SIMULATED IMAGES FOR EMERGENCY MANAGEMENT TRAINING

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ABSTRACT

The use of simulated images for training, planning, and communications in the emergency management community can yield significant benefits. Aerial photographs of emergency or disaster situations and scenarios that are not available prior to actual crisis situations can be depicted using simulated images and used to provide more realistic training. Images of dynamic emergency situations can be used to train personnel to plan in response to the features depicted in the images. Specifically, the integration of synthetic imagery created by SIGS (Synthetic Image Generation System) is discussed. SIGS can generate synthetic aerial photographs that approach photo-realism using inputs of aerial photographs, digital elevation data, and 3D models of cultural features (buildings, bridges) and mobile objects (trucks, aircraft, ships, etc.). The 3D models can be represented as operational, damaged, or destroyed and other cues such as vehicle tracks and ship wakes can be depicted. The SIGS operator can edit the contents of a scene interactively to depict a range of disaster scenes. The operator can also select from a variety of geographic locations depicted in the background scenes and the scene can be easily and quickly modified to represent changes over time, including the simulation of various weather conditions such as fog, smoke, and haze and the selection of daylight conditions such as sun angle and viewing location.

A training scenario is presented covering several aspects of recovery response, rescue, and from a simulated air crash into Boston Harbor. Sample synthetic images depicting the disaster scene are presented where specific aspects of mitigation and recovery can be emphasized by tailoring the synthetic image to depict unusual conditions. Implementation challenges include effectively scripting scenario alternatives to make use of synthetic imagery, quickly generating new imagery and finding ways to make this technology useful at all levels of incident management.

There is a Need for More Realism in Desktop Emergency Management Training

Everyone recognizes that full-scale emergency management exercises that involve personnel, equipment, and facilities are very expensive and must be closely scripted to accomplish specific objectives. In fact, most are used to demonstrate an existing capability or reveal deficiencies in standing procedures. There is usually little room for creativity and innovation. Consequently, full-scale exercises are supplemented by desktop paper exercises that involve a limited set of personnel (usually top decision-makers or department heads) and little in the way of equipment or facilities.

Desktop exercises can be supplemented with detailed computerized maps and database information as described by Morentz, et al. [1], to give some capability to "visualize" what is going on in an evolving emergency training scenario. However, a continuing drawback to desktop exercises is their lack of realism. Participants are always aware that they are not participating in the high-pressure, time-critical, ambiguous, information-sparse, imperfect environment of an actual emergency incident. As such, they miss out on the valuable learning experiences that can result from actively participating in a dynamic exercise that requires creative decision-making and innovative solutions to problems. Effective emergency management represents the culmination of years of training and experience and hinges on a manager's ability to quickly assess the emergency, develop a plan of action and then change that plan of action as myriad possible complications arise. How do you train emergency managers to develop this "gut feel" for the emergency situation? How can you expose them to the hundreds (or maybe thousands) of possible variations in a scenario that they might otherwise never see or experience in their entire careers? How can you do this with minimal expense and preparation?

A Synthetic Imagery Solution Addresses the Issues of Increased Realism

A key factor in creating added realism in a desktop emergency management exercise would be the availability of an "eye-in-the-sky" photograph of the emergency area. For a localized area such as a vehicle accident or an explosion this would be similar to having a camera in a helicopter overlooking the scene. More wide-ranging emergencies such as hurricane damage, forest fires, or chemical spills might involve both real-time aerial as well as satellite photographs of the event and surrounding area. While these sources will be available to emergency managers in real time someday (and some are available today to a limited extent), their simulation gives the exercise participants a better "feel" for being on, or at least over, the emergency scene.

