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Technological Advances in Evacuation Planning and Emergency Management: Current State of the Art

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16. Abstract

Evacuation of people in the event of hazard is one of basic problems of human society. From early ages people planned their habitat with possibility of hazards in mind. For instance, one of The Seven Wonders of the World, the Temple of Artemis, was built on a swamp, to protect it and its personnel from earthquakes often in that area. With the course of history, complexity of human built buildings and infrastructures grew, as well as a population density. This increased the dangers imposed by any hazard, occurring in densely populated areas, and imposed higher requirements on evacuation and emergency management. Nowadays, evacuation planning and emergency management became a sophisticated field of civil engineering sciences, aimed to save human lives by safe facility design and optimization of rescue operations. To do so, it uses latest achievements in number of various both fundamental and applied disciplines, such as Simulation, Process Control, Applied Mathematics, Psychology, Architecture, Physics and many others. In this work we attempt to present a survey of various approaches and technologies, being developed and being used for Evacuation Planning and Emergency Management.

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1. INTRODUCTION

Evacuation of people in the event of hazard is one of basic problems of human society. From early ages people planned their habitat with possibility of hazards in mind. For instance, one of The Seven Wonders of the World, the Temple of Artemis, was built on a swamp, to protect it and its personnel from earthquakes often in that area. With the course of history, complexity of human built buildings and infrastructures grew, as well as a population density. This increased the dangers imposed by any hazard, occurring in densely populated areas, and imposed higher requirements on evacuation and emergency management. Nowadays, evacuation planning and emergency management became a sophisticated field of civil engineering sciences, aimed to save human lives by safe facility design and optimization of rescue operations. To do so, it uses latest achievements in number of various both fundamental and applied disciplines, such as Simulation, Process Control, Applied Mathematics, Psychology, Architecture, Physics and many others. In this work we attempt to present a survey of various approaches and technologies, being developed and being used for Evacuation Planning and Emergency Management.

2. OVERVIEW

There exist numerous developments in the fields of Hazard Safety. Simply describing them will make it very hard for the reader to comprehend the structure and relationships between them. Therefore, in order to simplify the survey, in this work we introduce the classification of them by various factors, such as approach, technology and methodology.

By approach to hazard management problem all methods may be divided into two main classes: Evacuation Planning and Emergency Management. Evacuation Planning employs proactive approach to problem solution by modeling the hazard occurrence process via various kinds of simulation techniques and develops recommendations for improvement of evacuation procedures: building plan redesigning, creating additional shelter areas, evacuation training, etc. Emergency Management deals with the hazard upon its occurrence, i.e. uses reactive approach. Its goal is to optimize the evacuation process and the efforts of rescue teams, such that number of casualties is reduced maximally.

By problem solution methodology hazard safety methods may be divided into following categories: simulation, training and communication. Having the same goal of minimizing human casualties, hazard safety methods attempt to achieve via different routes. Simulation methods model real-life hazardous situation using collection of various mathematical methods, such as human behavior models, hazard propagation models, etc. Due to heavy computational requirements and long run times, simulation methods are mostly used in planning stage, e.g. helping architects to plan building such that human casualties are minimized in case of possible hazards. Training methods are used to educate people how to behave in emergency situations, how to coordinate their actions and evacuate the building in safest manner. Communication methods provide efficient and reliable communication between rescue agencies. Customized to given evacuation environment, they attempt to coordinate efforts between rescue agencies, such that emergency situation is relieved with minimal losses. Clearly, communication methods have purely reactive, i.e. emergency management, application.

Different methodologies employ different collections of technological tools. For instance, simulation methods use sophisticated mathematical models and fast computers. Training methods may range from simple building evacuation drills to replicas of real-life hazard environment - simulators. Communication methods vary from simple voice communication switchboards to complex multi-agent computer network systems. In this survey, we will provide in-depth look into different technologies used for hazard safety throughout this report.

The report is divided into two main parts by Hazard Safety approach: Evacuation Planning and Emergency Management. Each part is subdivided into subsections by solution methodology used. Within each subsection we will describe products, currently available in the market or being developed.

3. EVACUATION PLANNING

The ultimate goal of any evacuation planning effort is to maximally reduce the number of casualties in case of possible hazards. Being capable of promptly initiating an evacuation, ensuring that occupants take appropriate actions during the evacuation, and being able to account for people after an evacuation may make the difference between life and death. The concept used by Evacuation Planning approach is to analyze possible hazard scenarios for the given facility (building, town, etc.) and develop procedures for safe transfer of people from the affected area into safe areas.

An effective evacuation begins with a well-prepared plan. The planning process should begin with a risk assessment. This helps to identify what types of emergencies both inside and outside your facility might require evacuation or other emergency response actions. All foreseeable events should be considered. The probability of the event occurring and the severity of its impact should be used to prioritize preparation efforts.

Evacuations are planned in levels. Some emergencies may require the evacuation of only a small area near the problem, others might require the entire building be evacuated and larger emergencies might require the entire site be evacuated.

Considering stated above, an Evacuation Planning procedure assumes following steps:

1. Vulnerability assessment
2. Analysis
3. Probability impact assessment
4. Review of plans, resources, codes and regulations
5. Identification of internal resources
6. Identification of external resources

At the Vulnerability Assessment step the following factors are to be considered:

- *Historical:* Fire, Utility outage, Chemical spill, Weather related, Transportation breakdown, Terrorism
- *Geographical:* Flooding, Tornado, Nuclear plant proximity, Hazardous materials storage, Proximity to major transportation, Forest
- *Technical:* Telecommunications failure, Computer system failure, Power failure, Heating/cooling failure, Emergency notification system failure
- *Human Aspects:* Poor training, Fatigue, Carelessness, Misconduct, Poor maintenance techniques, Substance abuse, Workplace violence
- *Construction / Design:* Physical construction, Hazardous chemical process, Equipment and layout, Lighting, Evacuation routes / exits, Shelter areas

Next, during the Analysis the following factors are assessed:

- Loss of electricity
- Communication lines dead
- Water damage
- Smoke damage
- Building collapse
- Chemical release
- Economic factors: Supplier, customer, equipment

After each factor is assessed, then impacts of each disaster situation are analyzed:

- Impact on human life
- Impact on property
- Impact on business

During the analysis the following Internal Plans are developed, based on its results:

- Evacuation plans
- Fire protection plans
- Safety program
- Security procedures
- Insurance policies
- Hazardous materials plan
- Purchasing procedures

The following External Support Resources normally include:

- Elected officials: City, County, State Government
- LEPC
- Fire department
- Police department
- American Red Cross
- Public works
- Telephone company
- Neighboring businesses
- EMS services

Internal Resources and critical products include:

- Utility services
- Telecommunications
- Vital equipment, personnel, operations (key staff)
- Sole source vendors
- Products provided by suppliers

As a result, Evacuation Planning effort produces the following response procedures...:

- Evacuation routes outside facility
- Shelters for employees
- Care of employees, visitors, guests, contractors
- Organization of self help groups
- Security procedures
- Employee reporting centers
- Inventory of secondary skills
- Shut down procedures
- Data recovery
- Management of response activities
- Fire response procedures
- Plan for protection of vital records and documents

...and facility-related documentation:

- Site plans
- Floor plans
- Utility layout
- Equipment layout
- Gas lines and cutoff valves
- Water lines
- Sewer lines
- Fire suppression
- Fire extinguishers
- Exits
- Restricted areas
- Water hydrants
- Stairways
- Hazardous material
- Alarms
- Escape routes
- Cleaning supplies

Below we provide descriptions and examples of several Evacuation Planning methodologies.

