

# Augmented Reality in Collaborative Virtual Environment for Discrete Event Systems Modeling and Simulation

Anderson C. M. Tavares, Maria L. P. de M. Cruz, Sergio M. M. Fernandes  
ECOMP - Computer Engineering Department  
Polytechnic School of Pernambuco - POLI  
University of Pernambuco - UPE  
Recife, Brazil  
{acmt, maria, smmf}@ecomp.poli.br

**Abstract**— The construction of complex systems requires necessary planning for its success. The Modeling and Simulation of Discrete Event Systems can help this step with analysis of functioning before the physical modification at the real world. Current Modeling and Simulation software provides several components for the creation of models, but it is necessary to change focus between real system and model when it is created. This change can damage the model validation processing. The proposal intends to show how the development of the model can be directly viewed onto the real world, by using Augmented Reality techniques, and it shows the importance of collaboration modules in this system, which can help teams of complex systems. Theoretical and practical foundations are detailed. The prototype, since the planning until the tests, are described. Results and conclusions are raised.

**Keywords**-Augmented Reality; Collaborative Virtual Environment; Modeling and Simulation; Discrete Event Systems.

## I. INTRODUCTION

The man-machine interactivity, for 35 years supported by the interfaces *Windows, Icons, Menus and Pointers* (WIMP)[1], has been presenting new communication patterns so that information is passed more comfortably and quickly as possible. However, traditional WIMP tools may not be suitable for all profiles of people.

Due to the nature of the three dimensional world we live in, the two-dimensional representation of the information may not accurately portray the elements to be observed. Post-WIMP technologies [1] can help the user interaction with computer systems, making them better understand the information through three-dimensional representation. It serves as motivation for research in the *Human-Computer Interaction* (HCI) area[2], which composes the post-WIMP technologies.

One of the technologies that have helped in the interaction between people and visualization system is called *Virtual Environment*, consisting of *Realidade Virtual* (RV) and *Augmented Reality* (AR). RV integrates the user in a virtual world generated by computer [3]. AR incorporates virtual objects in the real world [3]. According to [4], the

development of virtual and augmented reality enabled the representation of interactive and immersive imagery was more easily obtained.

The increasing complexity of computer systems requires techniques for all stages of development, from planning to final product delivery. These steps include *Modeling and Simulation* (Modeling and Simulation (M&S)), which allows the study of real systems in an abstract and simplified way, without the need for its amendment, and helps answering questions like “What happen if there were one or more scenarios?”. A **model** is a representation of a system, whether real or imaginary, is designed to reproduce the desired system. In turn, a **system** is a set of components with the function of achieving one or more objectives[5]. The simulation is running the model with parameters chosen to analyze a specific scenario.

There are mathematically formulated and proven techniques for modeling systems, such as[6]: Markov Chains, Semi-Markov Process Generalized or *Generalized Semi-Markovian Process* (GSMP), Finite State Machine Nets, Petri Nets, Queue Nets, Automata (Deterministic Finite and Non-Deterministic) Language and Formal Calculus of Communication Systems. Modeling of Discrete Event Systems, or *Discrete Event System* (DES), is focused on systems that receive events and alter their states, and is based on the above techniques. Some systems, such as fixtures, production lines and queuing systems are discrete event systems.

The DES, in this paper, are dynamic, because the states are changed over time. They are also stochastic, because the states do model uncertainty. Finally, are discrete, because the set of states assumes a finite quantity [7, p. 45-46]. There are several used M&S tools to DES[8]: Arena[9], Simscript[10], AnyLogic[11], Simlox[12], etc.. They are still poor as to represent visually a more faithful the real or the imaginary being designed, for example, in view of the model and its comparison with the real system.

## II. CHARACTERIZATION OF THE PROBLEM

To create a model in a *software* for simulation, the user views first the real world, and then view the model. In this

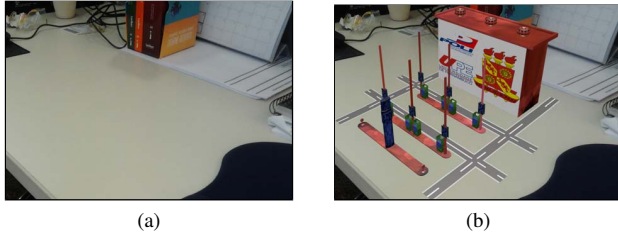


Figure 1. Study Case: (a) Real Environment; (b) Environment with 3D Virtual Gas Station

transition, the user loses focus, so it can not properly transcribe the information needed from real-world to designed model. If the view of reality and the creation of the model are integrated, the models generated could more easily be faithful to the actual models and the scenarios you want. The degree of immersion of this interaction can best be transcribed if the user starts the modeling just when you see the real world.

To illustrate this analysis, a case study throughout the paper is developed, and involves the behavioral modeling of the flow of vehicles from a gas station. Instead of going to the actual location of a gas station, it will be shown a 3D scene representing the station. The Figure 1a shows the actual environment in which will be shown the virtual gas station.

The environment shows a place to display the 3D gas station at an specific angle and to analyze its structure in order to begin modeling. The position in the virtual environment can be seen in Figure 1b. From the analysis of the system, it creates a model describing its dynamics. As an example, using the modeling and simulation software *Arena*, the result of modeling, as in Figure 2, can be run to start the system simulation.

