SENSOR DATA BASE CORRELATION

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ABSTRACT

As modern aircraft become more dependent upon sensors, sensor correlation presents a growing challenge for modern mission rehearsal devices and multi-sensor training devices. The crew members are learning to perform full mission functions using a variety of sensors. These sensor displays must appear realistic and correlate correctly to provide for low level flight and sensor discrimination tasks. This is especially important in crew coordination tasks in mission rehearsal devices. The correlation problem can exist in training devices since sensor data bases are often procured from different vendors or generated from different source material. Technology limits of the image generators compound this problem by reducing the number of features that can be represented in the scene. Developers must construct sensor data bases carefully, with certain compromises, to assure realistic training while maintaining sufficient correlation and accuracy.

This paper describes how Loral is applying this critical technology, learned on the F-15E WST, to the Special Operations Forces (SOF) Aircrew Training System (ATS). Loral is generating a set of data bases to support visual, EO/IR, and various radar sensor simulations with a high degree of correlation. These data bases also meet a high accuracy specification to the digital, map, and photo source data, while being produced in only 48 hours. In addition, the interactive threat simulation entities correlate with all of these data bases. The result is highly realistic training and mission rehearsal devices which overcome the sensor correlation problems.

INTRODUCTION

Modern flight simulators are designed to train aircrews to perform their tasks efficiently. They have the advantage of being safer than flying and they provide a more rigorously controlled environment. They have to create very realistically simulated conditions so the transfer of training to the real airplane can occur easily. One of the more difficult areas to simulate realistically is the area of sensors. Sensors include various radars, infrared, electro-optical systems, and electronic warfare displays. Since the crew members use several of these sensor devices along with out-the-window visual cues while flying the aircraft, the simulator must provide the same realistic cues. These sensor displays must also have a high degree of correlation with each other to provide correct, realistic training to the crew members.

HISTORY

The early flight simulators included visual and motion systems, which along with the instruments provided the pilots with all their cues. It was quickly learned that these sensory inputs had to correlate or bad results such as simulator sickness occurred. As aircraft added more sophisticated equipment, additional requirements were added to the simulators. Using radar while flying at high altitude did not present significant problems in sensor correlation because of the coarseness of the display and the longer range of the radar compared to the visual. The radar image resembled the visual scene but did not correlate strongly for most trainer functions. As aircraft electronics improved, the challenge became greater. The use of terrain following radar allowed aircraft to fly safely at much lower altitudes. This made the simulator correlation between visual and terrain following radar more critical for the pilot. These two inputs provide simultaneous displays of the same area; thus, a much better correlation was required. When we add to a single aircraft additional sensors of ground mapping radar with a high resolution synthetic aperture mode plus various infrared and electro-optical sensors, the simulation task becomes enormous.

BASIC PROBLEM

The training task in a multi-sensor aircraft becomes more complicated because it involves the synchronous use of more than one sensor at a time. It may also involve different tasks by several crew members coordinating with each other. For example, a pilot, while flying at low altitude, receives sensory inputs from the visual scene in front of him, from the terrain following radar display, and from the forward looking infrared (FLIR) display. These must all correlate so that he learns to use all of them together to perform his difficult task successfully. Other multiple sensor tasks are navigation updates and targeting. A synthetic aperture radar (SAR) is used for the long distance image of an area on the ground. As the aircraft approaches, an infrared sensor is slewed by the on-board avionics to the same location on the ground and provides the crew member with a new, closer range image. The navigation points often will be one unique building in a group of other buildings or some other cultural feature which is easily identifiable. These two images must correlate closely so the crew member can identify the selected object in the SAR image, and also identify the same features when he slews the infrared sensor to the given location. Now we add the last ingredient to the problem. All the crew members expect that all of these sensor displays will be realistic looking. They must look very much like they actually do in the aircraft. This is more than a desire, but actually a valid requirement for tasks such as target discrimination. This again is necessary for good transfer of training to the real flying environment. The simulation of these functions in a trainer requires a cost benefit trade-off. The simulator must provide sufficient simulation to train the crew members but at a realistic cost. Thus, certain compromises must be made along the way. Flying real aircraft provides excellent training, but it is very expensive and not all situations can be experienced as they can in a simulator.