3.1 Site Analysis Consulting

In most cases evacuation plans are compiled by various consulting agencies and firms. Usually those are made by experienced safety engineers. Consultant evaluates the scene by looking at plan drawings and/or coming onto premises and develops evacuation plan. Evacuation plan is a drawing of safest escape routes from given premises in case of hazard. In addition to evacuation plan, consultant may make recommendation on additional safety measures to be taken, such as creation of addition shelter areas or installation of additional fire sensors. While developing evacuation procedures, consultant relies mostly on his experience and governmental and municipal safety guidelines. Some consultants develop extensive simulation tools and use them to test their evacuation recommendations, others use purely human-base analysis or use simpler software components, which simulate simpler hazard situations. Below we provide overviews of several Evacuation Consulting firms strictly for illustrative purposes.

3.1.1 EPlan

EPlan was designed by emergency management professionals. EPlan is a web-based collection of references, such as evacuation plans, mitigation plans, governmental safety regulations, building safety codes, etc. EPlan takes the user through hundreds of references with the click of a button, thus making the process of creating and updating the evacuation plan simple and quick. The features of EPlan include:

- The Emergency Plan:
    - Easy to navigate
    - Easy to locate reference documents
    - Easy for the untrained to use
    - Roles and responsibilities of your EOC team
    - Local demographics, local laws.
- The Mitigation Plan:
    - Easy to navigate
    - References concerns and mitigation
    - Describes the history
    - What the plan is to help prevent or lessen the impact of disasters in community.
- Operating procedures:
    - Over a dozen procedures including those used for nuclear power plant events and exercises.
    - Proven to work
    - Easy to navigate, select the procedure and click
- Checklists:
    - Dozens of checklists that cover natural and manmade hazards. Each includes actions for: Planning, Response, Recovery
- Data base:

- Includes the things most emergency managers want: Damage assessment, Resources, Resource requests and processing, Shelters and shelter population, Significant incidents, Personnel

- Links to important sites:

  - Need more information, connect to the internet and just click. FEMA, Chemtrec, NOAA and more.
  - There are links throughout EPlan to help guide you through the maze of information available.
  - EPland does the research, just locate the information and simply click.

3.1.2 BTG

BTG's Research Planning business unit (RPI) provides domestic preparedness services that focus on the actions needed to protect public health and safety, restore essential services, and provide emergency relief to affected individuals, businesses, and governments. From emergency management and planning to consequence management and counter-terrorism, RPI assists local, state, and federal governments, and clients in the private sector to deal with potential natural, manmade, and technological disasters, including those involving weapons of mass destruction.

Emergencies such as these require special attention, and RPI is equipped to provide it. Some of our specialties include:

- Analysis of emergency plans and procedures
- Consequence and crisis management planning
- Chemical, biological and nuclear response plans
- Development of emergency plans and procedures
- Explosive ordnance disposal
- Integration of local, state and federal plans
- Risk identification and assessment
- Safety analysis and reporting

3.2 Simulation

Simulation is the main tool to reproduce the hazardous situation using computer technology in order to assess dangers and produce set of recommendations for evacuation procedures or alteration of environment, such as building layout changes, creation of shelter areas, etc. Since it requires only the plan or the map of the premises (building, town, etc.), simulation is a great tool to assess hazard risks and consequences at planning stage. By using simulation, architects and city planners can update their plans before an actual construction occurs, thus increasing their safety and saving costs on remodeling.

Evacuation simulation is usually quite complex process, which involves numerous factors to consider. Typical factors, considered by all evacuation planning simulation models are:

- *Scene layout*. This may be a plan of the building or town map. It defines evacuation routes – routes people can take to escape the hazard area. It may also contain shelters – protected areas, which may secure people within from hazards for some period of time. Such areas are usually made for cases when some people cannot leave the facility even during the hazard. Control rooms in nuclear plants or hospital operation rooms may be examples of shelter areas. Shelters commonly have limited capacity and are safe only from minor strength hazards.
- *Human behavior*. This is very important and very difficult aspect to model. Number of casualties depends on number of various human factors, such as people's age, preparedness to evacuate, ability to panic, to crowd, and many others.
- *Hazard propagation*. It is extremely important to know how certain hazard propagates in order to evacuate people first from most endangered areas. Hazards propagation models are different for different hazards (fire, flood, gas, etc.) and account for number of factors, such as scene layout, materials, environmental conditions, etc.
- *Environmental conditions* are closely related to Hazard propagation models, as in most of the cases they define how hazard will propagate. For instance, wind may cause forest fires spread in certain direction. Environmental conditions models are extremely complex mathematical formulations.

3.2.1 EXODUS

EXODUS is developed by Fire Safety Engineering Group (FSEG) of the University of Greenwich, Greenwich, UK. EXODUS can be named the best fire evacuation simulation tool currently available in the market and features very sophisticated fire and smoke propagation models, as well as complex human behavior models. EXODUS currently comes in several versions: buildingEXODUS, marineEXODUS and airEXODUS. vrEXODUS is an additional module, which displays simulation results as 3-D animations using Virtual Reality Modeling Language (VRML). railEXODUS is currently under development. FSEG also provides evacuation consulting services. Below we provide review of principles used in buidingEXODUS.

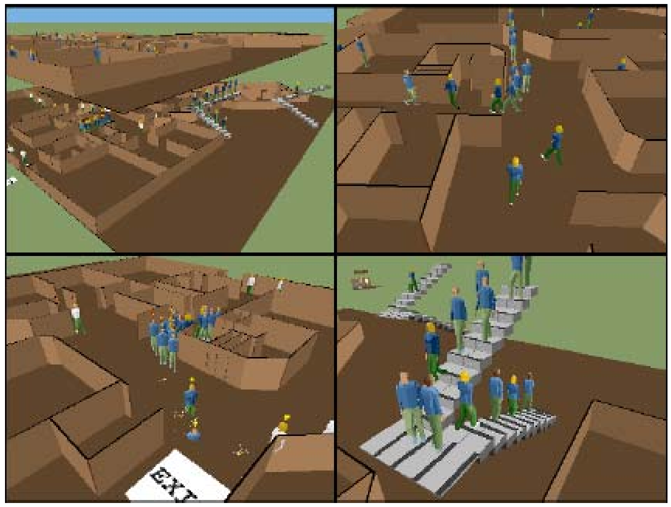
EXODUS is a suite of software tools designed to simulate the evacuation of large numbers of people from a variety of enclosures. The buildingEXODUS model comprises five core interacting sub-models: ***Occupant, Movement, Behaviour, Toxicity and Hazard***. The software, written in C++ using object orientated techniques, is rule-based, the progressive motion and behavior of each individual being determined by a set of heuristics or rules.

The spatial and temporal dimensions within buildingEXODUS are spanned by a two-dimensional spatial grid and a simulation clock (SC). The spatial grid maps out the geometry of the building, locating exits, internal compartments, obstacles, etc. Geometries with multiple floors can be made up of multiple grids connected by staircases, with each floor being allocated a separate window. The building layout can be specified using either a DXF file produced by a CAD package, or the interactive tools provided, and may then be stored in a geometry library for later use. The grid is made up of nodes and arcs with each node representing a small region of space and each arc representing the distance between each node. Individuals travel from node to node along the arcs.

On the basis of an individual's personal attributes, the Behavior Sub-model determines the occupant’s response to the current situation, and passes its decision on to the Movement Sub-model. The Behavior Sub-model functions on two levels. These are known as GLOBAL and LOCAL behavior. GLOBAL behavior involves implementing an escape strategy that may lead an occupant to exit via their nearest serviceable exit or most familiar exit. The occupant’s familiarity with a particular building may be determined by the user prior to commencing the simulation. It is also possible to assign individuals with an itinerary of tasks – such as visit a pre-defined location - that must be completed prior to evacuation.