Simulated images of emergency scenes need to be backed up with actual data that faithfully represents the terrain and other unchanging frames of reference. It is the damage and the dynamic objects in the scene that are manipulated to create realism. An example of this is the scenery for the extensive fires in Yellowstone National Park in 1988. TASC created imagery of the area from satellite photographs and then "flew" the observer through and around the area to establish the orientation of the fires. While fire fighting managers were already oriented on map grids, the response to the synthetic terrain fly-by was that it captured the realism of being there. Similar fly-by scenarios were prepared of facilities in the Middle East and of Sarajevo for ABC News. ABC Sports used a similar TASC rendition of downtown Calgary and the surrounding mountains as its lead-in for coverage of the 1988 Winter Olympics. Similar synthetic imagery of terrain fly-bys has been developed for Nova and National Geographic specials. The objective in each case was to give the viewers a general perspective of the terrain and a visual appreciation for the key features in the areas of interest.

Finally, if synthetic images are to add realism to emergency management training, instructors need to be familiar with the image creation and manipulation tools so they can set the pace of the training and draw out creative solutions in response to changing situations. One of the challenges summarized below is for synthetic imagery to be used where it will have the most impact on emergency training. Whether this is at the national decision-maker level, where participants are remotely distanced from the emergency and may need a greater appreciation for its scope, or if it is at the departmental or command level closer to the action remains to be seen.

An Operational Command System With Simulation and Training Capabilities Built in

This paper focuses on the use of synthetic imagery in emergency management training. However, we firmly believe that simulated or synthetic training should be viewed as only one part of an overall emergency management system. Figure 1 depicts the complete range of subsystems and technologies that make up this integrated system. *The training portion of the system should be embedded in the operational incident management system itself.* Training should not be an add-on but an integral part of the system that will be used in an actual emergency.

Three components of the overall architecture are worth noting. One is the *field imagery collection station*, the second is the *tactical (mobile) command unit*, and the third is the *strategic (fixed) command center*. All of these components have been integrated so that they can share images among themselves. The field imagery collection unit (SPORTS — Second-generation Portable Remote Telecommunications System) is capable of capturing high-resolution, still color images and sending them to the mobile or fixed command centers. (A video version will be available in mid-1994.) The SPORTS system can receive imagery from other sources as well as synthetic training imagery. The mobile command unit is designed for rapid deployment and serves as both a fusion point for collecting imagery from many fielded SPORTS systems and as a relay point up to the fixed command center. It can also send and receive real and synthetic imagery. Its high mobility and use of modern object-oriented graphics interfaces makes it easy to use in the high-stress field environment while tracking many activities simultaneously. (This was demonstrated during a deployment of the prototype as a command center at the 1992 Olympic Games in Barcelona, Spain.) Finally, the strategic crisis center is designed to operate on a continuous basis tracking worldwide incidents and summarizing them for federal-level decision-makers.

The Synthetic Image Generation System

SIGS, the Synthetic Image Generation System, is a software package (developed by TASC) that enables users to *very easily* and *very quickly* create near-photo-realistic synthetic imagery. The software was originally developed to support the needs of military training by providing the capability to create simulated aerial photographs that can meet the objectives of numerous training scenarios.

SIGS had to fulfill many requirements, the following being of most importance:

- SIGS had to be easy to use. This was important both because of the quantity of images that would need to be created and because of the variety of skill sets that the personnel operating SIGS would possess.

