

Simulation and Visualization Using a Remote Database

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Introduction

The National Advanced Manufacturing Testbed (NAMT) program was conducted at the National Institute of Standards and Technology (NIST) from 1996 to 2000. The NAMT was initiated by the Manufacturing Engineering Laboratory (MEL) to enable and accelerate the development of standards related to the interoperability of manufacturing systems and to aid in the injection of new technologies into next-generation manufacturing systems. The NAMT also served as a research testbed for development and analysis of computer-based manufacturing technology. The NAMT was conceived and deployed with the participation of both industry and government and provided a cross disciplinary research environment.

The NAMT consisted of equipment, personnel, collaborators, and projects that utilize resources within the testbed. The infrastructure put in place by NAMT allowed geographically distributed project participants to use new virtual enterprise technology to conduct research projects. The NAMT infrastructure consisted of : [NAMT99]

‘Physical communications components, such as networking gateways, routers, and networking software, that provide collaborators with access to equipment, documents, databases, project information, test data, and testing suites. Commercial and experimental software applications, such as design, engineering, and simulation packages, are remotely accessible, and will provide capabilities that include teleoperating physical devices. Multimedia communications, such as videoconferencing, groupware, and e-mail exploders, to facilitate effective collaboration among remotely located partners, as well as security and safety mechanisms. Advanced machine tools and research equipment that might otherwise be unavailable to collaborators. Vast and varied technical expertise that is immediately accessible through the national network. ‘ See figure 1.

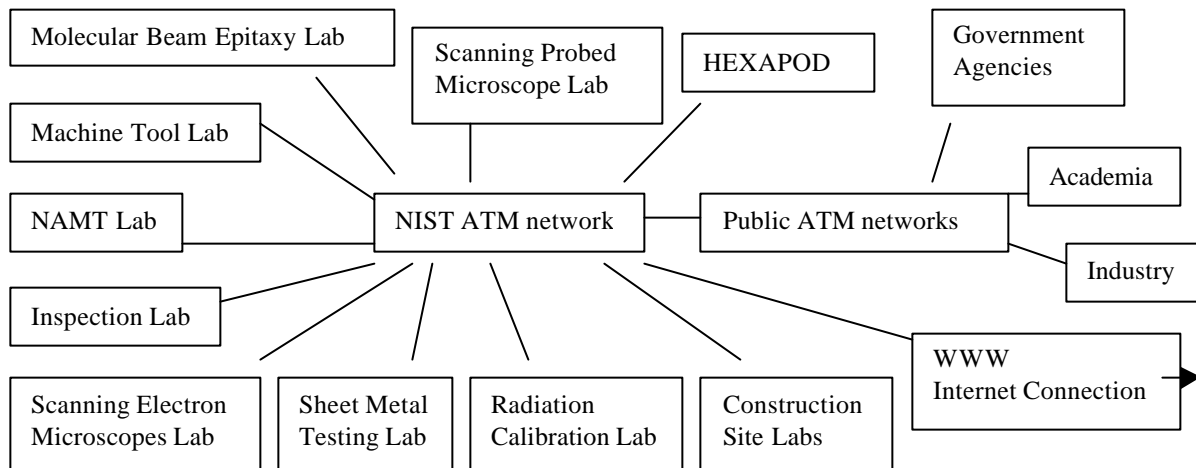


Figure 1: NAMT Infrastructure.

NAMT was implemented to also act as a collabortory. More and more enterprises are moving toward these types of environments. The NAMT was designed with adaptability in mind to allow research projects to move together in time with changing technologies.

The Virtual Cybernetic Building Testbed (VCBT) project was one of the NAMT projects. This paper describes work done in this project.