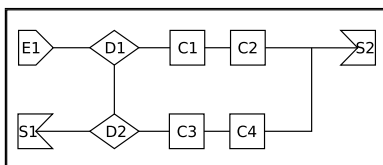


Figure 2. Behavioral Model of Gas Station

For a better understanding of the model shown, the entry of vehicles at the station is symbolized by the *generator* component *E1*. After entry, the vehicles decide to keep going to fill the gas tank, represented by the *processing* components *C1* and *C2*, or they turn right. This decision is represented by the *router* component *D1*. The diverted vehicles can still take the decision to fill the tank, represented by the *processing* components *C3* and *C4*, or leave the system by *disposer* component *S1*. Vehicles which used tank bombs leave the place represented by the component *S2*.

Given the problem, the solution proposed in this work fits

into the case study illustrated in Figure 3, a modification of the Figure 1b with the addition of the simulation model in 3D. The modeler can create the dynamics of the flow of vehicles directly into the scenario in study. The result is the better visualization of the dynamic model for simulation.

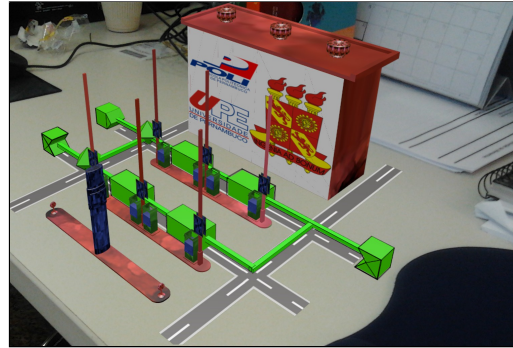


Figure 3. Behavioral Model directly on 3D Scene

You can think of simulations defined collaboratively, whereas systems of high complexity for modeling are often discussed and assembled by teams of professionals, who may have common goals or different views on the same system. This level of collaboration can be important for the model to ensure their validity in the real world. The Figure 4 displays a new version of the example of the station, along with its definition in a collaborative way, and possibly developed simultaneously by two participants in different locations of the project. On these templates, it can be made studies simulating the flow of vehicles.

With the demand for more complex systems, the need for better models and simulations leads to some questions about the above issues:

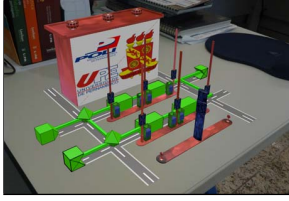
- 1) *Augmented Reality* can help the interaction between man and machine into a simulation model?
- 2) How can a model be more easily developed with manipulation metaphors used naturally by humans?
- 3) What is the degree of benefit in the implementation of collaborative modules for such a development?
- 4) How can a system with this kind have high availability and what fault tolerance techniques can be developed in the context of this environment in order to ensure reliability?

### III. GOALS

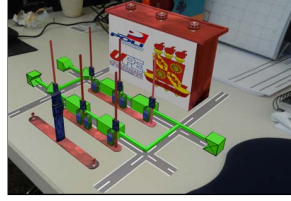
The goals are divided into general objectives and specific ones, described through targets.

#### A. General Objectives

The aim of this work is to propose a system that gives users the functionality to create simulation models in a collaborative and immersive way, using AR and version control techniques.



(a) Project viewed by person at left



(b) Project viewed by person at right



(c) Collaborative Modeling and Simulation

Figure 4. Collaboration between two people in different positions

Given the advances in virtual environments, this project has aimed to explore the integration of this area with M&S, providing a better representation of reality, thus meeting the need for more sophisticated environments.

### B. Specific Objectives

In order to comply with the overall goal, it took the establishments of intermediate ones, known as specific in order to organize the goals and facilitate understanding of the evolution of the project during its development:

- Gathering information for understanding the fundamentals and state of the art of the areas involved in the project;
- Proposing an improved interface for visualization and interaction of simulation models using AR;
- Describing and demonstrate techniques of versioning in the modeling process;
- Exploring features of computer networks and propose a collaborative virtual environment system;
- Suggesting future work based on the proposal.

To achieve each specific objective, the following goals were established, to facilitate project development and evolution of a system to M&S, which demonstrates the power of AR as a new form of user interaction developer, while contemplating the creation of projects in a collaborative manner:

- **Target 1:** planning and design of the system that helps in the area of DES M&S;

- **Target 2:** development of the interface which displays the three-dimensional environment for creating simulation models in augmented reality;
- **Target 3:** insertion of fault tolerance capabilities to raise the potential output in critical situations;
- **Target 4:** development of capabilities for modeling collaborative systems;
- **Target 5:** testing and generating results for validation of the proposal.

### C. Strategy Adopted

To achieve the proposed objective, it was set up a strategy to integrate different knowledge areas: modeling and simulation of discrete event systems, augmented reality, collaborative environments and fault tolerance. The mental map of Figure 5 shows the relationship between the areas used at work, in order to define the necessary scope for the project.