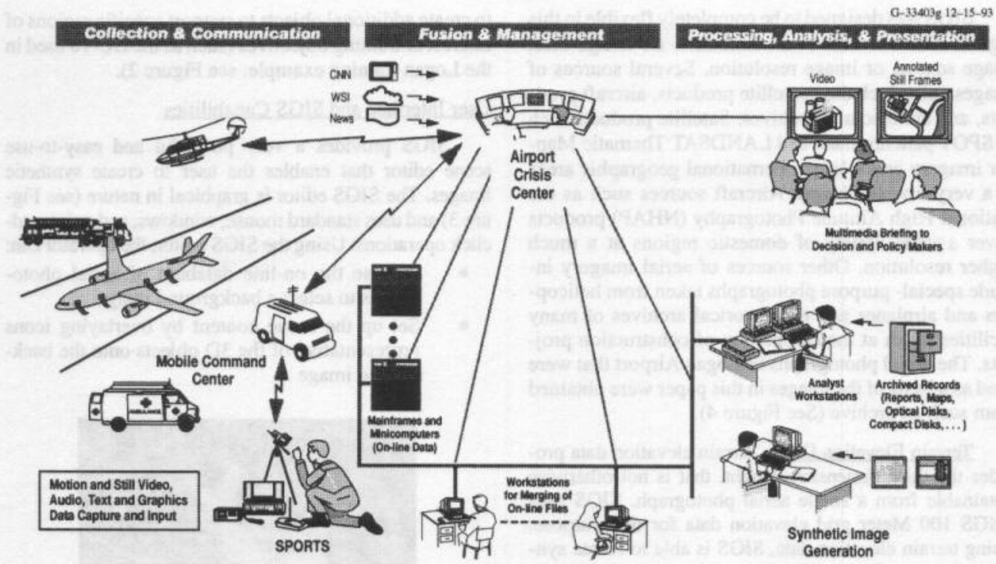

Figure 1 Integrated Incident Management Architecture

- The synthetic images created by SIGS had to be realistic enough so that they would be a *viable* training product and not be readily dismissed.
- SIGS had to be flexible and be able to create many different types of images, at various resolutions and with varying content.

The Synthetic Image Generation System succeeded in achieving these goals and more, and has been in active use in the military training arena for two years.

The flexibility of the system permits many natural extensions for the use of this capability to be explored, among them, the use of simulated, or synthetic images for Emergency Management Training. The following sections describe SIGS; the hardware and software necessary to run the software, database requirements and issues, the user interface and SIGS capabilities, and lastly, flexibility features that make SIGS usable in many training arenas. Additional technical information on SIGS can be found in a paper delivered at the 1991 International Simulation Technology Conference [2].

SIGS Architecture

SIGS is a software package that was designed to run on UNIX workstations with advanced graphics capabilities. It is written in the C programming language and uses two COTS (Commercial Off-The-Shelf) standard tool kits:

- X11 with OSF/Motif for the user interface
- GL for the image generation.

SIGS runs on most Silicon Graphics (SGI) and Sun workstations and is often accompanied by a printer and a scanner. The benefit of a printer is the ability to distribute hard copies of the simulated images to training participants. Adding a scanner to the SIGS hardware suite provides the capability to scan in aerial photographs of new areas of interest as they arise.

Databases

SIGS derives much of its flexibility to be suitable for a wide range of training arenas from the ability to vary the contents of three key databases:

- Aerial photographs
- Terrain elevation data
- Cultural and mobile objects.

Aerial Photographs. Aerial photographs are the backdrops on which each synthetic image is created. For each area of interest for which synthetic images are desired, a digital aerial photograph must be present in the SIGS database.

SIGS was designed to be completely flexible in this regard. There is almost no limitation on image size, image source, or image resolution. Several sources of images exist, including satellite products, aircraft products, and architectural archives. Satellite products such as SPOT panchromatic and LANDSAT Thematic Mapper imagery cover large international geographic areas at a very low resolution. Aircraft sources such as the National High Altitude Photography (NHAP) products cover a wide variety of domestic regions at a much higher resolution. Other sources of aerial imagery include special- purpose photographs taken from helicopters and airplanes and the historical archives of many facilities taken at the completion of construction projects. The aerial photographs of Logan Airport that were used as a basis of the images in this paper were obtained from such an archive (See Figure 4).

Terrain Elevation Data. Terrain elevation data provides the third dimension, height, that is not otherwise obtainable from a single aerial photograph. SIGS uses USGS 100 Meter grid elevation data for this purpose. Using terrain elevation data, SIGS is able to create synthetic images of mountainous areas in which the hills or mountains visually obscure buildings or vehicles that may be in the area. However, synthetic images can be created without the use of this data. The more hilly the area, the more important this data becomes. This technique would be most useful in simulating the deployment of firefighting resources against wide-area fires in rugged terrain.

Cultural and Mobile Objects. SIGS currently has a database of over 150 cultural and mobile objects that can be used to construct a synthetic image. Each object is a full three-dimensional model that was created using Alias, a commercially available model packaging. Use of a 3D model is critical because SIGS allows synthetic images to be created at any viewing angle (0 to 360 degrees azimuth) and any viewing elevation (directly overhead to 10 degrees off the horizon). The 3D model geometry is also used to cast realistic shadows from the objects onto the terrain (aerial photograph).

