Proceedings of the 1990 Winter Simulation Conference
Osman Balci, Randall P. Sadowski, Richard E. Nance (eds.)

USE OF MULTIMEDIA TO AUGMENT SIMULATION

Peter Aiken
Peggy Brouse
Mandy Hassanpour

Frank Armour
Ann Fields
Jianhong Liang

James D. Palmer

National Center for Regional Mobility
School of Information Technology and Engineering
George Mason University
Fairfax, Virginia 22043-4444

ABSTRACT

Multimedia workstations facilitate significant improvements to the understanding of the linkages between actual real-world models and simulation models. The paper describes our efforts to integrate multimedia and simulation. The general domain of interest is regional mobility. We have used multimedia to augment simulation of highway maintenance, interactive sessions of a Transportation Management Association (TMA), traffic mobility in a highly congested area, and traffic signage. Results of our efforts, thus far, show that one of the more important aspects for successful application of multimedia techniques is a graphical user interface. It is a difficult task to prevent information overload; however, the graphical user interface permits management of information transfer rates and presentation dynamics while reducing the potential impact of information overload. Other results indicate the value added from proper usage of audio, video, text, and graphics, and various combinations of these to enhance and augment ease of understanding of simulation model presentations.

1. INTRODUCTION

One of the very important facets of current techniques of simulation is the capability to present complex information in forms that are readily interpretable by those familiar with the approach being used. A major goal of the systems architecture that we have developed is to be able to extend this interpretation capability to those who are not necessarily familiar with the specific simulation technique being used. One of the primary requirements for simulation in Computer Supported Cooperative Work (CSCW) activities is to support a variety of user types in the decision support process. Within our context of CSCW, there is a need for clear presentations to facilitate the ability of users in assimilating the information presented and reach consensus as to the best plan for the situation presented. To achieve these goals we are utilizing multimedia presentation techniques for maximum information availability, while at the same time paying careful attention to basic Human Computer Interaction (HCI) principles to avoid information overload. Toward this latter end we are engaging in a substantial effort to provide optimal graphical user interfaces for each domain. This aspect of the activity will not be covered in this presentation.

For CSCW activities, we use simulation to explain and/or define systems or problems; to determine critical elements, components, and issues; to evaluate proposed solutions; and to forecast and aid in planning future developments in the domain of regional mobility. We are concerned with all aspects of regional mobility presentation, ranging from relief of congestion on urban interstate roads to the impact of route location for outer beltway systems and the implications of maintenance activities on traffic throughput. The type of simulation studies we have been concerned with typically involve users we have labeled *inexperienced* decision makers. By use of the term inexperienced we intend to imply that they are well-versed in their respective domains, but they are not accustomed to the formal use of simulation in problem solving. Typical groups in this category might include a citizen group concerned about transit routing through their subdivision, or a group of regional planners attempting to determine the alternatives to development of yet another beltway link around a major metropolitan area.

Our research at the National Center for Regional Mobility is focused on augmenting the abilities of these diverse groups through the use of the CSCW-based approaches to decision making and consensus building activities. By augmenting standard presentation of complex materials regarding the nature of regional mobility challenges, we are attempting to provide common information bases and to present complex information in terms readily understood by individuals who are well-versed in the problem domain. The users with whom we are concerned include the following categories of groups:

Social	Political	Economic
- citizens groups	- government officials	- merchants
- environmental groups	- staff	- architectural engineers
- ad hoc associations	- politicians	- builders
- human services	- policy analysts	- utilities
- educational institutions		- developers

Particular tasks confronting these classes of users include: consensus building; decision making; resource allocation; resource acquisition; crisis management; policy setting; planning; design; design implementation; and education. These tasks are often complicated by the need to be resolved in conjunction with a variety of situational factors including: stressful conditions; information overload; information shortfall; political implications; resource constraints; truncated and extended time frames; frustration from other interested groups for apparent inability to resolve conflicts; impact of congestion on quality of life including environmental degradation; and short planning horizons. The decision making or consensus building environment is usually anything but congenial; therefore, it is necessary to facilitate the process as much as possible by removing barriers to information acquisition, information sharing, information organization, and clarity of information presentation.