The desired GLOBAL behavior is set by the user, but may be modified or overridden through the dictates of LOCAL behavior. The LOCAL behavior includes such considerations as determining the occupants initial response to the call to evacuate i.e. will the occupant react immediately or after a short period of time or display behavioral inaction, conflict resolution, overtaking and the selection of possible detouring routes. The manner in which an occupant will react to local situations is determined in part by their attributes. As certain behavior rules, such as conflict resolution, are probabilistic in nature, the model will not produce identical results if a simulation is repeated.

The Toxicity submodel determines the physiological impact of the environment upon the occupant. To determine the effect of the fire hazards on occupants, EXODUS uses a Fractional Effective Dose (FED) toxicity model, this assumes that the effects of certain fire hazards are related to the *dose* received rather than the exposure *concentration*. The model calculates the ratio of the dose received over time to the effective dose that causes incapacitation or death, and sums these ratios during the exposure. When the total reaches unity, the toxic effect is predicted to occur. Within buildingEXODUS, as the FED approaches unity the occupant's mobility, agility, and travel rates can be reduced making it more difficult for the affected occupant to escape. The core toxicity model implemented within buildingEXODUS is the FED model of Purser. This model considers the toxic and physical hazards associated with elevated temperature, thermal radiation, HCN, CO, CO2 and low O2 and estimates the time to incapacitation. In addition to this behavior, the occupant is allowed to stagger through smoke filled environments and is slowed down according to the data of Jin. Occupants are also given the ability to select another exit path when faced with a smoke barrier based on their familiarity with the structure. The thermal and toxic environment is determined by the Hazard submodel. This distributes hazards throughout the environment as a function of time and location. buildingEXODUS does not predict these hazards but can accept experimental data or numerical data from other models. A software link has been established between the buildingEXODUS and the CFAST zone model. This allows CFAST (version 4.0) history files to be automatically passed to the buildingEXODUS model, thereby enabling the buildingEXODUS and CFAST models to interact in a relatively straight forward manner. To aid in the interpretation of the results produced by buildingEXODUS several data analysis tools have been developed. These are intended to be used once a simulation has been completed and enable large data output files to be searched and specific data selectively and efficiently extracted. In addition, a post-processor virtual-reality graphics environment has been developed, providing an animated three-dimensional representation of the evacuation.

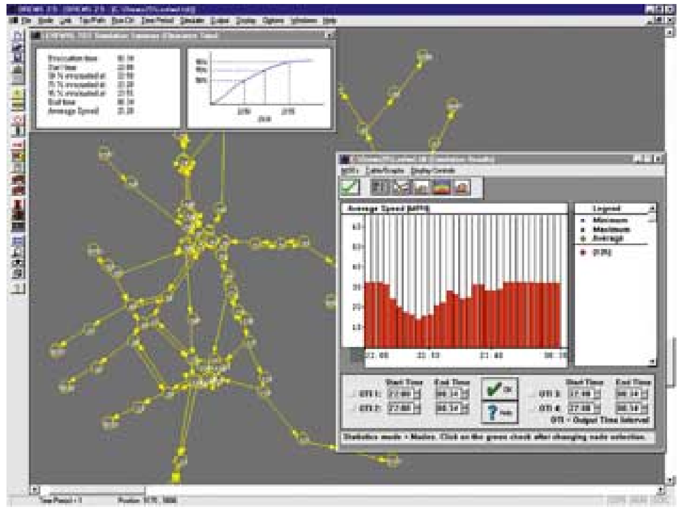


3.2.2. OREMS

Oak Ridge Evacuation Modeling System (OREMS) is developed by Oak Ridge National Laboratories and is a traffic simulation system, which aimed to be used to help emergency responders develop plans for moving people quickly and safely away from the site of most any disastrous event. Evacuation scenarios can range from a natural event, such as an earthquake or hurricane, to a deliberate attack on part of our energy infrastructure, to an accidental release of hazardous materials.

OREMS is based on data obtained from actual experiences and events, such as dam failures in Colorado and Wyoming and explosions at chemical plants. OREMS can be used to estimate clearance times for evacuating an area, predict traffic bottlenecks, and evaluate traffic control strategies.

OREMS models the flow of vehicles over a network of roads around a source of hazardous material, as could result from an accident at a plant in which a plume of toxic chemicals is released. Most road network data are available from local departments of transportation, and local population census data are available from the U.S. Census Bureau.



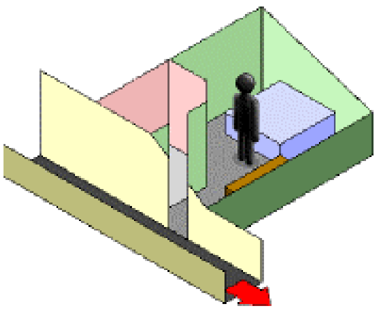
The OREMS tool can be used to predict how fast a town can be evacuated if lanes are reversed—for example, turning a two-way, two-lane road into a one-way, two-lane road. For example, OREMS was used to illustrate the best way to evacuate a small town in Kentucky that can be accessed only by a two-lane road.

OREMS is the only evacuation simulation model that uses state-of-the-art traffic simulation codes derived from U.S. Department of Transportation (DOT) models. Furthermore, it is the only model of its kind endorsed for use by DOT in regional evacuation planning. OREMS was developed to replace obsolete technology used in other evacuation simulation approaches.

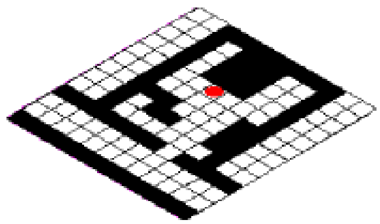
3.2.3. PedGo

PedGo is a software tool, used to simulate evacuations of pedestrians, developed by TraffGo, GMbh, Germany. PedGo was a result of implementing the scientific results into user friendly and fast software. PedGo is claimed to be the fastest program to simulate evacuations available on the market (10.000 Persons in real time on a 500MHz PIII). As a result, it saves valuable time to do many evacuation runs, which are mandatory for statistical evacuation analysis.

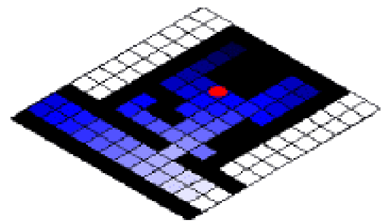
The model used in PedGo is a so called microscopic simulation model. This means that the decisions and the movement of every single person is simulated. In order to do this a multi-agent-model in discrete time and space is used. The floor plan of the investigated building is divided into quadratic cells of a size of 0.4 by 0.4 meters. Each cell represents the space a person occupies when standing in a queue. The direction in which a person has to move in order to reach his goal is contained in the cells. So when moving, a person first orientates by this cell information and then jumps from one cell to the next one, evading obstacles and other persons.



A room and a small corridor as a simplified example.

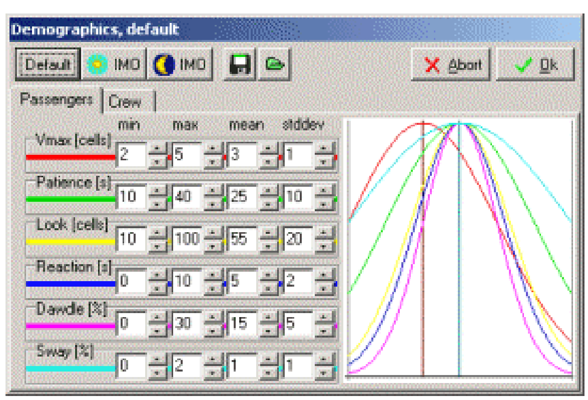


The geometry is transformed into cell informations. Next to free cells, the following celltypes are used: walls, doors, stairs.