Virtual Cybernetic Building Testbed (VCBT) Project Introduction

Building control systems are evolving to the point where they need to be more tightly integrated with each other. Building control system research can not be properly conducted in real buildings because real buildings can not be used to create conditions interesting to a researcher, i.e. a fire. This creates a need for an environment where simulations of building control systems can be developed, integrated, and tested together. The Building and Fire Research Laboratory (BFRL) at NIST has been conducting research in this area for many years. This research has led to various projects consisting of hybrid systems of hardware and software. Thus the VCBT project is aimed at providing a state-of-the-art environment where simulations, computer systems, building control hardware, and data can all be studied in a virtual testbed. This testbed could be used by control manufacturers, service providers, and software engineers to develop and evaluate control strategies, develop algorithms, and control products that use the BACnet [BACNET97] protocol. The existence and use of the VCBT by newly developing building service companies will greatly accelerate the emergence of new and better building services such as fault detection and diagnosis, automated commissioning, building system optimization, and predictive maintenance.

The VCBT consists of separate Heating, Venting and Air Conditioning (HVAC); building, and fire emulators located in different NIST buildings working together with a center coordinating object and a data logger. The HVAC and fire emulators are implemented as simulation models. The building emulator is implemented as a Virtual Reality Modeling Language (VRML) [VRML 96] model of a building that runs inside a World Wide Web (WWW) browser. A VRML interface to java allows a VRML model to be updated via a java applet running in the same WWW browser. It is this applet that provides the connection to the other emulators in the VCBT using the java, CORBA, database and JDBC technologies.

This paper is aimed at describing the implementation of the VRML building emulator/user interface. The building is being modeled based on a real building on the campus of the Massachusetts Institute of Technology (MIT).

VRML Building Model

The VRML building model can be updated using a VRML application programmer's interface (API) called External Authoring Interface (EAI) to translate, scale and color geometries in the VRML building model. This basic approach is used to visualize the

results of the simulations from the other emulators in real time. The details of the implementation of this approach are described below.

The VRML building model contains basic VRML geometry: polygons, cylinders, boxes, coordinates. These geometries can be combined into what VRML calls a node. These nodes can have names. It is by this name that an external java applet uses these names to refer to a node in a VRML model via the EAI interface. The VRML building model is a custom-built VRML model with nodes that have names like: vent1, vent2, vav3, ah1, supplyfan, and so on. The VRML building model consists of three basic components: (1) the building with all rooms dimensioned according to the Massachusetts Institute of Technology (MIT) floor plan, (2) a three-room detailed model where a simulated fire takes place with flames, smoke, temperature gauge and touch sensors on key objects like the air handling unit (AHU), and 3) an image of the floor plan for one of the floors of the MIT building mainly used to provide context.

Item 1 above was generated by a C application developed in the early stages of the project. The application automatically generates VRML models of buildings from data stored in a database. An information model was developed to support this purpose (See figure 2). In figure 2, the lines indicate a relationship and the relationship is marked with a "1" or "m" indicating a one-to-many or one-to-one relation between model entities. This information model was implemented in a schema in a relational database. The application was then developed to interact with this schema. The colors of the rooms are based on the current temperature of the rooms, i.e., red is hot, blue is cold, purple is very cold. We took the floor plans of three floors of the MIT building (See figure 3 for the second floor plan) and used a ruler to estimate the dimensions of the rooms. We then entered this data into the database and generated temperatures for the rooms. The application then generated the model of the MIT building. If we wanted to re-dimension or change the color of any of the rooms, we could simple change a value in the database and regenerate the model.

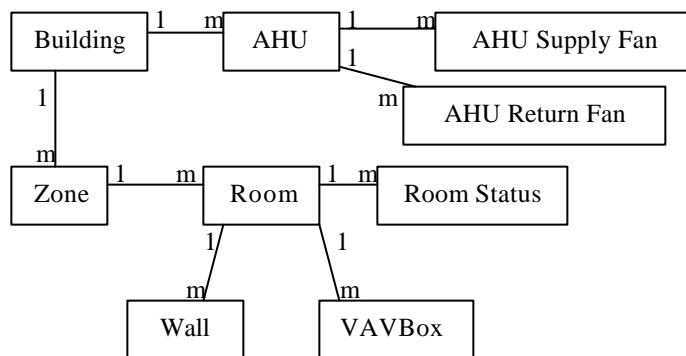


Figure 2: Relational VRML building information model.