The SIGS database contains cultural objects such as office complexes, warehouses, and aircraft hangars. Other fixed structures such as piers, bridges, dams, fuel storage tanks, power lines, and communication towers are also present. Mobile objects in the database include several types of large and small aircraft, trucks, and ships. Although the quantity and variety of objects in this database are large enough to support many different types of military training scenarios, it is often necessary to create additional objects to support specific regions of interest or training objectives (such as the DC-10 used in the Logan training example; see Figure 2).

User Interface and SIGS Capabilities

SIGS provides a very powerful and easy-to-use scene editor that enables the user to create synthetic images. The SIGS editor is graphical in nature (see Figure 3) and uses standard mouse, windows, and point-and-click operations. Using the SIGS editor, the operator can:

- Browse the on-line database of aerial photographs to select a background image
- Set up the scene content by overlaying icons representative of the 3D objects onto the background image

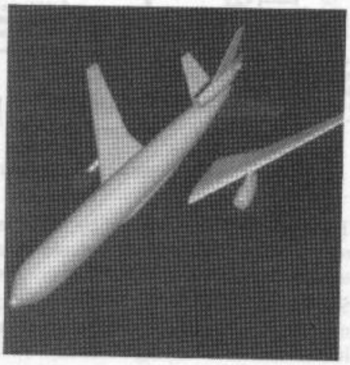

Figure 2 DC-10 Model

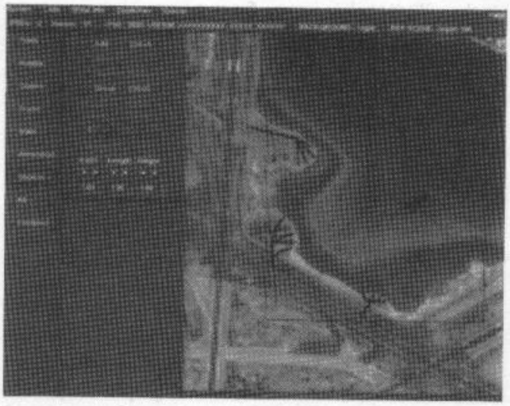

Figure 3 SIGS Interface

- Add movement cues such as vehicle tracks and ship wake
- Select the appropriate weather and atmospherics such as fog, haze, or smoke which limit scene visibility
- Add different types of trees to the base digital aerial photograph
- Set the desired output image size, image resolution, camera angle and time of day.

SIGS contains an image browsing tool that allows the user to call up an aerial photograph by its name or to browse through a catalog of image snapshots to visually select the photograph of interest. Once a photograph is selected, the user can perform scene editing.

Scene editing consists of positioning the object icons on the image, adding movement cues, adding any required damage, setting image output parameters, and then initiating the creation of the synthetic image.

If an image was being created to depict a crash at an airfield, the user would want to add several objects onto the aerial photograph. These would most likely include the crashed aircraft and numerous emergency vehicles such as fire engines and ambulances. The user positions each desired object in the image by first selecting it from a menu and then selecting the corresponding position on the aerial photograph. Each model can be resized in length, width, and height, and can be depicted as operational, damaged, or destroyed. Operations such as zoom-in, move, copy, and rotate make this process easy and accurate.

Next, the user will add any damage and/or movement cues necessary to meet the training objectives. In the case of the crash, the user may choose to depict the aircraft as damaged and may add smoke, additional rubble and debris scattered about. If a lot of rain had been received in the area, the user may add deep vehicle tracks through the middle of a field leading to the crash site to indicate that rescue operations will be difficult.

The SIGS operator can include a variety of atmospheric effects in the synthetic image, including snow, fog, and haze. In the airfield crash scene, it may be important to create a synthetic image as it would be seen in the middle of a sunny day, and then a second image as it would be seen if fog rolled in. Weather can certainly affect a rescue mission!