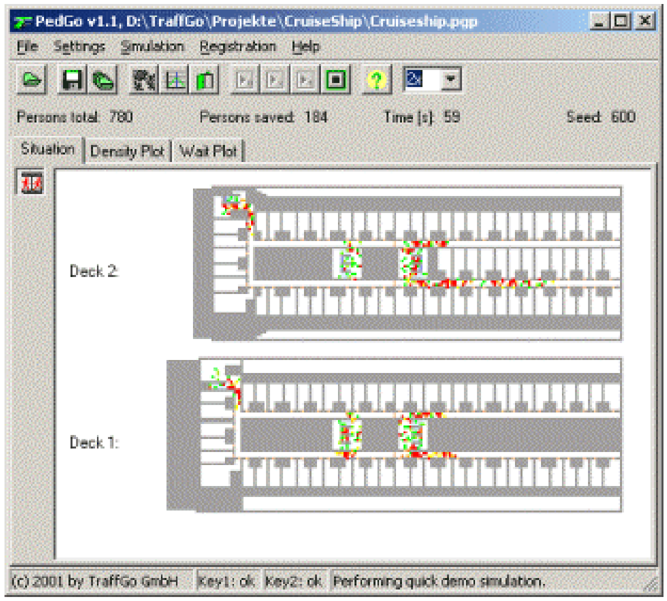
From the appointed exits, potentials spread according to the given egressroutes. The gradient of the blue color marks the potential value.

All persons in the simulation basically use the same movement algorithm. To take the variation of abilities into account, every person has her own parameters that influence her behavior. Of course, the list of factors affecting the movement of a person is nearly endless. However, at the end of the day, the movement of a person from a physical point of view is only characterized by her speed and her direction. This way, the number of parameters characterizing the abilities of a person was reduced to six.



The demographics-dialog of PedGo. All parameters are assigned by normal distributions with cutoffs (min/max value)

Because of the statistical distribution of the parameters, the result of the simulation can vary a lot. Next to this, statistical decisions of the persons, while walking, again spreads the outcome of the simulation. This is why every simulation run provides a different evacuation time, just like in reality.



Screenshot of PedGo, simulating the evacuation of the two aft firezones of a cruise ship.

3.2.4. Assisted Evacuation Simulation

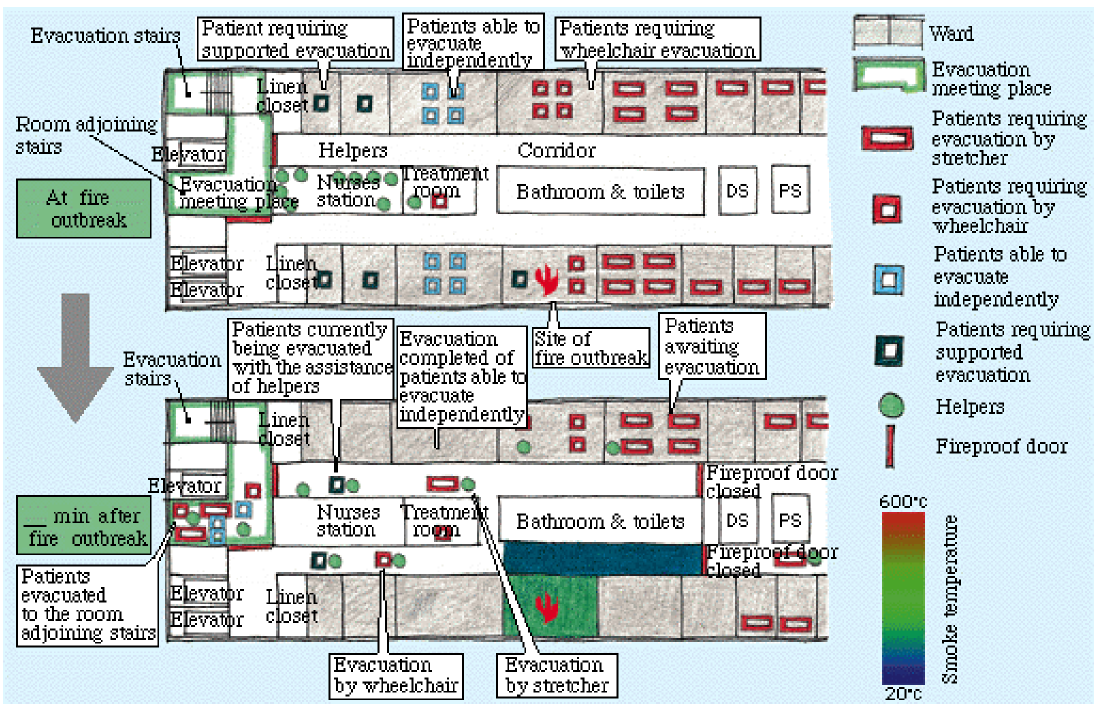
The Assisted Evacuation Simulation System by Takenaka Co., Japan, is designed to simulate evacuation of patients and personnel in environments, where some people are not capable of evacuating themselves. Hospitals and Assisted Living Facilities are examples of such environments. The uniqueness of The Assisted Evacuation Simulation System s that it incorporates into a model the characteristics of assisted evacuation, such as the number of patients and helpers, and assisted evacuation method (evacuation by stretcher, evacuation by wheelchair, and evacuation by helpers' supporting patients on both sides) to predict the evacuation time, the state of evacuation, and the flow of smoke in event of fire. This system can be used not only for new facilities, but also in the renewal plans of existing facilities and review of disaster prevention management frameworks of hospitals.

Features:

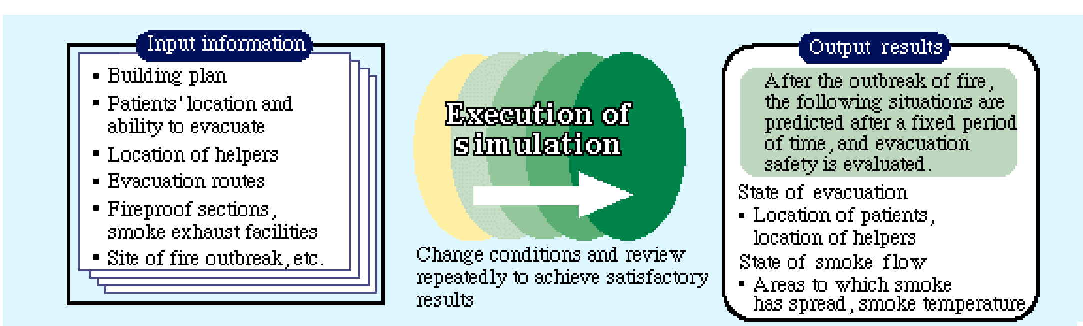
- Simulation of assisted evacuation activities such as stretchers and wheelchairs.

- It is possible to set detailed conditions such as the number and location of patients and helpers, and methods of help for each patient.
- It is possible to confirm the evacuation activities of each patient and helper on a computer screen, one at a time.
- Simulation of the spread of smoke at the same time as evacuation movements.

The system can be applied to evacuation training by carrying out repeated simulations with different conditions.



This system enables thorough simulations in accordance with the circumstances of hospitals and aged care facilities.



3.2.5. SEVEX

The **SEV**eso **EX**pert system or **SEVEX** is a software designed to estimate risks zones around hazardous materials handling and storage facilities like chemical activities, in particular the " Seveso-type " industries (*cfr. the European SEVESO Directives*), railway marshalling yards, ports area or pipe-line terminals (*cfr. announced European Directives*). It has been developed by the Walloon Region of Belgium in collaboration with the " Facultй Polytechnique de Mons ", the " Universitй Catholique de Louvain ", the " Universitй de Liиge " and the SOLVAY s.a. company.