Thus the situation we face is how to effectively and efficiently communicate the full range of the implications of the results of systems analysis to decision makers and consensus builders who may be unfamiliar with the simulation process. It is critical that effective and efficient communication take place because all members of the decision group have some implicit mental model of the problem. Understanding that each person employs implicit models is essential to the CSCW process because these models are carried around in the mind of the user. Mental models must be modified as the decision maker examines alternative scenarios as part of a larger analytic process. There are a number of problems with attempting to modify models used by these decision makers. If a particular observation is at odds with preconceived notions of the status of the actual situation, the observation acts to negate the current mental model which must be adjusted to account for what has been observed. Most of us have some difficulty in handling complexity in mental models. This complexity makes the models hard to manipulate, makes it difficult to share the models with others, and certainly presents a host of validation problems.

The formal models used in most simulation activities are often complicated. They frequently give unsubstantiated and often debatable results when certain complexities associated with the actual system are not represented in the model. These attempts to represent real situations are often difficult to adapt to new circumstances and information. Additionally, these models are not easy to communicate to typical users inexperienced at working with abstractions of real conditions [Treacy 1986].

A generalized development life cycle is used as the framework for our discussion of the use of multimedia to augment simulation. This life cycle, from Pritsker [1984], includes the following phases: problem formulation, model building, data acquisition, verification, validation, planning, analysis of results, and implementation and documentation. As shown in Table 1, there are some limitations associated with these phases. These limitations represent classes of problems addressed by our research.

Table 1. Limitations of the Simulation Life Cycle

Problem Formulation	Importance of gathering requirements has long been stressed, but far too often, simulations are incorrect because they model the wrong process or model the process incorrectly.
Model Building	The process of building the model often requires a group approach; increasing the number of participants increases the risk of poor or incorrect communication occurring.
Data Acquisition	The process of capturing data for the simulation is often a problem because the data exists in an inconsistent format, media, and/or is costly to gather.
Verification	It is difficult to verify all possible scenarios against original requirements.
Validation	It is costly and difficult to compare the model behavior with the real world capabilities.
Analysis of Results	Many simulations are difficult to understand by unaccustomed decision makers; therefore, they may perceive results incorrectly.
Documentation	Current simulation documentation is limited to textual media.

The remainder of this paper is concerned with the use of multimedia to mitigate these limitations. Section Two describes our research domain in more detail. This is followed by a section briefly introducing the topic of multimedia and the related topic, hypermedia. Section Four explores the potential value added by multimedia to simulation as it occurs in our problem domain. The paper closes with our conclusions as to how multimedia enhances the simulation life cycle.

2. THE DOMAIN ENVIRONMENT - REGIONAL MOBILITY

Some of the domains that bear particular relevance to regional mobility include highway maintenance, traffic signage, congestion, etc. Highway maintenance represents a hazard to the traveler, the vehicle, the repair crew, the ripple effect as closing or narrowing of roadways impacts other routes, and many other aspects including resource acquisition and allocation. Poor traffic signage contributes to traffic delays, congestion, and accidents. In this section, we will briefly review the purpose of the National Center for Regional Mobility and provide a general review of the transportation domain, as an object of our simulation efforts.

2.1 National Center for Regional Mobility

The National Center for Regional Mobility is a program funded by Urban Mass Transportation Administration (UMTA) of the U.S. Department of Transportation and supported by the Virginia Center for Innovative Technology. The Center was founded to address basic questions related to mobility, congestion, and to facilitate ways of bringing concerned groups together to achieve consensus. TMAs represent groups of interested parties who have bonded together to seek solutions to transportation mobility problems. They are concerned with problems such as providing adequate parking, park-and-ride solutions, improved signage to assist travelers, and reduction of accidents. Our overall goal is to facilitate information sharing, consensus building, and decision making for problems in regional mobility.

The basic tasks assigned to the Center are to develop a CSCW environment to aid decision makers and consensus builders in resolving problems related to congestion in metropolitan regions, to develop an information center for regional mobility information to be made available to interested individuals, to provide a cooperative work-study program for students in these areas, and to assist in information transfer among organizations concerned with regional mobility. Facilities for the National Center are located on the campus of George Mason University in the School of Information Technology and Engineering. The purpose of the Center is to develop technology-based solutions to regional mobility problems.