The scenario around which the VRML building model was developed involves a fire that starts in a room in the building. The fire starts on two pieces of paper located on a chair. The fire has flames and causes smoke and other contaminants like carbon dioxide, carbon

monoxide, and nitrogen. The idea is to see the effects of the fire and monitor how the Heating, Venting and Air conditioning (HVAC) systems handle and respond to the situation. The relevant data includes: the simulation time, the upper smoke layer temperature in the room where the fire starts, the lower oxygen layer temperature in the room where the fire starts, the concentrations of smoke and carbon monoxide in the room where the fire starts, the air handling unit's (AHU) supply and return fan's rotational speeds and mass flow rates, the variable air volume (VAV) unit's air mass flow rate and inlet/outlet pressures for all three rooms. These were the major items of interest in the development of the VCBT building model. The VCBT building model was built so that different nodes for each additional type of contaminant can be added in later, for example, the blue arrows. The arrows can be updated by changing their color and size or pulse to indicate conditions in the air ducts. The arrows also have names. The simplified system diagram of the VCBT emulators is shown in figure 4.

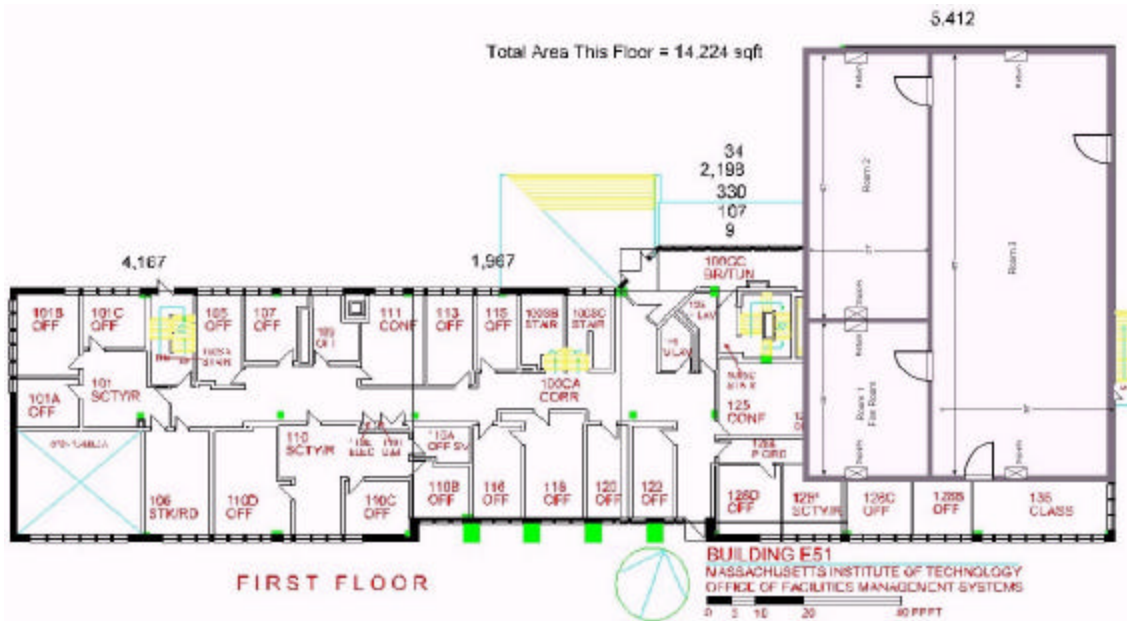


Figure 3: Second floor plan of MIT building being represented in the VCBT building VRML model.