SEVEX is an off-line hazard propagation tool, which can be used to generate the most realistic mapping of risk areas around chemical industries in order to build up effective and manageable Emergency Response Plans. SEVEX models the accidental release from single or multiple pipes, vessels or pool sources. The release can be continuous, transient or catastrophic. At this stage, 34 chemical substances are considered in the data base. Its extension to the most common substances is in progress.

The fields of applications of SEVEX are:

- Simulation of accidental release from chemical activities
- Risk Area mapping taking into account toxicity, over-pressure and radiation
- Emergency response planning preparedness and training

SEVEX computes all the aspects and consequences of accidental releases of hazardous materials (*toxic* or *flammable*) through a set of coherent scientific models :

1. The source term module (***SEVEX-SOURCE***) that includes calculations of : gaseous, liquid and two-phase flow rates, jet dispersion, aerosol vaporisation, pool formation and evaporation, dense gas dispersion, unconfined vapour cloud explosion (UVCE) and fireball thermal radiation (BLEVE). For quick assessment purposes allowing to design most relevant scenarii and situations the *SEVEX-SOURCE* module can be coupled to simple Gaussian dispersion model.
2. The 3-D meso-meteorological module (***SEVEX-MESO***) that is a 3-D numerical model solving the simplified Navier-Stokes equations for the wind flow in a vorticity mode. This model takes into account the topography and the main surface characteristics such as roughness length, heat and radiation transfer between the surface and the atmosphere

which extend up to 2000 m. Computations are made for different synoptic wind speeds and directions during cloudy days and clear nights. Those situations have been chosen because they lead to worst dispersion conditions.

3. The 3-D dispersion module (***SEVEX-TOXIC***) that is a Lagrangian dispersion model. It simulates passive transportation and dispersion of particles of toxic or irritating substances at a rate and in a state given by the *SEVEX-SOURCE* module. The wind fields and turbulence characteristics are taken from the *SEVEX-MESO* module.

These different modules are linked together and implemented into a user-friendly interface. Starting from a source description (or accidental release scenario) deduced from a safety analysis, SEVEX enables to produce ***maps directly usable by emergency planning teams***. These maps show various danger zones considering toxicity, overpressure and heat effects. Three levels of danger are taken into account: temporary diseases, permanent injuries out door and danger indoor. SEVEX maps show also where no danger is expected. These information enables to define clearly the behavior to adopt facing the danger: no change in behavior, avoiding exposure advised, self-confinement or evacuation.

The outputs of SEVEX are compiled into a Data Base of potential accident maps showing accidental scenario information (substance, effects, danger to public, meteorological conditions, …), realistic mapping of risk zones corresponding to defined thresholds and behavior to adopt. In case of an emergency, this so-called "**SEVEX Atlas**" provides an immediate answer or anticipated decision about the behavior to adopt and the instructions to enforce in each danger zone.

Such anticipated decisions are the only way to avoid the chaos of misleading orders. Indeed SEVEX prevention policy is to be prepared to the worst "realistic" situations. This will lead to conservative decisions for better conditions. SEVEX integrates in each level of the analysis the inherent uncertainties of emergency situations and builds up the most suitable emergency plan on the basis of the very few certainties available.

Technical Features:

Domain Extent: 37 km x 37 km

Grid Resolution :

- 1 km x 1 km for the wind field calculations by SEVEX-MESO
- 0.1 km x 0.1 km for the concentration calculations by SEVEX-TOXIC

Two levels of inputs are necessary. A first set is needed to produce the SEVEX Atlas. The second one enables to use the SEVEX Atlas in practical situations of emergency once the SEVEX Atlas exists.

Production of the SEVEX Atlas :

- Site description : topography, land use (as a standard a 5 land types data base provides : emissivity, roughness length, albedo and heat capacity) and corresponding scanned road map (or equivalent)
- Accidental scenario : substance involved, description and type of storage, vessels and pipe sizes, description of potential leak (those data are coming from a peer review of the studied facilities.)

Use of SEVEX Atlas

- Synoptic wind speed and direction,
- Substance involved,
- Accident type,
- Time of the day (day or night)

3.2.6. CyberSim

CyberSim (Pty) Ltd is an IT company in South Africa, developing unique software solutions for clients who want to enhance decision making, optimize operations and develop human resources. Services are rendered to clients in the use of the developed systems. This is achieved with multi-disciplinary teams that perform tasks to the highest quality standard. CyberSim provides the following:

- War and peace mission simulation systems
- Disaster management solutions
- Command and control systems
- User-specific software
- Exercise support
- Decision making support

The SimTek product range provides the tools to test and practice emergency plans and to improve the decision making performance of disaster and incident management personnel. SimTek allows for actual command and control, training and analysis of emergency plans for a variety of different systems and organizations. SimTek solutions can be applied in any system where the appropriate use of resources, crisis decision making and the application of emergency plans may be of relevance.

3.3. Training

Training is an important part of preparing for emergencies. Two types of training may be identified. First is the basic training, which all employees should receive some training when they initially begin work, when they change work areas within the organization, when procedures and/or hazards change and periodically during their employment. Second type is more specific and extensive training, provided to personnel who have specific responsibilities under the plan. For example, one may want to assign a person in each major area of a facility as an evacuation assistant. This person would help ensure that people in the area know there is an emergency and that they take the appropriate action. Management, local emergency response forces (fire squad, police, local government, etc.) are another examples of people, which require special emergency management training in order to manage emergency situations effectively.

Management and supervision of emergencies will normally be done within the regular management hierarchy unless an in-house emergency response team is present. Effective command and control procedures must be part of any emergency plan. These procedures must be carefully studied and if possible, rehearsed, by an emergence response personnel.

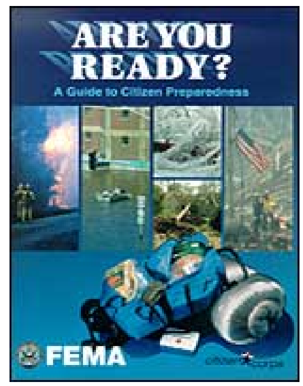
3.3.1 Educational Guides and Tutorials

Are You Ready? A Guide to Citizen Preparedness by FEMA

"Are You Ready? A Guide to Citizen Preparedness" brings together facts on disaster survival techniques, disaster-specific information, and how to prepare for and respond to both natural and man-made disasters.

As the most comprehensive guide to personal emergency preparedness published by the Federal Emergency Management Agency (FEMA), "*Are You Ready?"* will help individuals prepare themselves and their families for disasters.

Revised in September 2002, "*Are You Ready?"* provides a step-by-step outline on how to prepare a disaster supply kit, emergency planning for people with disabilities, how to locate and evacuate to a shelter, and even contingency planning for family pets. Man-made threats from hazardous materials and terrorism are also treated in detail. The guide details opportunities for every citizen to become involved in safeguarding their neighbors and communities through FEMA's Citizen Corps (www.citizencorps.gov) initiative and Community Emergency Response Team training program.



USFA Multimedia CD-ROM's

US Fire Administration, together with FEMA and other agencies, such as EMI (Emergency management Institute) offers a number of different CD-ROM based multimedia courses. Each course trains the user on a certain aspect of fire safety.

Incident Command and Control Simulation Series: Casper Hall

The student is presented with a fire in a six-story college dormitory. This is an occupied building of ordinary construction that presents a severe rescue problem, in addition to some ventilation and confinement challenges.

Incident Command and Control Simulation Series: Mansion Fire

A simulation depicting a very large, multi-story, single-family dwelling presenting fire spread and ventilation issues and a more complex rescue scenario. Due to the resource intensity of this incident, the student is given a second-alarm assignment.

Incident Command and Control Simulation Series: Ranch House

This simulation involves a scenario depicting a single-story, single-family dwelling and presents the student with a "room and contents" fire and basic rescue problem.