Areas of concern to the Center include transit, transit alternatives, high occupancy vehicle (HOV) corridors, TMAs, planning activities for new developments, interaction of land-use planning and development, and other action oriented activities aimed at relieving congestion. In this paper, the specific domains we consider for demonstration purposes are highway maintenance, traffic signage, congestion, and necessary decisions that must be made involving the national transportation infrastructure.

2.2 Transportation Domain

2.2.1 Transportation Infrastructure

The infrastructure for the Nation's transportation system includes bridges, highways, airports, rail lines, ports and waterways, pipelines, and other fixed facilities. In this presentation, we are specifically concerned with the highway and bridge system due to its central role in the national economic health. There are approximately 3.9 million miles of roads and streets in the U.S. highway system. In addition, there are approximately 577,000 bridges on the system. These assets are currently in differing states of disrepair. A concerted effort must be undertaken to maintain the existing highways and bridges. Inadequate maintenance of these transportation assets contributes to congestion. It is estimated that Americans lose nearly 2 billion hours annually in traffic delays on the streets and highways in our major cities alone. Freight movements held up in congestion on the highways cost consumers billions of dollars each year [U.S. Department of Transportation 1990a].

A major task for the transportation community is to maintain the existing system. By putting off maintenance, we risk increasing the eventual and inevitable cost of restoration. The ongoing deterioration from current system performance results in additional costs for highway operation. Either this additional cost must be funded or the demand for service must be reduced. Either of these could result in a decline in national economic capacity. Highway deterioration increases the cost of goods and services and reduces personal income [U.S. Department of Transportation 1989]. Other domain areas that our paper addresses include traffic signage, congestion, and suburban transportation issues in and around Tysons Corner, VA.

2.2.2 System Performance and Maintenance Considerations

A June 1989 report to Congress from the Department of Transportation [U.S. Department of Transportation 1989] confirmed what urban travelers have long been saying...that the highways continue to be congested. The percent of peak-hour travel on urban Interstates that occurred under congested conditions increased from 61 percent in 1985 to 65 percent in 1987. The percent of congested peak-hour travel on "urban other" interstates increased to 42 percent from a 1985 figure of 40 percent. This report also revealed that the percentage of pavements in good or excellent condition decreased on each functional system except rural collectors. Perhaps most alarming are the statistics on the Nation's bridges. Interstate bridges classified as being deficient rose from 10.6 percent in 1982 to 13.4 percent in 1985, and to 15.4 percent in 1988. The Department of Transportation has directly related congestion to problems associated with the condition of the Nation's highway infrastructure.

Maintenance expenditures have increased 195 percent since 1972; however, this is a misleading statistic. Accounting for inflation, maintenance expenditures in 1985 were roughly equivalent to the 1972 level [U.S. Department of Transportation 1990a]. It is the case now as it was in 1972, that close to half of the total annual Federal expenditures for highways goes to maintenance. This expenditure meets with resistance from taxpayers who do not completely understand the role of maintenance in alleviating congestion. Taxpayers have the sense that it is more appealing to add a new highway than to keep the current systems in repair.

2.2.3 CSCW and Transportation Considerations

We have compiled an extensive set of documents concerning maintenance and other transportation issues and have utilized this information to formulate a CSCW presentation domain. We have compiled documents, videotapes, audio tapes, and other materials pertinent to TMAs in action, signage issues, and traffic congestion. Examples of transportation issues include:

- use of simulation to indicate the impact of narrowing or closing of a lane of traffic for an extended period to effect repairs;
- use of simulation to determine optimal lane closings and times for heavily travelled roadways;
- use of simulation to search for alternative routings during maintenance activities;
- use of video to enhance the understanding of decision makers and consensus builders to comprehend the impact of maintenance activities by examining the present situation and the situation over time of day, week, month, and year so as to select minimal interference for maintenance;
- use of simulation to address problems of traffic congestion and gridlock;
- use of simulation to determine the relationship between maintenance funding levels and road conditions; and
- use of multimedia to present the problems associated with traffic signage and potential solutions.

In the next section we will illustrate how the use of CSCW enhances and augments the presentation of simulation outcomes to assist the user in developing an understanding of the situation.

3. MULTIMEDIA

This section defines the term multimedia, and the related term hypermedia, as used in the context of our simulation efforts. The use of multimedia and simulation for a CSCW environment is a relatively new occurrence; hence we will provide a brief overview of this technology.