Lastly, the SIGS operator can specify the image size, camera angle and the sun angle (time of day). SIGS generates the photorealistic image containing all of the specified effects in 1–2 minutes.

Flexibility

As described in the previous sections, SIGS is a very flexible software package for creating a wide variety of synthetic images. When used with the appropriate aerial photographic databases and 3D object models, SIGS can be used for many training scenarios to achieve a variety of training objectives.

SIGS offers the flexibility to create a set of images to support a specific training scenario and then easily tailor the images as the training event proceeds.

SIGS images can help to answer such questions as:

- What if the plane crashed on the west side of the pier instead of the east side, where the water was deeper?
- What if fog rolled in?
- Where should the emergency equipment ideally be located?

An Example Scenario for Training Realism

This section outlines a possible scenario for use in an emergency management exercise including synthetic images generated by SIGS. The scenario covers a civilian airliner crash at Boston's Logan International Airport. An existing aerial photograph of Logan (Figure 4) was processed and integrated into the SIGS database. All the images used in the scenario were based on the Logan aerial photograph. Each image took approximately 15 minutes to edit and generate. This section includes a "what if" provision to the original scenario including SIGS synthetic images. The "what if" scenario has the airliner located in a different portion of the airfield where the challenges of response, rescue, or recovery are different.

Scenario 1: Image 1

This image of Logan (Figure 4) and surrounding areas provides an overview of the airport and surrounding environments including residential areas, industrial areas, beaches, salt marshes, and the harbor. This image provides for orientation of the overall area and displays the spatial relationship between the airfield and the surrounding transportation routes and populated areas. This could be a historical image acquired prior to the actual incident.

Scenario 1: Image 2

This medium-resolution image (Figure 5) depicts the site of an early morning crash of a DC-10, immediately after the incident. Upon approach for a landing, the aircraft landed in the water short of Runway 33L. This image indicates the grade and type of shoreline as well as the distance from the aircraft to the shore. This information would be important in determining the type of rescue equipment and the optimal access point.

Figure 4 Scenario 1: Image 1

Figure 5 Scenario 1: Image 2

Scenario 1: Image 3

This high-resolution image (Figure 6) depicts the crashed airliner immediately after the early morning incident and the immediate surrounding area. From this image, the overall condition of the aircraft can be determined, including extent and specific location of damage. Such details of the structural damage could influence the type of equipment utilized in the rescue.

Scenario 1: Image 4

This medium-resolution image (Figure 7) depicts the crash site in mid-day, some time after the incident occurred. Rescue equipment is in place and passengers have been removed from the aircraft. The image provides an overview of the location of the rescue equipment and enables a reassessment of their placement to facilitate further operations. Post-incident analysis could determine if different positioning would have facilitated rescue efforts.

Scenario 2: Image 1

This medium-resolution image (Figure 8) represents a modification of Scenario 1 and depicts the site of the crash of the DC-10 immediately after the incident. Upon approach for a landing, the aircraft landed in the water between of Runway 27 and Runway 22L. This image indicates the grade and type of shoreline as well as the distance from the aircraft to the shore. This scenario is significantly different from Scenario 1 in that the aircraft has landed in a tidal flat where the water is shallow and the substrate soft and muddy. In addition, the effect of

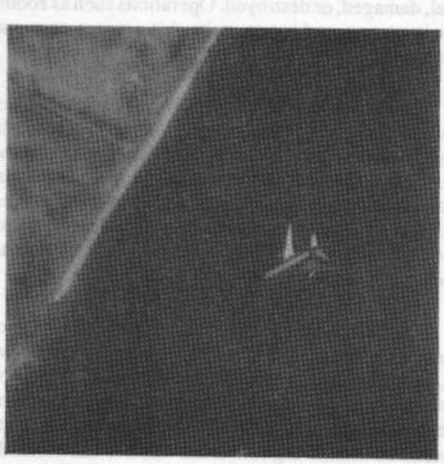

Figure 6 Scenario 1: Image 3

the incoming tide on the stability of the aircraft and the accessibility may be taken into account. The rescue and recovery equipment and techniques would be different from that employed in Scenario 1 where the aircraft landed in deep water close to a rocky shoreline.