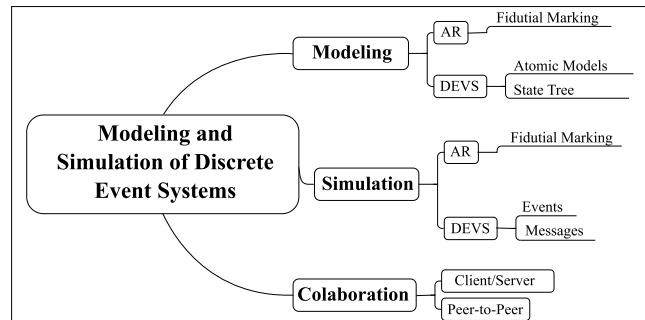


Figure 5. Relation between areas of project

The focus of this study was defined in the area of M&S of DES. The basic elements for the creation of the models were defined from a subset of the basic elements of the *Arena* simulation environment; this subset of components was chosen as a proof of the statement of objectives. While the built elements are facing the modeling simulation, dynamic simulation was not included (since it would increase considerably the scope of work). The main contribution is in adding Augmented Reality features (with fiducial markers) and Fault Tolerance (performing the *checkpointing* with *Audit Trails* technique[13]).

With respect to the system, it was initially done a plan, which included among other activities to define the scope, requirements gathering, modeling and database *Unified Modeling Language* (UML) diagrams building. After, the design the system was made, which consisted of an initial proposal that later suffered simplifications relations with the marker tracking, thereby generating the final design. Finally the system development and testing was done.

## IV. STATE-OF-ART

Some studies show the evolution of the Discrete Event Modeling and Simulation, both in model visualization (with

trend in 3D objects) and collaboration (evolving to M&S in *Internet*).

#### A. Animation in Discrete Event Systems Simulation

Fumarola *et al.*[14] shows ways to insert animation modules in simulation of discrete event system which are generic enough to maintain loose coupling, without much work to animate, in 2D or 3D, simulation of specific applications. Fumarola defines the separation of the components of animation and simulation of the model with the distribution of roles in different computers, using the client-server architecture. But it does not define the loosely coupling in a single application hosted on the client. The client needs to constantly poll the server to receive state changes of the simulation model.

In the proposal outlined in this article, the process of separation between the animation module with the logic of a simulation application can be achieved with design patterns in object-oriented programming. One of the patterns is the *Model-View-Controller* (MVC) [15], which organizes the elements of programming in layers of business, data and presentation. The prototype of the proposed project uses the default MVC in order to facilitate the addition of other features.

Using this method, the system reduces traffic and resource consumption on the server, and reduce dependence on the client. Each customer can perform your simulation and synchronize it with models and simulations of other people, in real time without overloading the server.

#### B. 3D Visualization of Building Operation Simulation

Behzadan[16] analyzes the process of tridimensional visualization of simulated building operations. The simulation models without visualization may hinder the validation in accordance with the established objectives. It is found that the tridimensional visualization of simulation model helps to analyze the geometric aspects not seen when using only 2D blocks. Techniques AR are used in the work of Behzadan.

A feature of the Behzadan project is the immersive vision of the user, which allows visualization of the virtual object directly in the real world, by using motion trackers and *Head Mounted Display* (HMD). The 3D objects are decomposed into smaller objects through the hierarchical structure known as the scene graph, which creates a tree of objects and transformations.

#### C. Augmented Reality with Collaboration on Web

Tavares *et al.*[17] demonstrates how augmented reality, in collaborative application on Web, can help remote teams to develop their projects using only Webcam. From the demonstrated results, the prototype apply them in modeling and simulation of discrete event systems area, adding remote video transmission features.

The proposed communication protocol is other than the work done by Tavares. Instead of performing the conversion

(serialization) of objects and variables in the XML format for transmission, binary data is transferred directly, reducing traffic and processing time. Another difference is made on obligatory of the policy server, which handles the initial communication with the client system for its permission. The proposed system does not require this subsystem.

#### D. Framework for Discrete Event System Simulation on Web

The work of Kim[18], seeks to demonstrate a design of a simulation *framework* called *RUBE* to Web with 3D visualization in X3D format, which use the XML standard, with tags to represent events and states. Kim performs comparisons between *RUBE* and other tools, like Modelica[19] and MOML[20], with argument about full compliance with official standards such as XML, thus achieving higher contribution to the community.

The structural and behavioral representations of the system are merged by a stylesheet transformation module, or *eXtensible Stylesheet Language Transformation* (XSLT). Before merging, the operation information are processed by other simulation components.

The hierarchical representation of *eXtensive Markup Language* (XML) makes *RUBE* an interesting solution to define submodels at various levels. A disadvantage is the lack of resources to perform the modeling. There is still a need for a modeling tool to generate models that serve as input to the *RUBE*.

#### E. Visualization of Traffic Operation Models with AR

Behzadan and Kamat [21] developed a solution to enhance the visualization and simulation of traffic operations models by using augmented reality. In this solution, the AR is proposed as alternative for traffic simulation visualization instead of *Virtual Reality* (VR), to give more realism to the simulation. The user views the virtual vehicles traffic directly on the real world using a set of equipments, like HMD and *Global Positioning System* (GPS).

Traffic rules are inserted in the Behzadan project like, for example, stopping the virtual vehicle if realizing a crossing traversed by the real one.

The prototype presented in [21] also uses the formal technique of Discrete Event Simulation, but the animation is focused on the simulation of the elements, missing features for the user to perform modeling of system behavior. The application of Behzadan and Kamat work is limited to traffic simulation, instead of being generic for various applications.