We use the American Heritage Dictionary [1982] definition of multimedia which states: "Including or involving the use of several media." In this context, the goal of multimedia-based systems is to create an efficient and effective analysis and presentation environment by synergistically combining various media (e.g., text, graphics, video images, etc.) to enhance user interaction [Brewer 1986]. Related work has shown multimedia to be effective in augmenting similar efforts in construction and presentation of software based systems [Palmer and Aiken, 1990]. A multimedia environment permits both model designers and decision makers to interact with a mix of video, audio, graphics, and text-based information. In addition, by using multimedia-based programming tools, it is possible for simulation experts to make the simulation presentations that are more realistic and more easily understood by users.

Hypermedia is defined as: "information representation and management systems that organize information into networks of multimedia nodes interconnected by links. Each node generally contains a chunk of 'content' such as a document, a drawing, or a voice annotation. The links are used to represent interrelations among these nodes" [Halasz 1988]. Hypermedia systems contain the following four components:

1. a computer-based data analysis and management system;
2. a high bandwidth human-computer interface;
3. capabilities permitting users to quickly and easily navigate, manipulate and maintain, multimedia data; and
4. the ability to link hypermedia objects into personalized associative indices.

Information is stored in hypermedia systems as hypermedia objects, each containing a variable amount of information stored on a variety of media types, as shown in Figure 1. Media types can be classified according to the general categories of text, picture, sound, and motion. The content of a hypermedia object can be as small as a single bit of information, or it can be as large as a digitized two hour movie occupying 550 megabytes on CD ROM disc. Larger amounts of information can be stored using WORM optical technology. Hypermedia objects are presented in windows, one window for each object. Using system utilities, users navigate, manipulate and maintain structures of hypermedia objects linked into associative indices.

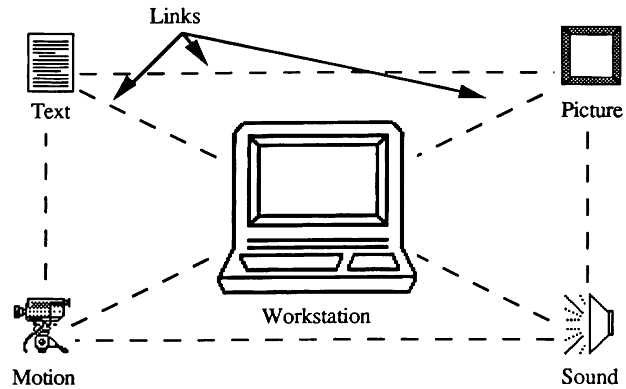


Figure 1. Hypermedia System Components

Akscyn [1988] and Conklin [1987] have described additional differences between hypermedia and other types of systems to help establish boundaries differentiating hypermedia systems. Hypermedia systems differ from other utilities as follows:

- **Windowing Systems** lack database capabilities;
- **File Systems** are databases but generally lack linking capabilities and navigational support;
- **Outliners** have only limited support for references occurring between outline entries and provide hierarchical links between entries;
- **Text Formatting Systems** allow only hierarchical links between chunks of text; and
- **Data Base Management Systems** lack both the ability to link multimedia items together and a unified user interface across media types.

The primary attributes of hypermedia systems are presented in more detail in work by Aiken [1989]. Hypermedia-based systems provide:

- **higher information bandwidth** in human-computer dialogue;
- the ability to **more closely simulate other materials** with which computer systems can be associated, increasing the potential for information access and exchange via a single interface;
- **support for reporting** using more versatile, user-defined, non-sequential linking of presentation media;
- **non-traditional linking** of facts permitting the application of wide spectrum analysis techniques [Bolt 1984];
- availability of **concepts unique to object-oriented systems** including procedure encapsulation, object classes, information inheritance, and polymorphism;
- **availability of a "tool kit"** approach to information manipulation regardless of the information's medium; and
- **facilitated user/systems participation** resulting from an increase in the available interaction modes.

An example of the differences between traditional human computer interaction and hypermedia-based human computer interaction are examined in more detail in Brewer [1986].

By using hypermedia techniques to simulate actual events, the user will be in a position to more readily understand the model and the subsequent functional system. Consider the case of animation. Popular animation packages use readily identifiable components such as: entities on the screen are *cast members*; the screen is called the *stage*; and the presentation is controlled by a *score* and associated *scripts*. (See for example, Wolverine Software's simulation package of cars going through toll gates, or numerous MacroMind Director examples).