F-15E EXPERIENCE

Loral encountered the challenge of sensor correlation with the F-15E Weapon System Trainer (WST). The F-15E aircraft is equipped with a real beam and synthetic aperture radar, a FLIR, a terrain following radar, a remote map reader, an infrared targeting pod, and electro-optical (EO) and infrared (IR) video from missiles. The F-15E aircraft flies at low altitudes and uses these sensors either simultaneously or sequentially in the operations. The F-15E WST simulates all of these systems plus the radar altimeter by means of correlated data bases. The result is a full system of many sensors providing the crew members with correlated displays. The F-15E WST is designed to meet a specification requiring that the radar data base be accurately generated with respect to its source data. This source data consists of Defense Mapping Agency Digital Feature Analysis Data (DFAD) and Digital Terrain Elevation Data (DTED) products which are enhanced by the addition of higher resolution data from map sources. The resulting data is quality checked to eliminate boundary inconsistencies and other possible anomalies. The radar data base has to match this source data with accuracies of up to 15 feet for point features in the target areas. Other accuracies are shown in Table 1. The IR and EO systems have their video generated by an Evans & Sutherland CT6 image generator. This system uses a standard polygonal data base but the resultant video has to correlate to the radar so that differences are imperceptible to the crew members. If the Digital Radar Landmass Simulator (DRLMS) data base only had to meet the accuracy specification, it could have been produced directly from the DFAD and DTED data, but it would not have correlated to the EO/IR system.

Polygonal data bases are used for visual systems because of time and memory constraints of the hardware. Providing a unique, real-time image of a large geographical area is not cost effective because of limited hardware technology. Using polygons for the terrain, with a set of features such as trees on them (called basis sets), allows the system to represent the large areas with relatively accurate terrain. The CT6 system

Table 1 — F-15E Radar Data Base

Accuracies	
Feature Type	Accuracy to Source Data (feet)
Target Areas	
Point	15
Lineal	15
Small Areal	15
Large Areal	64
Background Area	
Point	60
Lineal	150
Small Areal	150
Large Areal	1200

used on the F-15E WST employs a set of polygonal basis sets for the terrain with unique features placed on top as required. Each of the terrain basis set elements is an 800-meter equilateral triangle. It has various fixed features associated with it such as trees for a forest, cactus for desert, and buildings for cities. There are a limited number of these basis set elements possible in the system, so other features used to represent the real world features can be included. This data base was designed so that the terrain triangles all have vertices that are increments of 50 meters in height from the data base origin. The result is a set of triangles that match when positioned adjacent to each other, and form a good visual scene.

The following method was used to produce this data base. The DTED data is scanned and analyzed to get the best curve fit plane for each triangular area. Then the three vertices are adjusted to the closest 50-meter altitude. In addition, the city areas are given some variety by using different patterns for the roads and buildings. This adds realism to the scene by eliminating distracting repetitive patterns on the displays. The real cultural features are then located onto the terrain triangles. A limitation in this process is that the real features cannot cross the triangle boundaries as this may cause visual anomalies in the visual image. A correlated radar data base must therefore be made using the CT6 data base features so that only the same features in the same locations are placed into the radar data base.

Initial investigations, which used polygonal data bases for the radar data base, indicated that, though correlation was good, the image lacked realism because the polygons could be clearly seen. Figure 1 shows an example of a ground mapped radar image using a completely polygonal terrain data base generated by the F-15E DRLMS. It was therefore necessary to change the radar data base to make more acceptable images while still maintaining the correlation to the other sensor data base. This was accomplished by modulating the polygonal terrain data base before the 50-meter adjustment to the vertices with the source terrain data from the DTED tape. The result was a radar data base that generated acceptable images, met the accuracy specification, and correlated to the IR and EO sensors. The modulation process consists of converting the terrain triangle back into data posts spaced to coincide with the DTED data, then performing a weighted average with the original DTED posts. Figure 2 presents a radar image using this modulated terrain data base. Figure 3 represents a radar image from a pure DTED terrain without having been polygonalized. It can be seen that the differences from the Figure 3 image do not detract from the realism of the radar image generated from the combined polygon and DTED.