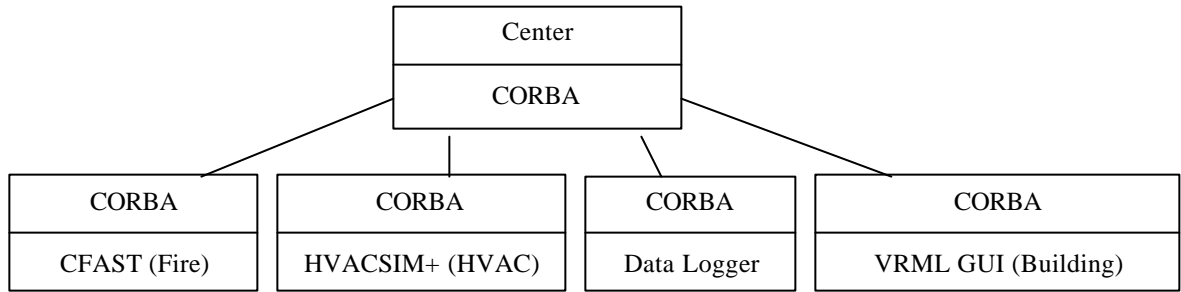


Figure 4 Simplified VCBT system diagram.

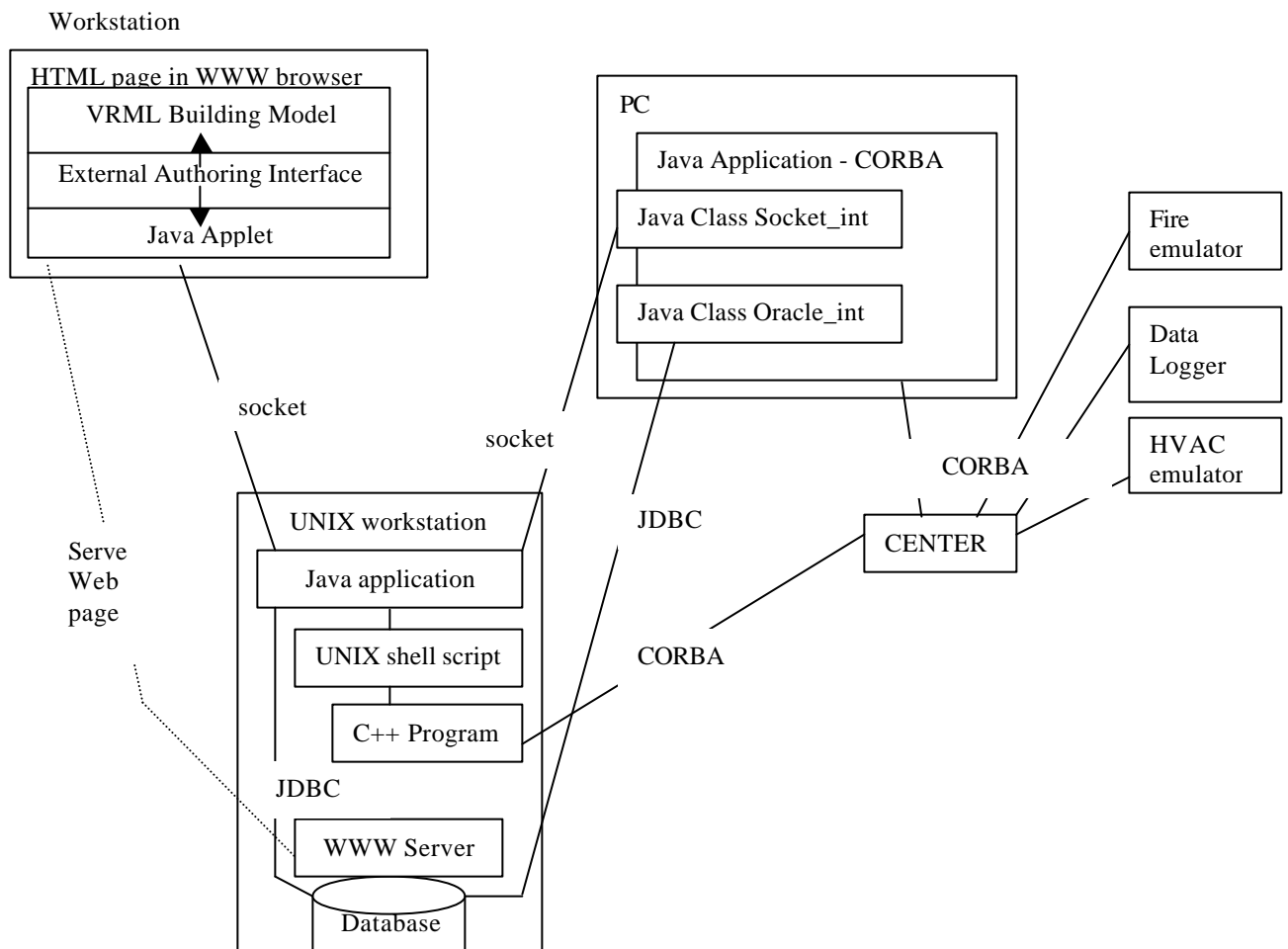


Figure 5: System diagram for VRML building emulator.

A detailed system diagram of the VRML building emulator is shown in figure 5. The main visualization component consists of a VRML building model that is controlled by a

java applet via VRML's EAI interface. This java applet receives data to update the VRML building model via a communications socket connection with a java application that runs on a UNIX workstation. This java application can get its data in one of two ways. It can use JDBC calls to access simulation data in a relational database. The data is populated into the database via JDBC from a java/CORBA application that communicates and receives data from the other VCBT emulators using CORBA as the emulators execute their simulations. The data path allows the simulation data to be recorded in the database for later playback. Second, it can open a socket connection with the java/CORBA application. This data path bypasses the recording of the simulation data in the database. See figures 6 through 10 for a representation of the simulation in the VRML building model.

Conclusion

The NAMT was initiated by the Manufacturing Engineering Laboratory (MEL) to enable and accelerate the development of standards related to the interoperability of manufacturing systems and to aid in the ejection of new technologies into next generation manufacturing systems. The Virtual Cybernetic Building Testbed (VCBT) project was initiated to allow researchers to integrate building control systems seamlessly under simulated controlled conditions. The VCBT consists of several building control system emulators that are implemented as simulations. When the emulators are executed together, the results of the simulation can be visualized using the VRML building emulator.

References:

[NAMT99], WWW pages for NAMT, "www.nist.gov/mel/".

[VRML96], Hartman, J., Wernecke, J., "The VRML 2.0 Handbook", Addison-Wesley publishing 1996.

[BACNET97], Bushby, S. T. , " BACnet(trademark): A Standard Communication Infrastructure for Intelligent Buildings.", Automation in Construction, pages 529-540, 1997.

DISCLAIMER

Commercial equipment and materials are identified in order to adequately specify certain procedures. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