4. VALUE ADDED BY MULTIMEDIA

In this section we discuss the value added to simulation analyses by multimedia-based technologies. This is presented through the use of the simulation life cycle phases as examples of where multimedia augmentation may provide added value. The pertinent life cycle phases are:

- Problem formulation
- Model building
- Data acquisition
- Verification
- Validation
- Presentation/analysis of results
- Documentation

We will consider each phase individually.

4.1 Problem formulation

Multimedia adds value to the problem formulation phase by:

- Helping to bridge the gap between actual artifacts and the simulation activity, and
- Providing a common ground for information transfer.

One of the first tasks in formulating a simulation problem is to analyze the system under study. Depending on the complexity of the system, one or more documents may be produced as a result of this analysis process. These documents contain information related to problem definition (a high-level description of the problem to be solved), and problem specification (an expanded and more detailed description of what the system must do to satisfy the requirements).

Until recently, technology limitations have restricted the inputs needed to develop documents of this type, as well as the documents themselves, to a narrative format. Multimedia provides the analyst with the capabilities to go beyond narrative documentation to include animation, video, and audio input as part of the requirements documentation.

The advantages of using multimedia in problem formulation include providing a common ground for information transfer. Because of the flexibility and ease of use of multimedia, users with different levels of technical expertise and domain knowledge can be brought to a common level of problem understanding fairly quickly. For example, in a highway maintenance domain, a video clip of road potholes and the potential hazards they present to traffic safety as vehicles attempt to avoid them helps document the need for pothole repair and convey some of the characteristics of the system to be studied in the simulation. Audio recordings of highway noise levels can help document the need for noise dampening measures, wherein the simulation can then be designed to experiment with the maintenance implications of the various noise abatement measures (i.e., planting shrubbery/trees, which require annual maintenance, or building noise barrier walls). Another example of using multimedia in this phase is the use of video to highlight the problem of congestion and the need for alternative transportation modes on Interstate 66 (outside Washington DC). When the congestion problem was demonstrated to a group of transportation experts via video, they were able to immediately recognize the context and the severity of the situation [Johnson 1990].

Multimedia enhances the advantages of simulation by providing a common ground for information transfer in which a flexible and easy-to-use environment can aid communication in the problem formulation stage of the simulation.

4.2 Model building

Multimedia adds value to the model building stage of simulation by aiding the model builders in their understanding of the system. In much the same way that multimedia contributes to the task of problem formulation by enhancing the ability of the analyst and user to come to a common understanding of the problem to be solved, multimedia can aid the model builders understand the system they are to model. For example, video clips can be an invaluable aid in conveying how the current system functions; animation can aid in portraying how a system that does not currently exist is expected to function. Multimedia facilitates an understanding of the system under study with less effort than a purely narrative description of the system by providing the analyst and user with the capability to use animation, video, and audio in addition to text to describe the system to be modeled.

4.3 Data acquisition

Multimedia enhances simulation data collection by:

- Reducing the expense of data capture
- Eliminating much of the incompleteness and inaccuracy associated with data capture
- Helping discover interrelationships and complexities
- Allowing data capture with minimal disruption to the real system

Simulation may require that data pertaining to system variables be collected over time. It may be very expensive, depending on the nature of the system, to observe, record and collect the data. Also, if the resources are not available to collect the needed data, the problem may be judged too expensive to solve through the use of simulation. Collection of data through the use of multimedia may help reduce this cost by providing a more efficient means to input the data into the simulation. For example, if textual reports are used as input information on transportation maintenance funding levels, text scanners may be used to input the information into the simulation database, a potentially far less expensive way versus keyboard input.

In addition, the data may also be incomplete or inaccurate due to missing observations or observation and reporting errors. This will result in simulation that fails to accurately model the problem. Multimedia helps capture data closer to its original form, reducing the potential for incompleteness and inaccuracy associated with the transformation of data from its natural state to numeric form. The numeric data that feeds the simulation can be captured using such techniques as time lapse photography, still photos, and video cameras. This allows the actual conditions to be viewed and translated in the lab, versus attempting to capture the data in the field, where the real-time nature of the observations may cause incompleteness or inaccuracy. Our group used video and sound capabilities to capture an accurate and complete record of the second TYTRAN Forum (TYTRAN is a local TMA) [Kane 1990]. The wealth of transportation information (i.e., road networks, parking, mass transit) that was presented at the meeting has been utilized in our lab for a number of projects.