Terrain following radar (TFR) presented a similar problem; the image had to look realistic for cockpit displays and still had to correlate with the ground map radar and the FLIR. The FLIR correlation became the predominant driving force since it and the terrain following radar are used simultaneously while flying low to the ground. The specification on the TFR to FLIR correlation reflects this need as shown in Table 2. The terrain following data base was generated by gridding the polygons after they had been changed in elevation to move the vertices to the 50-meter altitudes. This method achieved a realistic image while maintaining very high correlation to the FLIR. This solution resulted in an acceptable compromise, accomplishing correlation and fidelity of TFR image sufficiently to support training.

Another function of the F-15E aircraft is sensor handoff from one system to another. The radar is used to generate a synthetic aperture radar image at a long range. This image shows sufficient detail to identify specific features. The crew member

Figure 1 — Ground map radar image of polygonal terrain data base

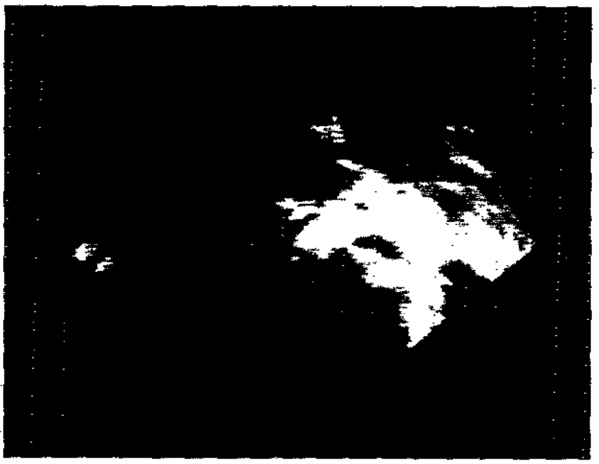

Figure 2 — Ground map radar image of DTED modulated terrain data base

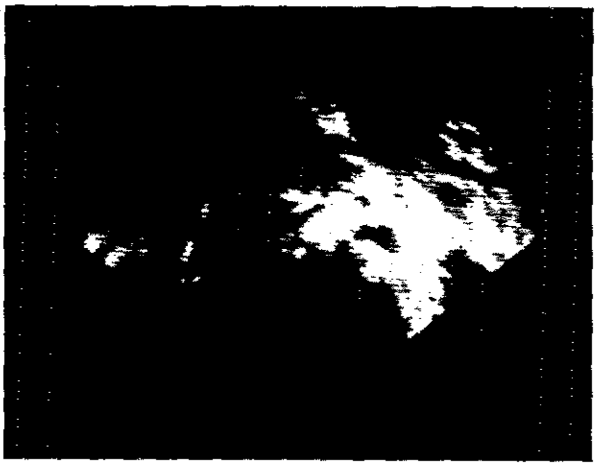

Figure 3 — Ground map radar image of DTED terrain data base

Table 2 — DRLMS to EO/IR Correlation

Specification Criteria	Ground Map to EO/IR	TFR to EO/IR
Mean	55 + 3R	10 + .5R
Standard Deviation	35 + 2R	30 + R
Maximum Deviation	100 + 25R	60 + 4R

Where R is the roughness index of the 61 x 61 points of terrain being compared.

then centers his cursor on a selected feature and saves the geographical location. As the aircraft approaches closer to the area, the crew member uses that saved information to slew his IR sensor via his avionics controls to the same location. He can then see a closer range image of the same scene. In the WST, this same function must be accomplished with a correlated image so the crew member learns the relationships between his equipments and their displays. When the selected target area is near a city, even the synthetic breakup areas must match, since the association of the correct target may be found by its relationship to adjacent synthetic features. The basis sets of the IR data base are used as models in the radar data base generation, so the synthetic features are located in the same relative positions in both data bases.