Incident Command and Control Simulation Series: Self-Study

This program provides the user with a basic explanation of the Incident Command System, including organizational structure, positions and functions, responsibilities and considerations. No certificate will be issued for this program.

Incident Command and Control Simulation Series: Strip Mall Hostage/Arson Fire

This scenario exposes the student to Unified Command with some unique considerations. Initially, it is a police problem and fire assumes a secondary role. After the situation is stabilized, fire assumes a lead role. Many of the considerations and actions are not encountered in day-to-day operations.

Incident Command and Control Simulation Series: Townhouse

The student is presented with a more complex fire and rescue problem in this simulation, one that might commonly be found in a townhouse, rowhouse, garden apartment or condominium.

Incident Command and Control Simulation Series: Tutorial

Prerequisite course for ICC Simulation Series 1. Provides the student with an overview of basic strategy and tactics and addresses the command skills that officers need to understand and use effectively.

USFA Technical Report Series CD-ROM

This CD-ROM contains 86 Technical Reports published by USFA from February 1987 through June 1999.

Wildland Tutorial Self-Study CD-ROM

Developed in partnership with USDA's Forest Service, this CD-ROM covers ICS 215 and 215A. This course is not part of the Incident Command and Control Simulation Series and a certificate will not be issued for successful completion.

3.3.2. Drills

No evacuation planning effort is complete without testing. All emergency plans should be tested periodically. A fire drill is the only way to get a realistic view of how plan will work.

Fire drills can be announced in advance or conducted without notice. If a new plan has just been developed, an announced drill is a good place to start. Once any difficulties with the plan have been worked out, then unannounced drills are a better test. One may also consider inviting local public response groups such as the fire department and emergency medical services to participate in a drill once one feels comfortable about your performance.

3.3.3. Simulators

Simulators are artificially-built facilities, which replicate the real-life emergency environment with high degree of reality. For instance, aviation evacuation simulator is an exact replica of a airplane segment, allowing flight crew to practice passenger evacuation in maximally realistic conditions.

Although being an excellent training tool, simulators cannot be used to train public due to their extremely high cost. They are mostly used by educational institutions (colleges, training companies, etc.) to offer specialized courses for safety professionals. This is especially necessary in the cases where proper safety education plays an important role in company’s performance. Manufacturing, pharmaceutical, petrochemical and marine companies may be good examples of those. Realistic and simultaneous fire handling and management response training has shown great value in preparing individuals for the conditions felt in a real-life incident.

3.3.4. Games

Due to impossibility to use simulators to train common personnel, alternative ways of training are being investigated. One of most promising ways is the creation of 3-D virtual reality environment using latest achievement in 3-D gamin technology. The same technologies that powers interactive 3D video games might save lives. Such game allows turning virtually any PC into an emergency training system. Such game may be developed by using general-purpose 3-D game engine, such as RenderWare. Although simulated drills will not replace real drills, they may drastically increase awareness in the participants by showing them the consequences in form of simulated injuries or even death.

Facility management of bigger buildings usually performs fire drills one or twice a year. These drills mostly consist of the complete evacuation of an office building. The realism of these drills usually does not go beyond the emergency sirens and lights in the building go off. The staff usually has no motivation to leave the building quickly and thus most of the complications arising in reality do not show during the drill (e.g. jams at doors).

Most of today’s office workplaces are equipped with a PC powerful enough to execute 3D computer games. The environment and the player’s actions in many of the classic first person shooter games are similar to that of a fire drill: Interior of buildings, player/actor moving/running through that environment, hazards. Modern multiplayer games can host hundreds of players in the same environment at one time. All this technology is readily available and can be used to simulate fire drill in two different ways:

• **Simulated Evacuation:** Given a building and the typical distribution of workers in the building the evacuation can be simulated using AI actors. The simulated evacuation can then be evaluated to find critical spots along the evacuation pathways and weaknesses in the evacuation plan.

• **Virtual Evacuation:** In case of buildings where most of the workspaces are equipped with PCs each worker can participate in a virtual evacuation. To add realism and increase the motivation of the “players” the system tracks the “health status” and total time of each participant.

Virtual FireDrill

"The concept of creating a computer training tool simulating emergencies is not unusual, but the use of a game engine to power it is," says Dr. Norbert Schiffner (Department Head, SDT).

The Virtual Fire Drill project by SDT of Fraunhofer Center for Research and Computer Graphics (CDCG) creates technologies and applications to simulate the evacuation of commercial and public buildings, using RenderWare game engine. Game designers use sound effects, music and other cinematic effects to emotionally involve the player. If a simulation's goal is to increase awareness this might be the way to go and computer game technology provides the necessary tools to do the job.

Study of burning CRCG Lab

Emergency Public Information Competitive Challenge Grant

This effort to create an emergency management training game was made by Essential Technologies, Inc. in 1985. It was sponsored by Emergency Public Information Competitive

Challenge Grant by FEMA, the Federal Emergency Management Agency. The Center for the Application of Science and Technology to Emergency Management was developing computer games that would teach the public emergency management techniques. "Saving Lives: The Emergency Management Game" was supposed to be designed for 3 types of users:

1. children aged 5 to 9,
2. older children and teens,
3. adults.

Its levels of play are:

1. hazard awareness,
2. preparedness actions,
3. warning responses,
4. event behavior, and
5. recovery behavior.

Variations include:

1. a children's educational game,
2. an adventure game,
3. a mystery novel game,
4. a simulator game.

Current condition of the project is unknown.

3.3.5. Incident Simulation Systems

JANUS Battle Simulation System

JANUS is an interactive, six sided, closed, stochastic, ground combat simulation featuring precise color graphics. Interactive refers to the interplay between the military personnel making decisions in crucial situations during simulated combat and the systems modeling that combat. Up to six sides may be simulated. Closed means that the disposition of opposing sides is largely unknown to players in control of a side. Stochastic refers to the way the system determines the results of actions like direct fire engagements, according to the laws of probability and chance. Ground combat means that the principal focus is on ground maneuver and artillery units. JANUS integrates weather and its effects, day and night visibility, engineer support, minefield employment and breaching, rotary and fixed-wing aircraft, resupply actions, and a chemical environment. The JANUS Battle Simulation Trainer provides the tools to train staff, exercise SOPs, and communication links. This ultimately will facilitate units in being successful on the Battlefield. JANUS is an upgrade from the Army Training Battle Simulation System (ARTBASS). JANUS is developed by Lawrenceville National Laboratories and is currently used by US military for training purposes.

Capability of JANUS to simulate real-life incident environment with high degree of accuracy and its flexible architecture makes it an excellent candidate for training tool for incident management team training. By "de-militarizing" JANUS (for instance, by importing civilian vehicles and rescue vehicles) one may be able to produce a great cooperative emergency management training tools. Such efforts are now being performed by several companies.

SimViz Suite

STAR Technology's SimViz/System training products support individual self-paced study or instructor-controlled styles of training. Interactive CD-ROM applications focus on specific learning objectives, provide personnel with the information required to participate in group exercises, and may be customized to operate in specific customer environments to meet their specific requirements and training objectives. SimViz is an incident simulation system that provides one or more views of an incident that is controlled by and instructor is a powerful training tool.

STAR Technology offers several version of SimViz, differing by the set of offered simulation and visualization options.

SimViz /2000

The SimViz/2000 Series is designed to provide emergency operations center students and instructors with a "top-down" view of an incident environment. Command and control training is the emphasis of the SimViz/2000 Series, which provides a global view of an incident and its surroundings. The SimViz/2000 Series is capable of displaying resource icons that can be dynamically updated during an exercise. Other informational data can be displayed on the base image—such as user-defined boundaries, structures, and natural features.