The flexibility that multimedia provides in capturing data can help reduce the cost of observation. For example, to record the effect of closing of a bridge lane for maintenance on traffic flow during specific time intervals during a day, remote cameras can be placed to observe the bridge and its associated traffic. This can help reduce the manpower needed to observe and count the traffic flow. These videos then can be viewed in the lab, with the sections of the video pertinent to the simulation viewed, while the rest of the video can be fast-forwarded through. The video also helps ensure data accuracy, since the traffic flow count can be played in slow motion video or replayed if needed.

The data may contain undiscovered interrelationships and complexities. The method of collection may introduce bias into the data [Graybeal 1980]. Multimedia may help to reduce this bias, since the users, modeler, and designer can all view the same unfiltered data, and in turn can represent different contexts and provide different perspectives.

Simulation has the advantage that it minimally, if at all, disturbs the actual system. Data collection through multimedia can further enhance this advantage, by allowing the data to be collected in a less obtrusive manner and with less frequency. Multimedia can allow the capture and viewing of data without disturbing the actual system multiple times, because conditions can be captured quickly and then viewed and documented in detail from the multimedia representation. For example, documenting certain bridge damage such as rusting girders or rotting wood may require the closing or partial closing of the bridge and connecting roadways; with video, the bridge conditions may be recorded in a manner that enables a more detailed inspection in the lab instead of the field, thereby reducing the down time.

4.4 Verification

Verification is defined as an attempt to determine whether the model is performing correctly, based on simulation requirements and captured data. By allowing the visual inspection of the simulation operations, the use of animated display proves to be very useful in testing and debugging the simulation, in specific the computer program components. As with other forms of multimedia, animation allows the designer to view the system in a more understandable manner, allowing the modeler to view the key elements of the simulation and their interaction. Through visualization, animated verification alerts the designer to the behavior of the model under unusual or extreme conditions. We refer the reader to recent articles by Brunner and Henriken [1989] and Sadowski [1989] for further information on verification techniques and animation.

4.5 Validation

Multimedia enhances simulation validation by:

- Reducing cost of the validation effort
- Shortening the time needed to perform the validation
- Improving the ability of domain experts to judge the accuracy of the model
- Discovering hidden assumptions and interrelationships

Validation is defined as the process that the designer and user perform to determine how accurately the simulation models the actual system. The validation process attempts to determine if the simulation represents the actual system accurately enough to be used as a decision aid.

The time and cost needed to validate a model are almost always factors in the amount of effort that is able to be expended for validation [Carson 1989]. By providing as close and accurate representation of the system in the lab as possible, multimedia allows a more cost and time effective validation to be performed, compared to having to validate by observing the actual system. Returning to our example of the effect bridge repair has on traffic flow levels, validating the simulation in the lab by comparing the results to a video is certainly more time and cost effective than having to validate by comparing the simulation to a real-time bridge repair.

As in data capture, hidden assumptions may cause the model to inaccurately reflect reality; through multimedia, the captured data from the actual system can be viewed and compared to the simulation in a form closer to reality, with hidden assumptions and undiscovered interrelationships more easily ascertained.

Face validity is a validation technique that elicits domain experts' impression of a model's realism. This requires good communication between the designer and user [Carson 1989]. Multimedia facilitates good communication by providing data in a more natural and original form with which to relate. In a simulation modeling road conditions and maintenance funding levels, a split screen image could be provided, with one side representing a video or still pictures of the actual road conditions that result from a certain level of maintenance funding, and the other side demonstrating the corresponding simulation results.

Another technique used to validate models is to have the model reviewed by "neutral" domain experts, individuals not associated with either the user or modeler. By providing a version of the simulation that is in multimedia form, these domain experts may be able to more easily understand and relate the simulation to the system being modeled, hereby making a more critical comparison. For example, if the simulation that models the effect that levels of maintenance spending have on road surfaces (e.g., potholes, broken pavement, etc.), is being validated, video images can be linked to simulation results, and displayed instead of paper reports. Neutral experts would be able to make a more accurate validation of the model if they were able to draw on multimedia representations of the simulation and road system versus comparing paper simulation results and textual descriptions of the real situation.