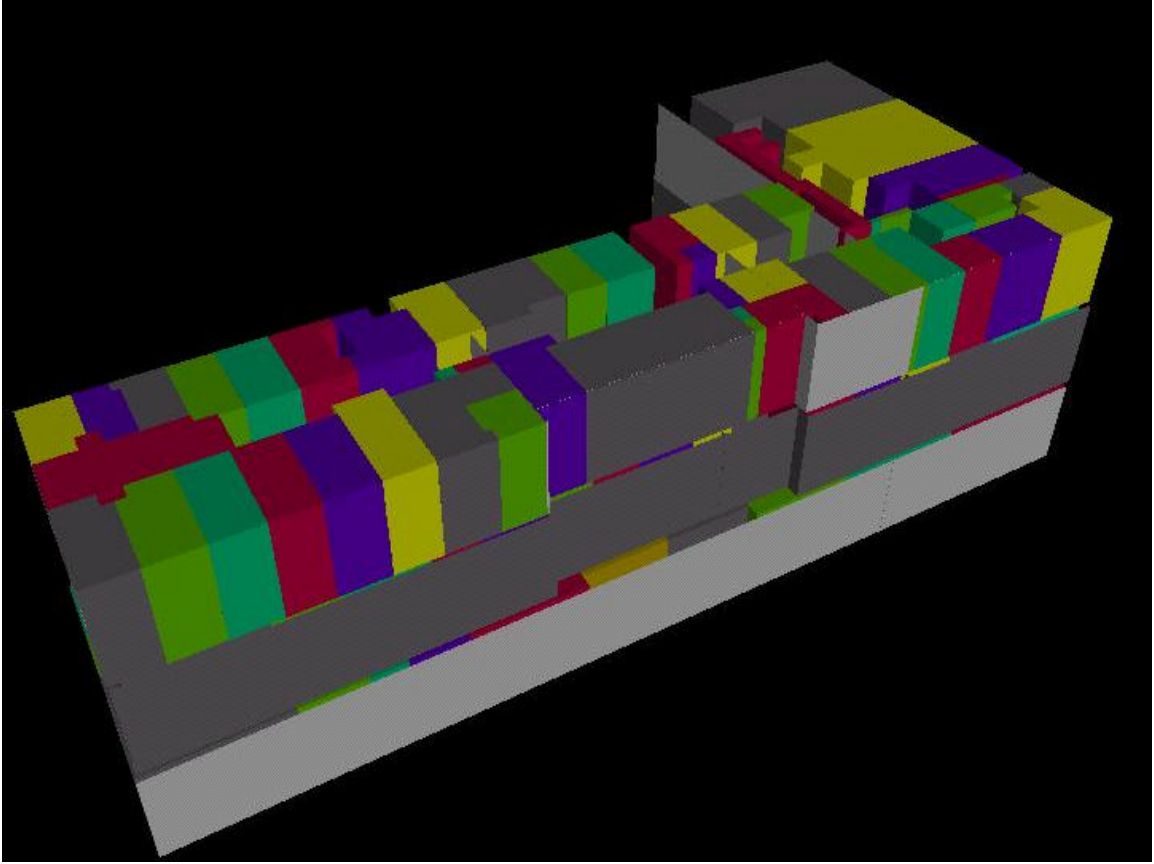


Figure 6: Three floors of MIT building with color coded rooms according to room temperature.