Scenario 2: Image 2

This high-resolution image (Figure 9) depicts the crashed airliner immediately after the incident and the immediate surrounding area. From this image, the overall condition of the aircraft can be determined, including extent and specific location of damage. In addition, the image can provide an indication of channels that would allow access by boats.

Scenario 2: Image 3

This medium-resolution image (Figure 10) depicts the crash some period after the incident occurred. Rescue equipment is in place and passengers have been removed from the aircraft. The image provides an overview of the

Figure 7 Scenario 1: Image 4

Figure 9 Scenario 2: Image 2

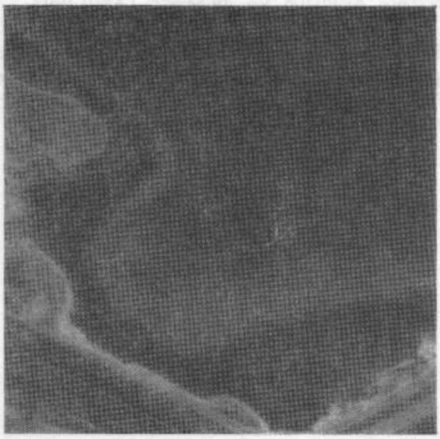

Figure 8 Scenario 2: Image 1

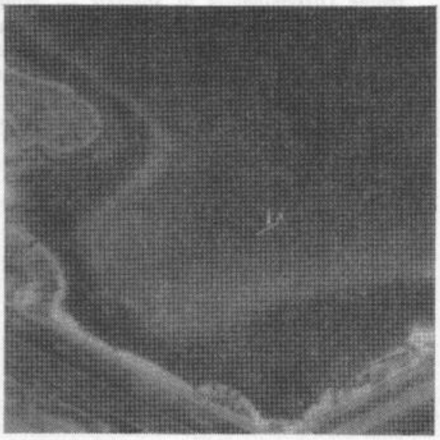

Figure 10 Scenario 2: Image 3

location of the rescue equipment and provides for a reassessment of their placement to facilitate rescue operations. Secondary analysis may indicate that a different evacuation route would have been more efficient in getting the passengers to shore and to awaiting ambulances.

Synthetic Images in Emergency Training — Implementation Challenges

Our development of synthetic imagery systems has concentrated to date on military exercise scenarios. In these cases the imagery has been an add-on to the large-scale training deployments of personnel and equipment with which the military has vast experience. We see several implementation challenges when converting this technology to use in civilian emergency management training:

- *Exercise Scripting for Effective Use of Imagery* — Desktop exercises will have to be made more dynamic and new scripts will have to be tailored to fit the training scenario. Scenario developers and trainers will have to better understand the capabilities of synthetic imagery and factor the strengths into their exercises.
- *Image Generation Realism and Speed* — Image realism may have to be different for some emergency training situations. Disaster-related (rather than combat-related) objects will need to be added to the SIGS object library and more detail may be required for close-in views of emergency targets. And, of course, users will ask for image generation times in seconds rather than minutes.
- *Image Dissemination to Students* — While traditional desktop exercises require everyone to be in the same room at the same time, video-conferencing, and collaborative computing technologies could support dispersed participants in an exercises. In fact, consideration should be given to having the exercise, with all associated synthetic imagery, run with the players located at their normal operational bases or in mobile vehicles.
- *Image Display During Training* — How the synthetic imagery is displayed during the exercise can influence the training impact and value. Large-screen displays may be suitable for top-level decision-makers but other participants will need a range of displays from laptop computers in vehicles to personal desktop displays.

A final challenge will be determining the extent that synthetic imagery technology can contribute at the various management and operational levels involved in emergency management training. While overview imagery may be useful for the orientation of agency and department-level executives, emergency managers at the command and team level will demand more detail, more scenario options, and faster response to scenario changes. As we continue our development of the SIGS system and its integration into civilian emergency management training these challenges will be at the forefront.

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