#### F. Collaborative Work in Discrete Event Simulation Modeling

Sung *et al.*[22] released a study on the importance of collaborative work in modeling and simulation of discrete event system for defense. An interesting point in this project is the proposal of the process in cascade of the development phases of a model, from the collection of requirements until the simulation analysis.

Sung *et al.* illustrates an example of a group of professionals with different roles within the modeling and simulation of a military system. The professionals are called *stakeholders*.

The scheme of the modeling and simulation processing of Sung *et al.* can serve to organize the whole process of modeling and simulation. In this case, there is a need for a tool so that *stakeholders* can do the modeling in real time directly in the real world and facilitating the visualization of the model.

### G. Impact of Virtual Reality on Discrete Event Simulation

An interesting survey by Akpan and Brooks [23] results in several statistic results about opinions related to the adoption of Virtual Reality in Discrete Event Systems Modeling and Simulation. Although the AR differs from VR, this study can assist in making decisions of the adoption of AR for M&S.

Respondents highlighted the ease in finding errors in the model if viewed in 3D, as well as easy handling of the model by non-specialists in modeling. Another advantageous aspect of 3D technologies (AR and VR) takes place in communication with the customer in the process of model building (70% of respondents agreed).

Another important information obtained by Akpan and Brooks [23] is that the result of simulation is usually provided in statistical figures, which has no spatial information. This reinforces the need to use WIMP systems in two dimensions, to display this information, because the way to display the model does not affect the solutions obtained in the simulation.

## V. DEVELOPMENT

The proposed system shows a new way to create *Discrete Event System Specification* (DEVS) models in a collaborative and immersive way. The system, although locally developed, can be run as a service on Internet. Groups of users can create and edit projects of simulation models.

With the use of telepresence, users automatically sense the actions of other participants. All actions are structured in the database server for the group to create versions of the model, after analysis at different points of view.

1) *Used Technologies*: The prototype was created with the following technologies:

- Adobe *Flash*[24]: Platform for Development of multimedia content in Web;
- IN2AR[25]: tracking markers library, returning the orientations in transforming matrices.
- Red5[26]: Opensource Environment for multimedia distribution (streaming), developed in Java..
- MySQL[27]: Database Management System (SGBD) used to concentrate and store necessary data to the system.

- OpenRTMFP/Cumulus[28]: streaming server for multimedia and communication in real time in *User Datagram Protocol* (UDP), with sound and image..

### A. Project Manipulation

The elements proposed in this work are displayed in this interface. On this screen the picture is loaded, and the models are edited using the AR. The connections to the *Real-Time Media Flow Protocol* (RTMFP) server are initialized and the actions are shared between participants.

From the loading process, the whole picture can be guided by the fiducial marker. The image of the marker is obtained by Webcam and passed to the In2AR library, responsible for the recognition of image patterns. Before the In2AR library initialization, it must be configured with the camera calibration parameters. The lack or poor quality calibration results in distortion of the orientation of the marker detected, and consequently three-dimensional objects are not exactly synchronized with the movement of the user.

In the prototype two markers are needed: one to set the scene and another to serve as a pointer, with the metaphor of 3D Mouse. Two users can model the dynamics of the system seeing the scene from different angles, just guiding it with the first marker. The following topics describe the features of editing project.

1) *Objects orientation*: For the model to track the movements of the user, it is necessary that the positioning and orientation be updated with the transformation matrices. The detection library returns two matrices: one for the translation and another to rotation. The 3D object should only receive an array as a parameter. The array must have the following format:

$$\begin{bmatrix} r_{xx} & r_{xy} & r_{xz} & 0 \\ r_{yx} & r_{yy} & r_{yz} & 0 \\ r_{zx} & r_{zy} & r_{zz} & 0 \\ t_x & t_y & t_z & 1 \end{bmatrix} \quad (1)$$

In Equation (1), the variables  $t_x$ ,  $t_y$  and  $t_z$  denote the position of the object, a process of translation. The translation is a linear operation. Thus, it can be directly incorporated in the matrix if homogeneous coordinates are used. The size of the final matrix becomes  $4 \times 4$ .

A screen of functioning of the scenario orientation can be seen at Figure 6a. The scenario of the example consists on the gas station for modeling the flow of vehicles.

2) *Selection of operation*: The operations described in this section (selection, adding, removing, and connecting components) are operations to be performed on the prototype for modeling projects. Before obtaining the operation, you must select it. The selection marker is the movement of controlling the position of an arrow-shaped figure, serving as a selector. The arrow is positioned toward the graphic images to the left of the screen, serving as a palette of operations, selecting an operation and leading it to the desired location.



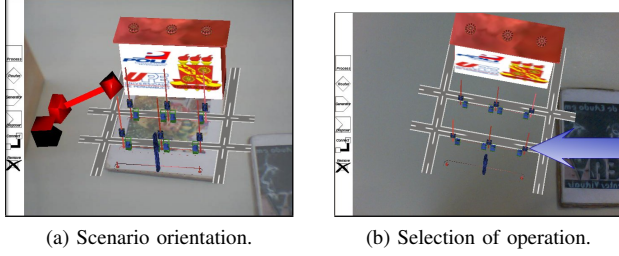


Figure 6. Beginning action of the user.

Note that the figure becomes three dimensional when it passes from the palette of operations for the 3D scene.