A transportation group at George Mason University is using video and graphics to simulate the current problems associated with traffic signage and potential solutions. The multimedia nature of simulation made it very easy for independent experts familiar with the current signage and road network of Tysons Corner to validate the model [Gantz 1990].

4.6 Presentation/analysis of results

Use of multimedia extensions add value and improve the quality of presentation and analysis of simulation results by providing for

- Visualization
- Common grounds for information transfer
- User acceptance of simulation

The values added by using multimedia for presentation of results in each of the above three categories are described in more detail below.

4.6.1 Visualization

Perhaps the most important value added to the presentation/analysis of simulation results through the use of multimedia capabilities is its ability to provide for visualization. Multimedia provides a vehicle to effectively present simulation results and help decision makers visualize or "see" the results, and to be able to also "see" the effects of sensitivity analysis performed on the results of what-if type exercises.

For example, consider an application in highway maintenance of scheduling for least disruptive traffic flow while one or two lanes of a busy four-lane highway toll bridge are being repaired. A simulation model using multimedia capabilities can provide for visualization of the results of the simulation by displaying animation or motion video of the results.

In a similar manner, when presenting the results of the simulation to decision makers and exercising what-if type questions, the various choices and solutions can also be displayed using multimedia capabilities. Referring back to our traffic signage example, the multimedia nature of the simulation allowed a group of decision makers to visually exercise what-if type analysis of potential solutions to the signage problem. This would greatly help decision makers in visualizing the results of different solutions to the problem at hand, instead of having to read and analyze pages of statistical analysis and numerical values in the limited time available. Another benefit of using multimedia extensions for presentation/analysis of simulation results is that it helps users and decision makers generate and maintain interest in exercising the analytical power of simulation [Brunner and Henriksen 1989].

Visualization through multimedia is also an asset in situations where there is a group of decision makers gathered to make a decision based on simulation results which may be difficult to understand without considerable effort. When using multimedia capabilities for presentation/analysis of simulation results, several features such as zooming for a more detailed view, panning for a broader overview, various viewing orientations, and control over the speed of the presentation provide for more effective demonstrations.

Poorte and Davis [1989], in their study on computer animation, discuss several advantages of using animation for presentation and analysis of simulation results. They point out that the ability to provide credible information to a decision maker is associated with the ability of the modeler to effectively communicate the results of a simulation. They indicate that animation provides the analyst with a powerful vehicle to give the domain expert insight into a complex model and to help explain the proposed solution.

Poorte and Davis [1989] and Sadowski [1989] indicate that animation can play a major role in bottleneck analysis. With animation, bottleneck situations are usually simple to locate, since animation provides the modeler with the ability to observe interactions of several simultaneous and interrelated events (information which is unavailable in aggregate statistical performance measures). Equally important is that through animation, the pre-conditions under which such unfavorable situations occur become apparent.

It should be stressed that the purpose of using multimedia is not to replace statistical analysis techniques and procedures, but to augment and provide for an effective presentation of simulation results to decision makers in a limited time normally available to them.

4.6.2 Common Grounds for Information Transfer

Incorporating multimedia capabilities for the presentation and analysis of simulation results helps provide common grounds for information transfer. Understanding statistical results and analysis may be difficult to a population of decision makers who may not have the necessary background and/or in some cases the simulation results may not be perceived correctly.

In such situations, multimedia (through the use of animation, sound, and motion video), because of its flexibility and ease of use, can bring users with different levels of technical expertise and domain knowledge to roughly the same level of problem understanding. Thus, it would help the simulation experts to present a clear and understandable presentation and analysis of simulation results. For example, it is often difficult to impart the dramatic effect that acid rain has on the Nation's highways. Acid rain creates pot holes and may lead to the complete deterioration of the road bed. It is more effective when presenting results from acid rain simulation to use video or still pictures versus giving decision makers a textual description.

Another use of multimedia presentation in the above example would be to demonstrate and compare two time-lapse studies. In such a presentation, a time-lapse study which has been collected over a period of years on the effects of acid rain on highways can be compared with a similar study where acid rain has not occurred.

