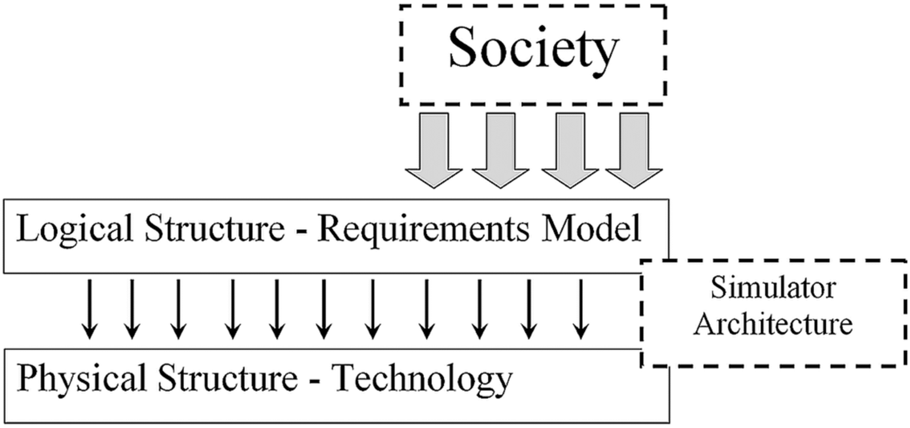

Fig. 1. Structural model of simulator.

3.1 Skopje Bicycle Inter-Modality Simulator

Skopje Bicycle Inter-modality Simulator [7] was created to find useable solution for bicycle station and track location in the City of Skopje. The citizens were also involved in the collection of ideas on how bicycle inter-modality can be fostered. The citizen participation was supported by simulation and e-ticketing.

The relevant elements of the Skopje Bicycle Inter-Modality model were the profiles of the people, the stations along the city and the tracks between stations. The profiles were used to generate the agents. They indicated a population percentage depending on the type and the age.

After validation the concept the simulator based on ABM/MAS in Repast Symphony environment was designed. The main task of the simulation was clarification what must be the bicycle paths network to move as many as possible citizens from other kinds of transport to bicycles. Communication with the citizens was implemented by e-ticketing, but parameters of routes and simulation results were stored in PostgreSQL databases. During simulation significant amount of data was gathered. To ensure usability of data the semantic analytics and visualization tool SemaVis was applied [8].

3.2 VeloRouter - Dual Use Bicycle Path Network Designing and Exploiting Simulator

The ABM/MAS bicycle path network and exploitation simulator (VeloRouter) [9] was designed in the Repast Symphony environment and uses OpenStreetMap spatial data. The product has dual applicability as it is adapted to both the needs of municipalities and cyclists. Each agent is a cyclist or a group of cyclists that move on a chosen route considering route occupancy, traffic restrictions and the quality of the route.

VeloRouter provides municipalities with bicycle path discussion, voting and geofencing opportunities by receiving feedback from cyclists directly and by interviewing.

VeloRouter user authentication and authorisation is ensured using social networks: Facebook, Linked-in, Twitter, ResearchGate etc., given that cyclists are avid users of social technologies, whereas municipalities have the option to use individual registration options.

VeloRouter has two representatives of audience: municipality and cyclist (see Fig. 2). The municipality is interested in some basic question: Is the offered cycling route map satisfactory? This is determined by summarizing potential comments during project deliberations. The second question is: Which potential cycling route sections should be built first? The cyclists want to know what the occupancy of a route will be in certain weather conditions on a specific date, as well as if the route is suitable for the group i.e. terrain etc.?