To facilitate the display pointer, Figure 2D with an arrow shape is obtained, always in front of the 3D environment. As the figure are located in two dimensions, the coordinates of the fiducial marker, comprising the matrix of rotation and translation, must be designed from three to two dimensions.

For operation, the marker should be pointing on the screen. The system makes the projection transformation matrix of the object in the 2D plane perpendicular to the normal vector of the camera. The resulting 2D coordinates are analyzed in order to choose the module from the palette. The Algorithm 1 describes the procedure.

---

**Algorithm 1** Selection Operation at Modeling

---

```

loop
  Get Webcam image
  if detected marker then
    get 3D coordinates of marker
     $coordinates2D \leftarrow projection2D(coordinates3D)$ 
    if  $coordinates2D.x < 0$  then
       $option \leftarrow \frac{coordinates2D.y}{component.height}$ 
       $state\_selection \leftarrow USING\_MODULE$ 
       $addReference(option)$ 
    end if
  end if
end loop

```

---

Because the variety of modules and operations to be performed, the environment stores the state of the marker, denoted by *state\_selection* in Algorithm 1. If the 2D figure of the selector collide with the component palette, i.e., if the left side of *x* coordinate is negative, selection operation is detected.

The choice of operation is to set the operation in the variable *state\_selection*, remove the pointer 2D and begin the process of dragging the component to the desired location for the insertion, also known as *drag*. The Figure 6b shows the operation of the selector.

3) *Insertion of a Module*: To add a module, it should use the marker and place it in the component palette on the left. After selecting the component to be added, each time the transformation matrix is sent to the component, so that it

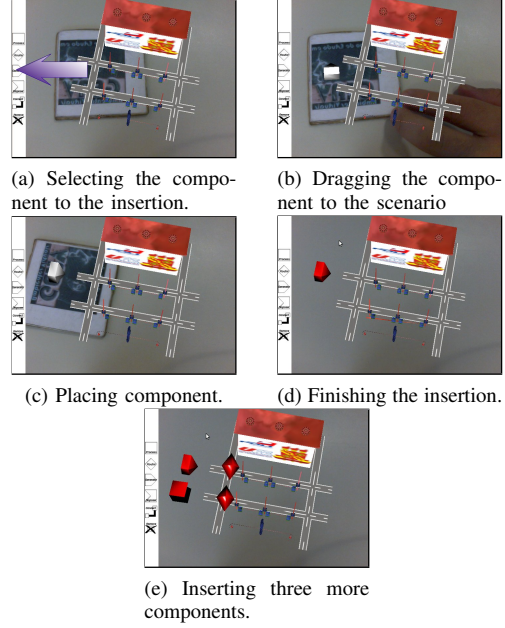


Figure 7. Inserting the module on environment

remains always on the marker with the correct orientation, dragging the three-dimensional object.

As a result, an action is added to the server and distributed directly, without the consent of the server, to the other participants. The state tree adds a new node representing the user action. The dropping process, inverse to drag, is made with the completion of the dragging process and definition of location of the new component. The sequence of movements can be understood on the present screens in the Figure 7. The selector and the component and are led by the marker until the marker to the desired location.

The Figure 7 shows a screenshot of the system. The Figure 7a shows a user choosing a component to add; the Figure 7a illustrates the environment during the insertion process, at the dragging process. The Figure 7d shows the new component inserted in the environment, reflecting the change on the screen of another participant and the tree updated.

The marker is free to perform another operation and the values of variables *state\_selection* and *option* are changed to *STATE\_FREE* and *OPERATION\_NONE*, respectively.

4) *Connection of modules*: To activate the connection operation, the *option* value must be equal to *OPERATION\_CONNECTION*. The modules connection contains similarities in the insert operation. The same marker is used and a three-dimensional object is dragged on the marker. But the object is not any of atomic modules. The 3D object, called in the work as *selector*, select the components to be connected using the collision detection system. Initially it was used a physics library: *AwayPhysics*. In isolated testing, it were shown a good performance.

In testing the complete system, the performance was lower due to the use of resources used, such as video and network. Another problem of *AwayPhysics* found in the stage of development was its size: twice the size of the project, being an important issue for an application in Web. In modularization and simplification of the project, the entire *AwayPhysics* library was replaced by a simple collision detection called *Axis-Aligned Bounding Boxes* (AABB)[29]. The algorithm checks whether the coordinates minimum of two forms are less than their maximum coordinates. The algorithm is described in Algorithm 2.

---

**Algorithm 2** AABB Collision Detection

---

```

if  $object1.minX > object2.maxX$  or  $object2.minX > object1.maxX$  then
  return false
end if
if  $object1.minY > object2.maxY$  or  $object2.minY > object1.maxY$  then
  return false
end if
if  $object1.minZ > object2.maxZ$  or  $object2.minZ > object1.maxZ$  then
  return false
end if
return true

```

---

For an illustration of the process, the Figure 8 shows the collision of two objects, with the analysis in  $y$  axis for simplicity. The dashed lines of the two objects denotes the maximum coordinate of the object. In a collision, they should be above the minimum coordinates, denoted by solid lines.

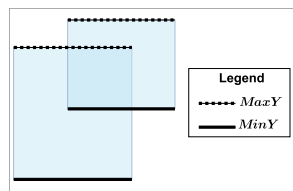


Figure 8. AABB Collision Detection.