SimViz 3000

The SimViz/3000 Series provides the on scene view required for many Emergency Response training exercises. This series has both 2D and 3D SimViz/IDS capabilities. The on scene view displayed by these systems includes different visual effects based on the type of incident.

The SimViz/3000 Series is designed to provide emergency management personnel with the appropriate visual cues to reflect current incident conditions. A realistic training environment is created through the display of fire, smoke, vapor, and spill effects that are affected by student actions. The SimViz/3000 Series also incorporates advanced graphics modeling techniques to create realistic 3D incident environments. The use of 3D modeling techniques support the placement of virtual cameras anywhere in the environment in order to display the view that emergency incident management personnel would see from that vantage point within the environment. Incident effects—such as fire, smoke, vapor, and spill—are true 3D objects designed to move throughout the environment.

SimViz/4000

The SimViz/4000ICS is a SGI™ Octane^2-based emergency incident management simulation system with the increased performance provided by a high-end graphics workstation that presents a dynamic view of the incident environment using a 3D model of the environment with 3D fire, smoke, vapor, and spill effects. This system allows personnel to conduct emergency response exercises with an "on scene" view based upon the incident operating on the SimViz/ICM.

SimViz/5000

The SimViz/5000 Series is a more powerful version of the SimViz/4000 Series. The main enhancement is that the SimViz/5000 Series is performance tuned for use in a large-scale training installation.

A-TEAM

A-TEAM is an IT firm in Austria, working in the field of development of e-Learning tools for Safety Education and Training. The main objective of the A-TEAM project is to improve the learning process in complex, technical domains, using the example of technological emergency management. Improved learning is achieved by integrating information technology (dynamic simulation, visualization, GIS, expert systems and case-based reasoning) within an innovative didactic framework that fully exploits the potential of multi-media information systems. Improved efficiency and effectiveness of the learning and teaching process in complex technical domains difficult to cover with traditional didactic methods is seen as an important contribution toward a technological and information society.

A-TEAM is intending to develop and test a new approach to advanced technical training using an integration of artificial intelligence (AI) technologies and dynamic simulation modeling to create fully interactive multi-media content within a real-time knowledge-based system framework for the domain of emergency management applications. The underlying client-server architecture supports easy access in Intranet/Internet distributed systems.

The Features of A-TEAM system are:

- **A new paradigm for computer-based learning:** The system guides the learner through a simulated emergency, and monitors his reactions to the systems requests for information or decisions. Any deviation from the expected optimal path will lead to an intervention of the system. The error will be pointed out, in-depth background information on the concepts involved will be provided. Learner comprehension will be verified through embedded multiple-choice tests or simple training exercises, until the overall training case can be resumed. By logging and time-stamping any learner response, the system can evaluate the training run in a post-mortem analysis and provide constructive critique including suggestions for further study.
- **Flexible didactic framework:** the system is embedded in a hybrid forward-backward chaining real-time knowledge-based system (KBS). The KBS guides through the simulated emergency just as in a real emergency management application and coordinated the information resources, including the simulation models. At the same time, it monitors the trainee's responses, and can trigger additional explanatory

material, tests and questionnaires, or modify the sequence of events such as returning to a previous stage to re-run a critical part.

- **Case-based reasoning training scenarios:** Case-based reasoning within the framework of the overall real-time KBS will adapt these methods to the specific training scenarios. The possibility to move between levels of abstraction, i.e., go from a semi-empirical method to the underlying physical phenomenon, or abstract from a specific simulation to a generic class of cases interactively, adds an important experimental and explanatory component for the learning process.

- **Fully interactive immersive experience:** The project aims at providing fully interactive immersive experience through dynamic 3-D modeling of emergencies and their impacts with high- performance visualisation. This allows the trainee individually or in a team to gain experience in a domain where experimentation is largely impossible and the real-world experience necessarily very limited: low-probability high-consequence events such as chemical spills, fires, and explosions related to the chemical process industry and hazardous goods transportation.

- **Integrated advanced simulation models:** A major objective is to integrate advanced simulation models such as 3-D CFD codes and probabilistic models for the simulation of accidents and their consequences. This will provide realistic training scenarios. The use of dynamic 3-D graphics and dynamic GIS will support an intuitive understanding of complex physical and chemical processes and phenomena and make the training situations intellectually challenging.

- **True interaction:** A related objective is to make the system truly interactive despite the heavy computational demand of simulation based multi-media content and the corresponding high- performance visualization required. To guarantee the fast response that a fully interactive real- time training system requires, both to capture the uninterrupted attention of the trainee and to convey the real-time nature of emergency management, the detailed simulation models will be implemented in a parallel (cluster) computing environment; they will also be augmented by the simplified methods more commonly used in daily practice, but based on machine learning (neural networks, ID3,...). The training cases for the machine learning will again be generated by Monte Carlo simulation.

- **Technical components:** From a technical point of view, the system will integrate:

  - a real-time hybrid forward-backward chaining knowledge-based system as the driving engine of a training session;
  - embedded 3-D dynamic simulation models and high-performance visualization and animation of the model results;
  - an XML/CSS based structure of the didactic hypermedia material;
  - VRML and Java3D interface components for the Internet access;
  - student management and evaluation features.

- **Multimedia contents:** From a content point of view, the system will be based on the experience of several domain experts, trainers, and end users involved in the project. The contents will be represented in the systems knowledge base, the models and their examples case library, and the accompanying didactic hypermedia material as well as background information such as a set of Material Safety Data Sheets (MSDS) for hazardous substances, including, inter alia, first aid instructions.

- **Multiple languages**

4. EMERGENCY MANAGEMENT

Emergency Management is a science of optimal coordination of rescue efforts in order to minimize the casualties and property losses during the rescue.

Emergency Management Elements include:

- Life Safety
- Communications
- Property Protection
- Logistics
- Administrative
- Recovery
- Incident Command
- Resuming Operations

The key of successful Emergency Management is efficient communication between rescue groups and agencies.

4.1. High-Level Architecture (HLA)

High Level Architecture (HLA) is a simulation interoperability standard currently being developed by the US Department of Defense (DoD 1996). The key features of HLA are:

- Communication is about objects, their attributes and interactions between objects.
- A documentation standard specifies the object hierarchy, attributes, and interactions both within each simulation, or federate, and the set of federates, or federation. The documentation standard is used to configure a federation's communication infrastructure and also to promote reuse of single federates or a federation as a whole.
- The amount of communication between federates is minimized by using a number of mechanisms, i) federates offer to produce information about single instances or classes of objects that they are evolving, but only when other federates subscribe to attributes of these objects will values start to be sent, ii) only incremental changes to object attributes are sent, iii) filtering based on attribute values can be used to further restrict the amount of information being sent.
- Ownership management of objects and attributes allows the federate owning and evolving an object's attributes to change over time.
- Various time management polices can be used to control the timing co-ordination of federates.
- Federation management functions govern a federation lifecycle and control the overall state of the federation, for example initializing, saving and changing execution mode.

What should be clear from these points is that HLA is not specific to military applications, the issues it addresses and the design proposed are equally valid for civilian applications requiring simulation interoperability. Using HLA may allow researcher to develop standards and procedures for emergency rescue efforts.

The mechanism utilized in the HLA specification to describe the programming interfaces between components makes use of the Interface Definition Language (IDL). This standard, developed by the Object Management Group, defines the operations supported by software components. The IDL specification of HLA defines the operations that components must support in order to be used as part of a HLA federation. IDL is computer language neutral and it is possible to automatically generate most of the required code in specific languages directly from the IDL specification. The communication method typically used in conjunction with IDL is the Common Object Request Broker Architecture (CORBA), this mechanism allows software components implemented in different languages to inter-operate. At the minimum this includes mechanisms to support remote method invocations on CORBA objects.