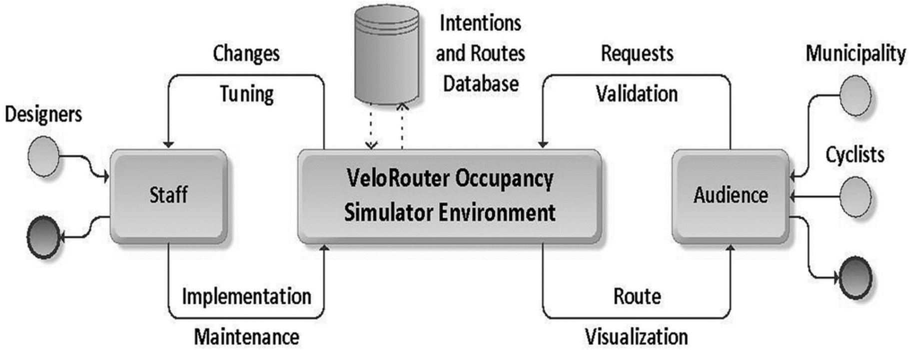

Fig. 2. VeloRouter requirements model.

Occupancy simulation provides monitoring of bicycle path network development scenarios and can influence planning. Critical in current model was significance of data stored in Intentions and Routes Database, which depends of data credibility, deterioration and quantity. It was recognized that gathering of data credible enough is problematic without semantic search in social networks. This is important also for validation of simulation models.

3.3 Man Health Early Awareness and Easy Diagnostics Simulator (He-Man)

The goal of He-Man project is to promote the goals of Latvian Research and Innovation Strategies for Smart Specialisation (RIS3) in interdisciplinary field of information, communication and medicine technologies. He-Man is developed in collaboration between Riga Technical University and University of Latvia. As a result of the project development conceptual and functional models of heterogeneous and distributed sociotechnical system simulator architecture are being researched. He-Man demonstrator is based on new semantic diagnostic methods and is a testbed for the innovative simulator software design technology validation. Project promotes usage of smart technologies related with preliminary diagnostics in situations when there is lack of access to health care (see Fig. 3).

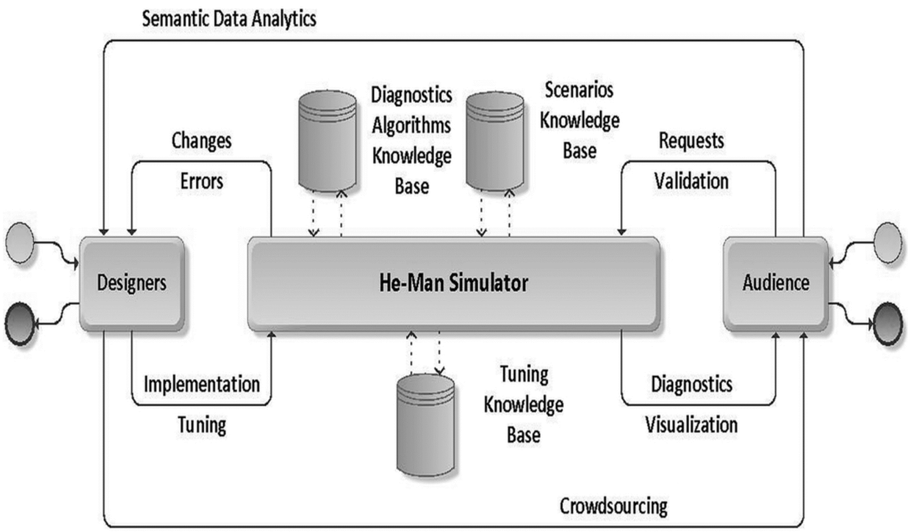

Fig. 3. He-Man requirements model of simulator.

The circumstances of diagnostics is based on observable indications (temperature, pain, secretions etc.) and the corresponding thresholds. The set of possible diagnosis is calculated by observed indications with a certain probability. For each diagnosis there is defined a set of recommendations and prohibitions, that can sometimes be too much for the patient to be able to accomplish. Each of the elements in the set has its own weight that determines its relevance. The simulator can examine all the possible recommendations-prohibitions scenarios included in Scenarios Knowledge Base by modifying them according to Tuning Knowledge Base. As a result the patient receives multiple tuned scenarios, ordered by priority, because execution of the whole recommendation set is impossible.

Architecture of simulator is based on web-service and SOA. Interoperability is provided by Easy Communication Environment (ECE) [10] or in more complex cases HLA [6] is used.