The method utilizes the process shown in Figure 8, however, it runs for the three axes in a 3D environment. If any of the three axes in the condition is not satisfied, then there is no collision. One of the two objects is the selector, while the other is the component. When connecting, two components are needed. Thus, the selection process is performed twice, sequentially, with the same selector. According to the DEVS systems modeling technique, there are restrictions on the connection of components:

- Output Ports can not connect to output ports;

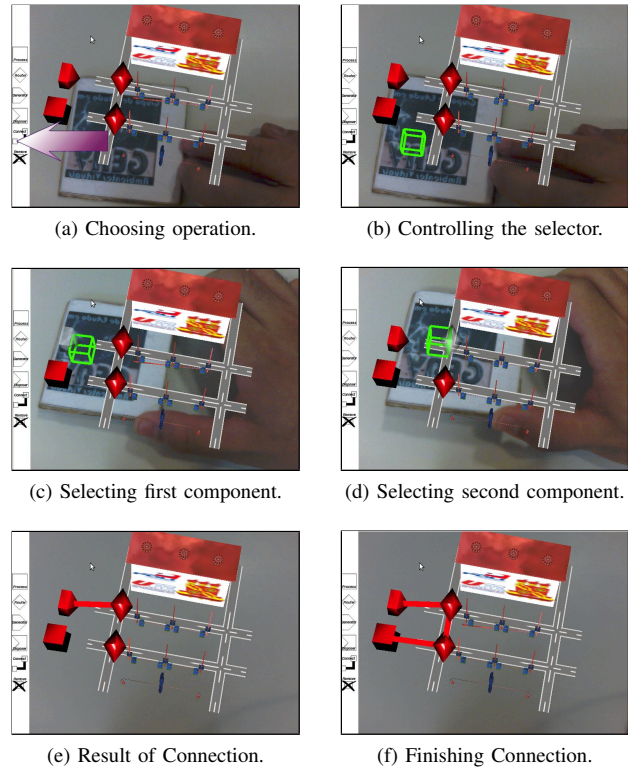


Figure 9. Connection between two modules

- There must be available output ports for the component to become eligible in the selection;

An illustration of the sequence is shown in Figure 9. By using the collision detection algorithm, the components are bumped and selected by the cube that contains only edges, in the *wireframe* format. After the two teams, the components are connected.

An example is the Figure 9. The Figure 9a shows the user selecting the connection operation, while the Figure 9b displays the cube which will select the components to be connected. The Figure 9c and Figure 9d show the steps of the connection process. The Figure 9e shows the result. The Figure 9f shows the operation repeated to complete the example.

The connection is symbolized by lines in the environment. If the connected components have been entered by different users, the line will contain a color gradient between two colors.

5) *Remotion of a module*: In the removal step, the marker displays a 3D object to select the module to be removed, using the collision process. The method of collision detection indicates that the module is removed. Unlike the connection operation, the removal is done in one step by selecting only one object. However, the complexity is higher due to the following:

- Before removing the object, all connections must be

removed;

- Although the object is removed, information must be stored so that the user can undo the removal.

As the connection, the removal operation uses the collision system, but requiring only the selection of one component. For the user may have the availability to undo the removal, each disconnection generates an action, inserted in the state tree. So the number of actions generated by the removal is  $n + 1$ , where  $n$  is the number of connections of the component. The removal is sent to the server to the correct storage. It is then sent to all other participants, directly through the RTMFP protocol, reducing traffic on the server. The state tree is updated by adding a new state.

6) *State changing at project editing*: To make the modeling fault-tolerant, a mechanism, based on the technique *rollback*, was developed to allow users to change the model to a previous version, selecting nodes preceding the current state of the tree. The user can also select alternative versions of the model, not necessarily previous ones.

This topic explains the example. The Figure 10a shows the sequence of actions made by previous actions. If a participant select some previous state, the last action is undone. In the example of Figure 10c, removal actions (and their disconnection) are undone. From the selected state, new actions result in a new sequence, as in Figure 10e. To clarify the reading of the states shown in Figure 10, the state is shown visually in the form  $XY$ , where  $X$  are the initial operation ( $A = \text{Add}$ ,  $C = \text{Connection}$ ,  $R = \text{Removal}$ ) and the  $Y$  are the identifiers of the modules, chosen standard to illustrate the example of the case study.

In selecting the penultimate state, the penultimate action will also be undone. Following the process, click on one action with  $n$  states away breaks  $n + 1$  actions, recursively and in the opposite direction: from the last action to the selected one.

The group now can start a new version of the model, with a new sequence of operations, parallel to the original sequence, from the action illustrated in Figure 10a. The Figure 10e demonstrates the further example.

Following the sample, the group can compare the two versions. The algorithm in this case performs two steps:

- 1) Undoes all actions of the current sequence to the last action common to both versions;
- 2) Redo the previous sequence of actions to the selected action.

7) *Distribution of actions to the group*: This topic seeks to clarify the synchronization of group information, beyond the perception of the presence of another participant in the modeling, screen receiving of Webcam of the participants with the absence of server overload.