The F-15E sensor data bases provide a realistic image for the radars and IR/EO sensors that are simulated. These data bases and their images correlate and meet the accuracy specifications to the source data. Thus, they are providing a good training system.

THE SOF ATS CHALLENGE

The Special Operations Forces Aircrew Training System (SOF ATS) provides both WSTs for training full aircrews and Mission Rehearsal Devices (MRDs) for allowing fully trained crews to rehearse missions that are to be flown in the near future. This mission rehearsal requirement dictates that the data bases must be extremely accurate along with having the full sensor correlation. The mission rehearsal device is designed to support an aircrew in performing their critical functions in the environment in which they expect to be flying their mission. It must provide highly realistic visual, sensor, and environmental cues to the crew members. They are preparing for an actual mission and this realism could mean the difference between success and failure of their missions.

The SOF ATS contract calls for the simulation of the Talon I and Talon II aircraft, with time-phased options adding helicopters, gunships, and a tanker. The Talon aircraft are basically C-130 airplanes used for transporting cargo or personnel. However, these airplanes have been modified with the addition of special sensors and other equipment to enable them to fly low level flights at night. As a result, the simulation of the full airplane presents a larger challenge than the F-15E, since it involves more crew members using more equipment that needs correlation.

The Talon airplanes are equipped with ground mapping radar, terrain following radar, forward looking infrared, radar altimeters, and many electronic warfare (EW) systems and displays. The crew consists of pilot, co-pilot, flight engineer, navigator(s), electronic warfare officer, and communications officer. In the later options of additional simulators for the gunships, there are additional crew member positions which have TV systems and other equipment. The purpose of the mission rehearsal facility is to provide a good mission rehearsal capability for these crews. The critical element of mission rehearsal is to see and hear the same things in the device as the crew will see in the real world. This means that the MRD must provide a good out-the-window visual scene along with the accurate sensor displays that correlate with the real world and with each other. To meet this challenge, Loral is building a Data Base Generation System (DBGS) to make visual, infrared, and radar data bases that will be both highly accurate and have a high degree of correlation. Adding to this difficulty is the time requirement to produce these data bases in 48 hours.

The MRD will use the new Loral DRLMS for the ground map and TFR simulations and the Evans & Sutherland ESIG-4000 Image Generator for the visual and infrared simulations. However, along with having to simulate these systems, the SOF ATS systems must provide an accurate simulation of the electronic warfare environment. The Talon aircraft are required to fly in dangerous areas to perform their missions. They attempt to do so by avoiding contact with the enemy. Thus, the WST and MRD must provide them with a realistic threat environment so that they can train and rehearse the tactics that allow them to do this. This threat environment must also properly correlate with the visual and radar data bases. The navigator makes much simultaneous use of his real world maps and his IR and radar displays while directing the pilot where to fly. Therefore, the data bases must match those maps very well. In the SOF ATS WSTs and MRDs, the threat and radio environment must be accurately simulated with respect to the real-world terrain. It may be critical in the MRD to know at what altitude you can fly and not be detected, so the real mission is a success. Another requirement of SOF ATS is to link two or more MRDs together so they can fly coordinated missions, detecting each other with their sensors and interacting as they would in the real world. These MRDs must have identical data bases so that the crew members see the same features since they are in audio communication with each other.

To achieve all of this, a fully coordinated approach to sensor simuation is required. In addition to the radar and visual data base coordination, the threat and weather environment must be integrated into this approach. The MRD simulation makes use of the DRLMS and visual data bases to assure that the threat environment is fully correlated and realistic. The real-world threat environment is volatile, with last minute changes possible in the location of the threats. Therefore, the physical data bases of terrain and permanent features are processed separately from the electronic environment to make the DRLMS and visual data bases. The Electronic Order of Battle information for the threat environment and weather information are added at the start of the simulated mission. During a Plan Mode, the various threats are placed in the data base, based upon their known locations. They are placed in the visual, radar, and electronic data bases at the same locations so all sensor systems correlate. A visual check is made in the Plan Mode to assure there will not be any visual anomalies at these locations. This is possible since differing source data may not match perfectly; a SAM site location from one source may overlap the edge of a lake from another source. A minor correction to the SAM site location would be made in Plan Mode to assure that these anomalies do not appear to the crew members in the rehearsal.