He-Man heterogeneous simulator architecture model involve two types of parallel and interacting actors, who personify users (Audience) and developers (Designer):

- Designers – (Simulator Developers). He-Man information system developers: medical and social sciences professionals, knowledge managers, software engineers, modelers, business and marketing professionals;
- Audience – (Service Users). Service subject, i.e. persons, for whom face-to-face consulting with medical specialists is now limited, but who has Internet access. Audience can also be social network users. Audience can be with different social/ financial and marital status, cultural environment/origin, as well as place of residency/region;
- He-Man Simulator – (Simulator). Heterogeneous ABM/MAS/SD based open source modeling software, that provides Audience request processing on the Internet,

providing results of potential illnesses diagnostics by specifying the recommendations and scenarios according to Audience specific factor set, as well as realizing semantic visualization of modeling results;
- Diagnostics Algorithms Knowledge Base - (Main Knowledge Base). Knowledge and ontology based easy diagnostics and early warning algorithm set, that provides diagnostics according to indications and potential risks (in conditions of limited information);
- Scenarios Knowledge Base - (Knowledge Use Scenarios Base). Set of interconnected scenarios, that determine further action of Audience with certain probability;
- Tuning Knowledge Base - (Simulator Tuning Knowledge Base). Appropriate attributes set of Audience is used for scenarios tuning by changing action probability values. One of information sources is semantic search. Attributes for He-Man demonstrator can be age, temperament, social status, typical diagnosis, possible diagnose, financial capabilities, marital status, national/traditional features etc.;
- Validation - Determination of simulator operational compliance based on semantic search of Audience data (crowdsourcing) in social networks in particular region, as well as analysis of the data;
- Visualization and Virtualization - Adaptive and semantic modeling results representation suitable for Audience comprehension.

For the notation of diagnostics algorithms ONTO6 methodology is used, as it provides systematic clearance of fundamental concept for specific domain and formalization in form of web ontology language OWL. As software designing environment for the knowledge base interface visual ontology editor OWLGrEd [11] is used. Above mentioned tools allow to develop open source solutions in OWL language un provides compatibility with He-Man software. Interface are developed based on suggestions that are mentioned in publications about human-computer interface [12] by involving users themselves in the development and evaluation [13] of the interface.

Simulation model tuning principles are based on factor values [14] and law adaptation.

Basic data source for model tuning is Tuning Knowledge Base, that is mainly filled with information from semantic search. Semantic search of information is based on Solr [15] that ensures wide functionality, geospatial search, Java based environment for new functions development, high reliability, scalability, load balanced queries and etc. Above mentioned solution anticipates information extraction as JSON, XML, CSV etc. that ensures comfortable enough and effective collaboration with chosen knowledge base organizing technology.

One of the main components of He-Man simulator is adaptive and semantic visualization and virtualization of simulation results. It is important for each user to receive information in the form appropriate to his professional understanding and perception. Currently, built-in tools with limited functionality mainly are used to display simulation results. Still a valid concept of visualization and virtualization of simulation results on the heterogeneous and distributed environment is problematic. Existing solutions do not ensure visualization adaptation to the user's domain. To correct this a semantic data analysis is implemented. D3 and InfoVis [16] allows to dynamically work with semantic information, however open source solutions of semantic visualization are limited [17].

Also the ideas of commercial solutions such as SemaVis [8, 18] are used under He-Man framework.

For He-Man heterogeneous and distributed simulator architecture dynamic and static [19], as well as formal validation [20] method sets are used.

4 The Concept of Simulator Unified Requirements Model

Previous research and industrial projects experience allows to offer the following requirements model (see Fig. 4):

- Staff - represented by designers and administrators;
- Audience - users, which authentication is carried out through social networks;
- Simulator - multilevel, heterogeneous and distributed with ABM/DEVS/SD models support, based on web-services and SOA;
- Models/Algorithms Knowledge Base - web ontology language OWL or compatible can be used;
- Attributives Database - SQL based for storing of simulation initial data, parameters and results;
- Significance Assessment - regular and automatic credibility, deterioration and quantity evaluation;