When a user wants to view the environment seen by another person, his name should be selected in the list of participants. Automatically, an UDP connection is performed

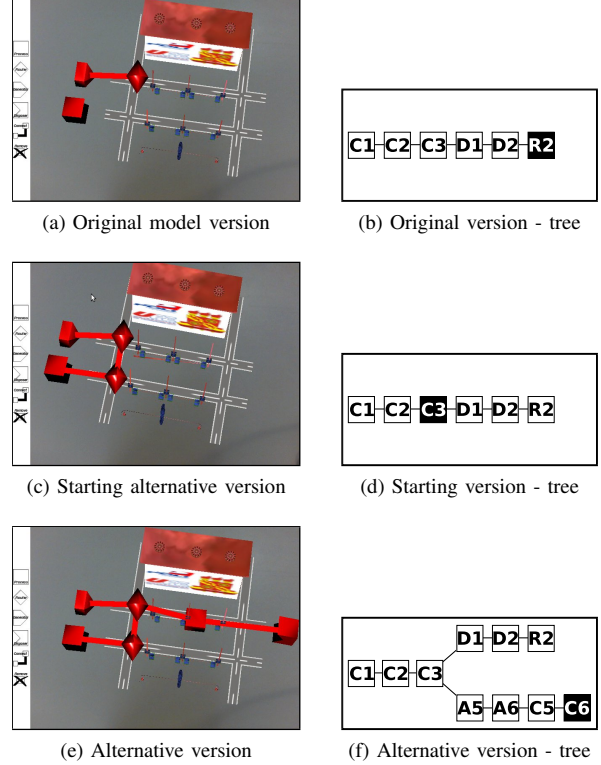


Figure 10. Version changing process of model.

and the user gets all the stream of images from Webcam without going through the server.

On the main server, each user uses only one network connection. This connection involves the protocol *Real-Time Media Protocol* (RTMP), based on *Transmission Control Protocol* (TCP) to obtain the security and delivery order of packets. All control, such as entry and exit in the design, modeling and simulation are passed to the main server by this connection.

Another server is responsible for *Peer-to-Peer* (P2P) and group connections. It allows the user to begin sharing the Webcam to other participants, using the RTMFP protocol, based on UDP, reducing the latency in transmitting the video. The server only processes the transmission control. All transmission is passed directly between clients.

In addition to video in real time, the actions taken are shared by the server RTMFP. In Figure 11, the second participant adds a new module and connects to the example. The first participant realizes the real-time telepresence getting the new action, synchronizing the state tree and the scenario.

## VI. CONCLUSION

The article proposes a solution for improving the modeling process, using augmented reality and computer networks resources. The area of Information Technology (IT) actually gets named as Information and Communication Technology (ITC), due to the trend of globalization. Services are being



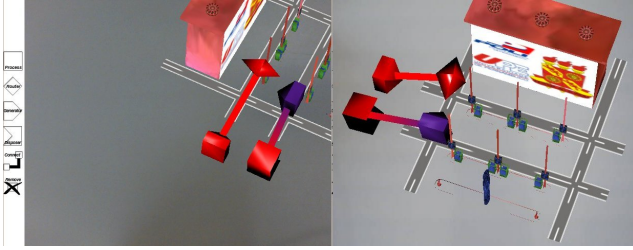


Figure 11. Screen of collaborative environment with user viewing at same time his and other participant points of view.

inserted into the Internet and information are being shared and disseminated instantly.

Modeling and simulation systems follow the trend, with all the steps necessary for a thorough and detailed analysis of systems in a collaborative and remote way, from modeling to optimization. The proposal allows to explore this trend.

With the popularization of Augmented Reality in Web, interfacing between man and machine are becoming more natural and accessible at low cost. This led to the development of the prototype resulted in an application in Web.

#### A. Contributions

As a contribution, the work shows a way of building models using behavioral interaction with the technology of Augmented Reality for Modeling Discrete Event Systems, leveraging resources to provide functionality for collaborative teams of professionals.

The design, development and testing of the prototype made it possible to form a system that improves the work of teams of professionals from different disciplines and points of view:

- Modeling and Simulation Professionals: models can be developed and simulated, and visualized directly in the source system, giving more realism and immersion;
- Augmented Reality Professionals: virtual environments can be constructed in conjunction with the logic of functioning. Thus, applications that use augmented reality to display 3D elements can display their dynamics.

Several contributions were made from the whole development project described in the article:

- A bibliographical study was made on recent work to develop the areas of Augmented Reality and Modeling and Simulation;
- A set of tools was raised and analyzed based on criteria of cost, performance and availability for development in the Web;
- Techniques for man-machine interaction have been analyzed and described;
- An analysis was made on the organization of computer resources for the collaborative modeling systems;

- A proposed integration among the areas of Augmented Reality and Modeling and Simulation has been described;
- This proposal was exemplified by the conduct of the case;
- The steps of planning and project development were shown.