4.2. Multi-agent Systems to Support an Escalating Noncombatant Evacuation Operation (NEO)

Researchers at Computer Science Department in Carnegie Mellon University, developed Multi-Agent System (MAS), using agent technology to provide a support for rescue team in Noncombatant Evacuation Operation (NEO).

NEO illustrates the interaction of agent teams in aiding human teams to cooperatively plan and execute a hypothetical evacuation of US civilians from a Middle Eastern city in an escalating terrorism crisis. In NEO, RETSINA and Open Agent Architecture (OAA) agent teams and systems cooperate with each other and their human counterparts to evaluate a crisis situation, form an evacuation plan, follow an evolving context, monitor activity, and dynamically re-plan. NEO demonstrates the interoperability and use of two disparate agent systems' teams for aiding humans (officers and Ambassador) to effectively monitor the scenario, retrieve and fuse information for immediate use, and to plan and re-plan an emergency evacuation.

In NEO, a team of agents cooperates to effectively aid a human team. Each team member is represented and aided by a dual task and information agent, known as the Messenger Agent. Humans communicate with the system through their interface agents, which can be activated through VoiceAgents and other means of input. VoiceAgents eavesdrop on human team members' conversations and take action based on the input of commanders and people in the field. Information is presented on various platforms and displays, and in multiple formats.

The following steps illustrate the sample rescue effort.

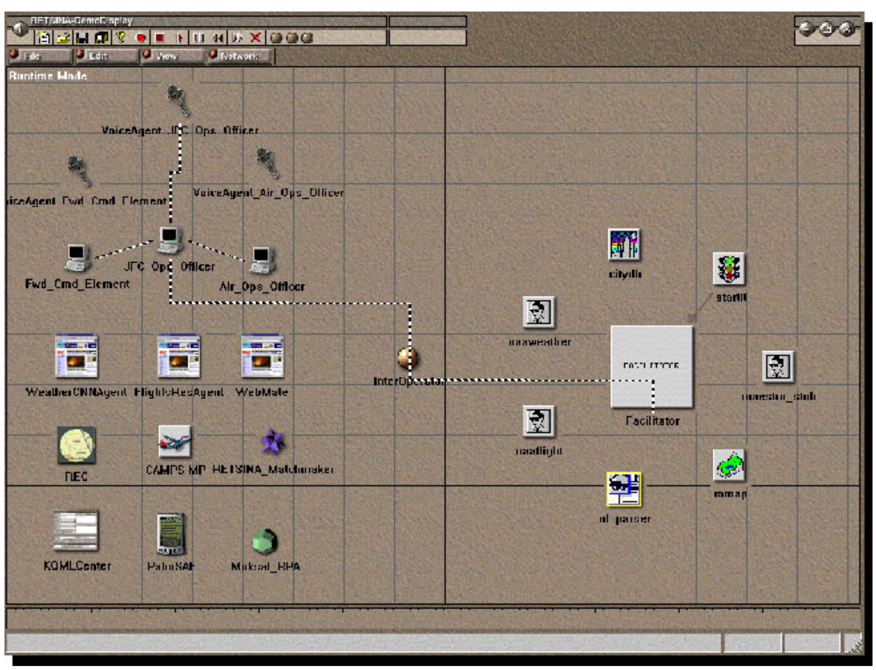
- When an officer mentions the need for flight information for evacuating US civilians from Kuwait City, the oaaflight agent responds. The oaaflight agent returns to the Messengers a schedule of departing flights from Kuwait International Airport.
- In response the VoiceAgent's activation by a commander's mention of the need for weather information, the RETSINA WeatherAgent returns weather information for Kuwait City, and displays it graphically, using a web browser, and/or as text alone.
- When the need for a route to the airport is mentioned, the RPA is queried. Given its access to a multi-modal map and knowledge of other contingencies, the RPA plans a

route to the airport. It sends this plan to the Messengers, which then display a multi-modal map with a planned evacuation route.

- Through an OAA Phone agent, a source in the field informs the system that the environment has changed: a roadblock interferes with the originally planned route to the airport. This information is propagated from the VoiceAgent to the Messenger, which passes the message along to the RPA. The RPA returns a revised route to the team members through their Messengers.
- The Visual Recognition Agent (VisRec) discerns that a bomb has exploded at the airport. It notifies all Messenger Agents. Given this new information, the Ambassador calls for a rendezvous at OKAS, the military airport. The VoiceAgent is activated, the Messenger receives the message and sends it to the RPA, and the RPA plans and distributes another route.
- The Air Officer calls for an airlift at OKAS. CAMPS gets activated and a map of the airlift is displayed. The Messengers display the airlift schedule.

In NEO, *interoperability* of two disparate MASs is demonstrated by use of agents in two agent systems, the RETSINA architecture, and the Open Agent Architecture (OAA). The use of our InterOperator acts as a two-way translation and messaging agent, allowing agents of both systems to communicate.

Below is a Demo Display of the NEO Agent Configuration:



In CoABS NEO, the RETSINA Messenger queries agents from both the RETSINA architecture, and, through the InterOperator, agents from the OAA MAS.

The InterOperator translates messages for OAA communication, and passes translated requests to the Facilitator, the middle agent within OAA. The Facilitator then sends messages, based on its own matching criteria, to the appropriate agents within OAA, and, if the needed service is available and has the requested information, receives its information. The Facilitator forwards the reply to the InterOperator, which then retranslates the messages for RETSINA, and forwards these replies to the RETSINA Messengers.

NEO demonstrates *substitutability* of agent sources from two different agent architectures on a dynamic basis, while also bridging different Agent Communication Languages (ACLs)--with the use of the InterOperator. When a requested service is unavailable in RETSINA, for instance, the Messengers will query the Matchmaker for other agents capable of the task. The Matchmaker stores the capabilities from both the RETSINA and OAA MASs, and forwards these to the Messenger, which then queries the available agents. When the capable agent(s) reside in OAA, the Messenger will query the InterOperator, which represents the OAA agents to RETSINA, and translates the request into the OAA ACL. Alternatively, when a requested service is unavailable in OAA, the Matchmaker will return a capable agent residing in RETSINA.

NEO shows the *reusability* of agents from other agent-system contexts. The Route Planning Agent (RPA), for example, which was developed for running tests on human-agent teamwork interaction, is used in this demo for planning an evacuation route, as well as in CoABS TIE1 for helicopter flight path planning. The VisRec agent was developed for other contexts and reused here. Messengers were first developed for MURI JoCCASTA, and are reused here. And finally, the Matchmaker is used in multiple agent contexts.

NEO also demonstrates the *"agentification" and reuse of legacy systems* within an agent architecture (CAMPS). Developed over many years by BNN, it is agentified and reused in the CoABS NEO demo.

4.3. E-Team

E Team, Inc. provides enterprise-level collaborative software to public agencies and corporations for use in emergency response management, facility and event security, disaster preparedness and recovery, and business continuity. The E Team solution enables all users to communicate and collaborate in real time and manage resources as the situation demands.

E Team enables customer to manage resources more effectively, achieve higher productivity, and reduce the economic impact of disasters with more timely and effective response. E Team provides its customers with an ongoing benefit by preventing or mitigating human and economic loss from both natural and manmade disasters.

Based on XML open standards, E Team to E Team enables you to connect all the key players at every level – federal, state, local – for an even more powerful collaborative solution by:

- Sharing data in real time within and across agencies and jurisdictions
- Partitioning shared data by type of data and destination
- Receive notification upon receipt
- Transfer control of any document to another E Team system (e.g., city to state, state to federal)

Government Edition of E-Team offers the most comprehensive functionality available today for emergency and event management, including these important new features:

- RealTime Messaging
- Enhanced GIS Mapping
- Enhanced Personnel Profiling
- Support for Crystal Reports

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