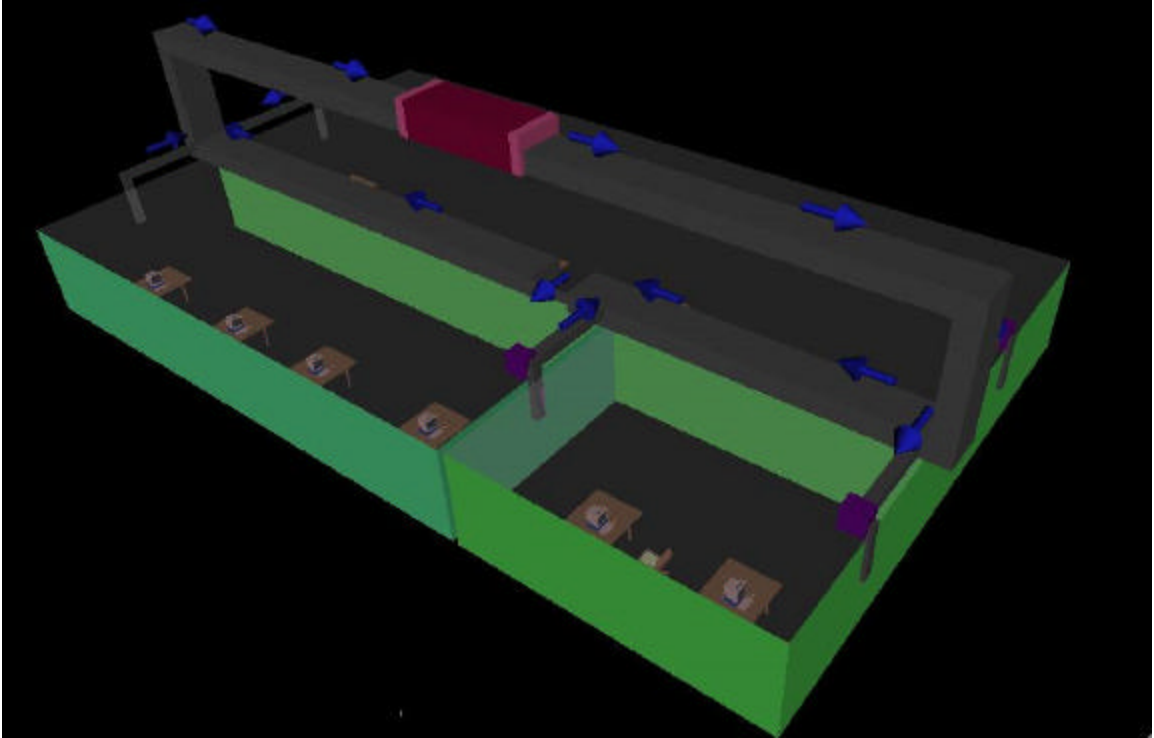


Figure 7: Three rooms of MIT building where simulated fire takes place.

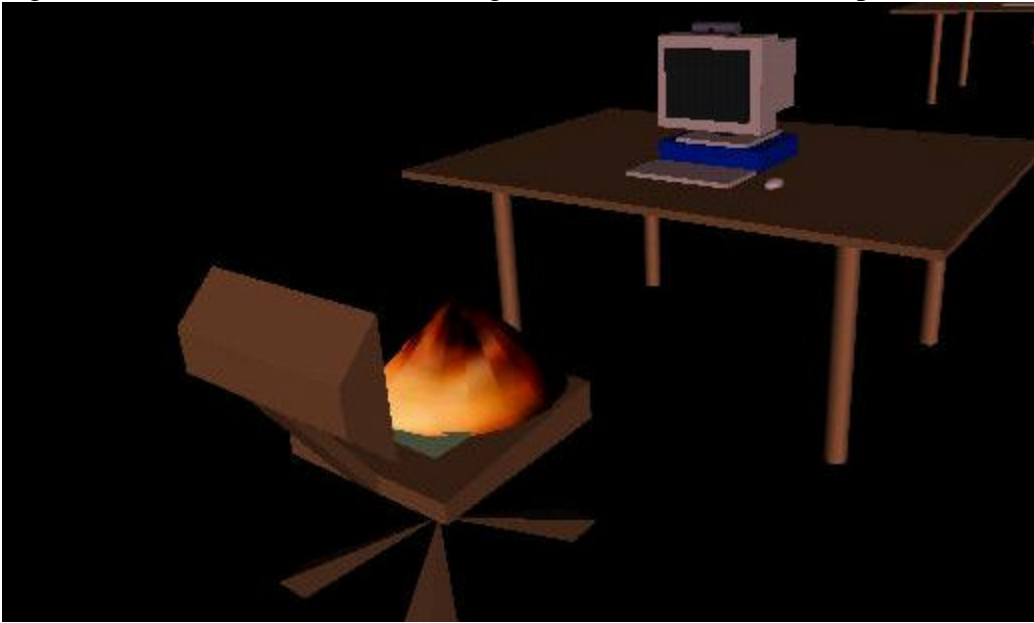


Figure 8: Fire starting on chair.