#### REFERENCES

- [1] a. van Dam, "Beyond WIMP," *IEEE Computer Graphics and Applications*, vol. 20, no. 1, pp. 50–51, 2000.
- [2] C. Gong, "Human-Computer Interaction: Process and Principles of Human-Computer Interface Design," in *2009 International Conference on Computer and Automation Engineering*. Bangkok: IEEE, Mar. 2009, pp. 230–233.
- [3] C. Kirner and R. A. Siscoutto, "Fundamentos de Realidade Virtual e Aumentada," in *Symposium of Virtual Reality*. Petropolis: SBC, 2007, pp. 2–21.
- [4] R. Tori and C. Kirner, "Fundamentos de Realidade Virtual," in *Symposium of Virtual Reality*. Belém: SBC, 2006, pp. 2–21.
- [5] B. P. Zeigler, H. Praehofer, and T. G. Kim, *Theory of Modeling and Simulation, Second Edition*, 2nd ed. Academic Press, 2000.
- [6] G. A. Wainer, *Discrete-Event Modeling and Simulation: A Practitioner's Approach (Computational Analysis, Synthesis, and Design of Dynamic Systems)*, 2nd ed. New York, New York, USA: CRC Press, 2009. [Online]. Available: <http://www.amazon.com/Discrete-Event-Modeling-Simulation-Practitioners-Computational/dp/1420053361>
- [7] C. G. Cassandras and S. Lafortune, *Introduction to Discrete Event Systems*. Springer, 2010. [Online]. Available: <http://www.amazon.com/Introduction-Discrete-Systems-Christos-Cassandras/dp/1441941193>
- [8] A. E. Rizzoli, "A Collection of Modelling and Simulation Resources on the Internet," 2009. [Online]. Available: <http://www.idsia.ch/andrea/simtools.html>
- [9] P. J. F. Filho, *Introdução a Modelagem e Simulação de Sistemas com Aplicações Arena*, 2nd ed. Visual Books, 2008.
- [10] Simscript, "Simscript," 2011. [Online]. Available: <http://www.simscript.com>
- [11] XJTek, "AnyLogic," 2010. [Online]. Available: <http://www.xjtek.com>
- [12] Simlox, "Simlox," 2011. [Online]. Available: [http://www.systecon.se/case/C3\\_SIMLOX/](http://www.systecon.se/case/C3_SIMLOX/)
- [13] L. L. Pullum, *Software Fault Tolerance Techniques and Implementation (Artech House Computing Library)*. Artech House, 2001. [Online]. Available: <http://www.amazon.com/Software-Tolerance-Techniques-Implementation-Computing/dp/1580531377>

- [14] M. Fumarola, M. Seck, and A. Verbraeck, "An approach for loosely coupled discrete event simulation models and animation components," in *Proceedings of the 2010 Winter Simulation Conference*. IEEE, Dec. 2010, pp. 2161–2170.
- [15] W. Sanders and C. Cumararatunge, *ActionScript 3.0 Design Patterns: Object Oriented Programming Techniques (Adobe Developer Library)*. Adobe Developer Library, 2007. [Online]. Available: <http://www.amazon.com/ActionScript-3-0-Design-Patterns-Programming/dp/0596528469>
- [16] A. H. Behzadan and V. R. Kamat, "Enabling smooth and scalable dynamic 3D visualization of discrete-event construction simulations in outdoor augmented reality," in *2007 Winter Simulation Conference*. IEEE, Dec. 2007, pp. 2168–2176.
- [17] A. C. M. Tavares, S. M. M. Fernandes, and M. Lencastre P. de Menezes Cruz, "NHE: Collaborative Virtual Environment with Augmented Reality on Web," in *2010 International Conference on Cyberworlds*. IEEE, Oct. 2010, pp. 438–444.
- [18] T. Kim, J. Lee, and P. Fishwick, "A two-stage modeling and simulation process for web-based modeling and simulation," *ACM Transactions on Modeling and Computer Simulation*, vol. 12, no. 3, pp. 230–248, Jul. 2002. [Online]. Available: <http://portal.acm.org/citation.cfm?doid=643114.643118>
- [19] M. Tiller, *Introduction to Physical Modeling with Modelica*, 1st ed. Springer, 2001. [Online]. Available: <http://www.amazon.com/Introduction-Physical-Modeling-International-Engineering/dp/0792373677>
- [20] E. A. Lee and S. Neuendorffer, "MoML - A Modeling Markup Language in XML - Version 0 . 4," *Language*, pp. 1–14, 2000.
- [21] A. H. Behzadan and V. R. Kamat, "Simulation and visualization of traffic operations in Augmented Reality for improved planning and design of road construction projects," in *2008 Winter Simulation Conference*. IEEE, Dec. 2008, pp. 2447–2454.
- [22] C. H. Sung, I.-c. Moon, and T. G. Kim, "Collaborative Work in Domain-Specific Discrete Event Simulation Software Development: Fleet Anti-air Defense Simulation Software," in *2010 19th IEEE International Workshops on Enabling Technologies: Infrastructures for Collaborative Enterprises*. IEEE, 2010, pp. 160–165.
- [23] J. Akpan and R. Brooks, "Practitioners' Perception of the Impacts of Virtual Reality on Discrete-event Simulation," in *Proceedings of the Winter Simulation Conference, 2005*. IEEE, 2005, pp. 1976–1984.
- [24] Adobe, "Adobe Flash." [Online]. Available: <http://www.adobe.com/products/flashplayer.html>
- [25] Eugene, "In2AR." [Online]. Available: <http://www.in2ar.com>
- [26] D. Accattato, "Red5." [Online]. Available: <http://www.red5.org>
- [27] Oracle, "MySQL." [Online]. Available: <http://www.mysql.com/>
- [28] S. Herrlinger, "OpenRTMFP/Cumulus." [Online]. Available: <https://github.com/OpenRTMFP/Cumulus>
- [29] T. Ullrich, C. Funzig, and D. Fellner, "Two different views on collision detection," *IEEE Potentials*, vol. 26, no. 1, pp. 26–30, Jan. 2007.