4.6.3 User Acceptance of Simulation

In order for users or decision makers to accept and use the results of a simulation model, it is necessary for them to be able to understand it clearly and to relate to the model. As described in our acid rain example above, multimedia capabilities can make presentation of simulation results more effective and easily understood as opposed to using only statistical results and pages of numerical values. Similarly, in the Tysons Corner traffic signage problem, the use of video and graphics helps present potential solutions more effectively. Such a presentation helps decision makers better understand the solution and its real world implementation. Thus, augmenting simulation capabilities with multimedia helps users/decision makers to be able to form a more accurate mental model of the simulation model (more closely related to the actual) with less effort and thus to have a better and clearer understanding of it.

4.7 Documentation

Documentation is usually considered a tedious but necessary task for any system. If the model is utilized for a long time, changes to the data and logic will need to be made from time to time. If the model is extremely large and complex, documentation will be needed to understand the model during its life time [Sadowski 1989].

In multimedia systems, because related information is linked together, the user can get desired information such as footnotes, references, definitions, and "see also" by a simple click. Tedious searching can be eliminated. In addition, direct linking can also help data organization. New information can be easily added and redundancy can be reduced.

The capability of merging multimedia data such as text, sound, video, etc. can make the simulation documentation more understandable and enjoyable.

5. CONCLUSIONS

In a simulation development process, the correctness of the user's (i.e., decision maker's) mental model of the simulation model and simulation result is vital to the success of definition, development, verification, and validation of the simulation model, presentation/analysis of the simulation results, and documentation. Results of our efforts to integrate multimedia and simulation indicate that the use of multimedia is a valuable tool to address several stages of the simulation development process. More specifically, multimedia enhances the analyst's ability to effectively formulate problems, collect data, validate models, and present/analyze simulation results.

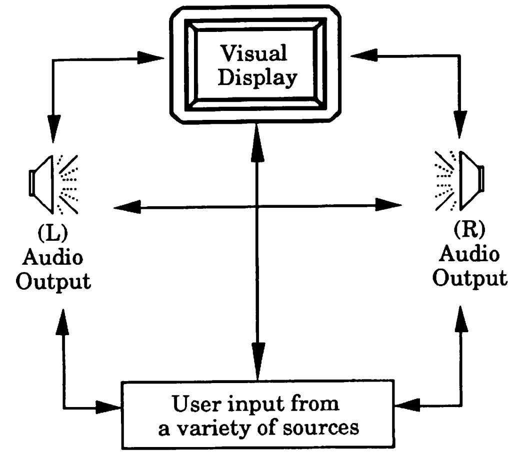
In our experience, multimedia allowed for a clear definition of simulation requirements by enhancing the ability of the users to recognize and better understand the problem and its context, as demonstrated in our Interstate 66 example. Multimedia also provides an effective tool for data acquisition. The ability of multimedia to capture data in an accurate and complete manner was demonstrated in our TYTRAN Forum example. Our efforts also indicate that multimedia provides effective presentation for model validation and analysis of the results. In our traffic signage example, multimedia provided the group of decision makers with the capability to effectively visualize the signage problem and its potential solutions. There are twelve possible types of interactions that we feel are important for hypermedia-based Human-Computer Interaction. These are depicted in Figure 2.

Finally, it should be stressed that the use of multimedia in simulation is to provide for effective communication with decision makers, and is not to replace, but to augment, traditional simulation techniques and practices.

ACKNOWLEDGEMENT

This work was sponsored in part by the United States Department of Transportation, Urban Mass Transportation Authority, under a contract through the National Center for Regional Mobility at George Mason University, and the Virginia Center for Innovative Technology, under a contract through the Center for Software Systems Engineering at George Mason University.

HYPERMEDIA-BASED HUMAN COMPUTER INTERACTION



12 possible types of interaction

- Visual display directed to right audio channel
- Visual display directed to left audio channel
- Right audio channel directed to visual display
- Left audio channel directed to visual display
- Right audio channel directed to left audio channel
- Left audio channel directed to right audio channel
- Visual display directed to user
- User response to visual display
- Right audio channel directed to user
- User response to right audio channel
- Left audio channel directed to user
- User response to left audio channel

(Adapted from [Brewer 1986])

Figure 2. Hypermedia-Based HCI

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