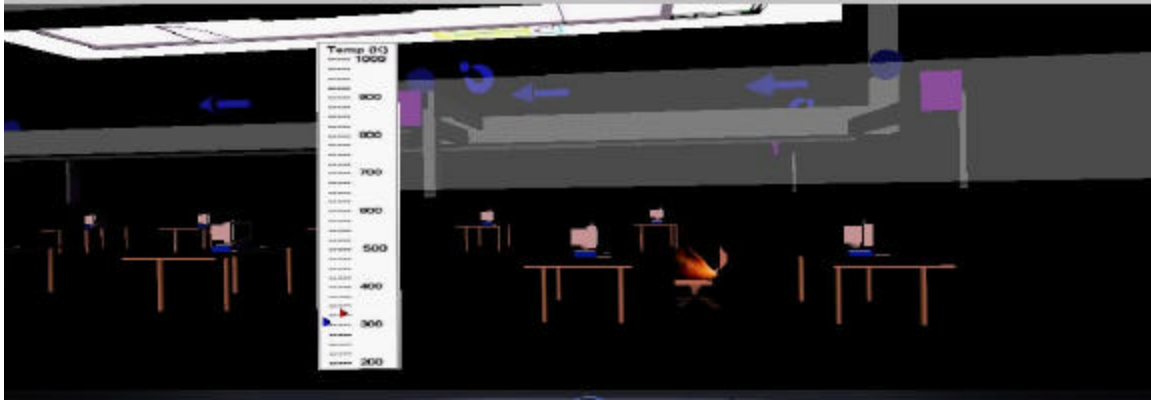


Figure 9: Side view of room where fire starts with temperature display and smoke cloud.

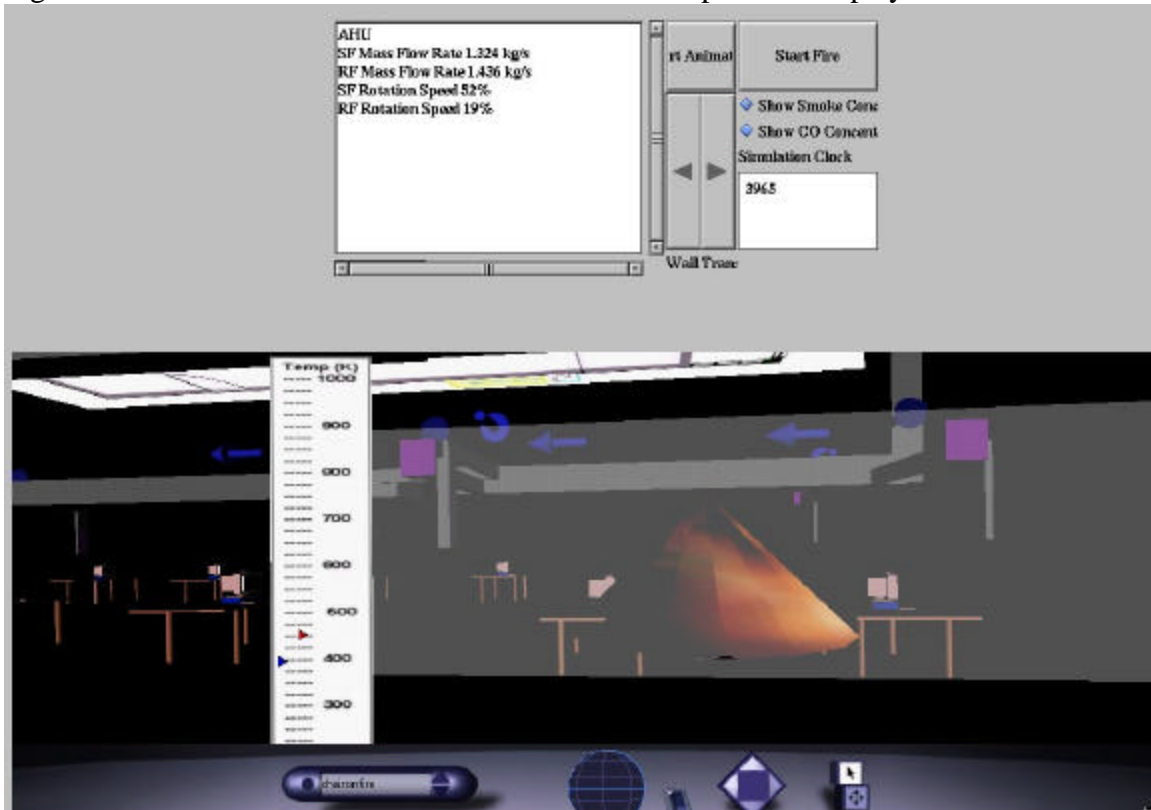


Figure 10: Side view of room with smoke and fire progressing.