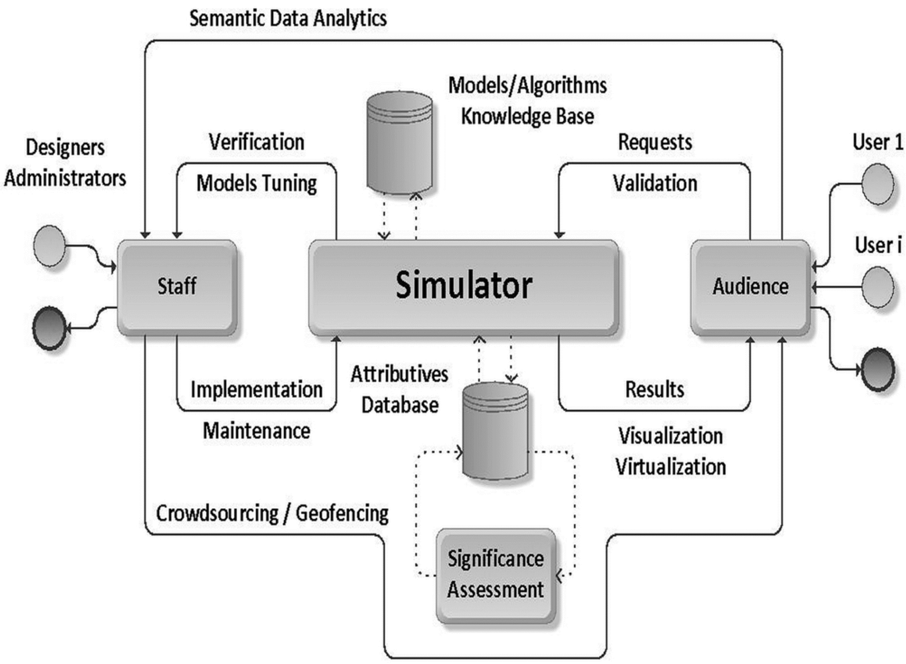

Fig. 4. Requirements model of unified simulator architecture.

- Crowdsourcing/Geofencing - semantic search in social networks and in predefined region;
- Semantic Data Analytics - semantic analysis of gathered information;
- Validation - statistical and face validation, based on the quantitative results and social measures;
- Verification - initial and after tuning debugging of simulation models;
- Models Tuning - simulator adapting based on semantic search and specific initial conditions;
- Visualization and Virtualization - to users domain adapted semantic visualization and immersive virtual and augmented reality use.

The requirements set mentioned above is just basement and does not exclude involving other specific demands. The requirements create the base of simulator logical structure and determine the selection of appropriate physical structure or technology.

5 Conclusion

Sometimes systems designers forget that the time when functionality was attuned with technologies capacity is already passed. Nowadays direct influence of society determines the ways of technologies development. Perhaps this is one of the reasons why discussions about Future Internet are so long.

Designing of simulator architectures is not exemption because it must be sustainable. Today it is clear that architecture must be based on web-services. However the architectures already predesigned for the time being does not convince. Few unified solutions exist therefore designers rarely use prototyping and too much resources are spent for designing new simulators of the scratches. The same time HLA despite of complexity is used for distributed models engineering.

One of the reasons why efforts in unified architecture designing are bootless is shortage of joint requirements concept, which is the aim of the authors efforts.

The amount of stored information in the world is growing day by day, but it is not so clear how to use it. Big Data activity is one of attempts to solve this problem. The same situation is typical for simulation where quality of the results is based on initial data, but data tends to become obsolete. Especially important is credibility of data, but interviews sometimes are not true source of information. One of the solutions is semantic search in social networks. Although analysis of the results is not easy in this case the credibility is higher. For the reasons mentioned above data significance calculation is important to provide adequate modeling results.

All the customers are interested in reducing of software designing and maintenance costs because expenses of technological solutions introduction exceed expected profit. Requirements to software intelligence are growing. It is asked for ability of software adapting by domain specialists without specific knowledge in software engineering. This determines complicated mechanism of verification. The same time the requirements to visualization of simulation results are growing. Important factor is development of virtual and augmented reality solutions which are used not only for visualization the results, but also for designing of simulator desktops.

The simulator requirements model provided can be considered as base for further research and development.

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