During the mission, the threat simulation software controls the actions of the threat entities. These entities perform as they would in the real world in a linked command and control structure. The early warning radars search for any incoming aircraft and signal the tracking or intercepting systems to perform their functions. The simulation uses the DRLMS system to compute the line-of-sight capabilities of these systems and assure that they will only see the ownship aircraft when it is not occulted by terrain or cultural features. This occulting function is performed by giving the DRLMS system the two locations; it then verifies that no obstructions block the view. When the view is unobstructed, the threat entity begins to perform its normal functions. In the case where very near range occulting must be performed with great accuracy, the visual system is used. The two locations are sent to the ESIG-4000 and the line of sight is verified to not be obstructed. This function is needed because the resolution of the DRLMS data base does not allow this fine discrimination for very close ranges.

The ownship sensors also react and provide the crew members with the appropriate outputs. These outputs may consist of audio or visual display warnings that the ownship is being detected. Likewise, the radio communications are processed to assure that they can only be heard when they could be heard in the real world, so that they are not obstructed. Again, the DRLMS is used to verify that threats and radios would be detected by the ownship and not occulted by the terrain. If there is a limited obstruction, as detected by the DRLMS, the radio simulation will introduce noise to simulate the real world transmission difficulties. This becomes especially important for multiple aircrew communications when more than one MRD are rehearsing together.

The generation of the visual and DRLMS data bases for the SOF ATS is handled by the DBGS. It processes maps, photographs, and digital data of various sorts, including DFAD, DTED, and Digital Chart of the World (DCW). All of these products are converted into an intermediate data base which contains terrain, cultural features, and texture information. This data base is then simultaneously processed by the visual and radar post-processing software. The visual system software converts the data to the ESIG-4000 system data base. This state-of-the-art system maintains a separate terrain and cultural data base on line, thus eliminating the need to convert all terrain into large polygons. The result is a much more accurate data base. The photo texture capability allows for maintaining many more features than previous systems, since fewer polygons are required to simulate these features. As a result of these improvements, the radar data base can be processed directly from the same intermediate data base instead of the resultant visual one. For areas that use synthetic breakup, the same algorithm is used to place the synthetic features in both the visual and radar data bases so that they correlate in the final products. The ground map and TFR data bases can be the same ones, thus saving disc space in the DRLMS system and data base generation processing time. Where the F-15E DRLMS had a separate TFR data base with terrain and feature height only, the SOF DRLMS uses one common data base, with the TFR processing using only the part that it needs, i.e., terrain and feature heights.

Another area of sensor correlation involves weather simulation. The aircraft are equipped with a weather mode in the radars so they can detect severe weather conditions and avoid them. The proper weather effects have to be simulated in the visual, radar, and threat environment. The Plan Mode accommodates the updating of weather data from recent meteorological reports. This weather data is put into a global weather data base for the whole flying area. As the crew flies along, they may encounter different weather conditions. These same conditions are simulated in the other MRDs so all crews experience the same effects in the correct geographical areas. This single weather simulation also provides the parameters needed to simulate the weather effects on the radio, radar, and electro-optical transmissions. Thus, the realism is maintained for consistent effects in all the sensors. Weather conditions and fronts are simulated in the weather radar and the visual systems that are seen directly by the crew members. The weather effects on other sensors such as EW and radio are correlated by having one global weather simulation.

CONCLUSION

Aircraft sensor simulation is improving in its accuracy and correlation through the use of new, improved hardware and software systems. The demand for additional sophisticated functions continues to increase as the technology develops to accommodate it. Thus, through the growing technology of improved hardware and sophisticated software, the correlated sensor simulation of SOF ATS has progressed from that of the F-15E. The WSTs and MRDs of the SOF ATS will be completed in early 1993 with the inclusion of the fully integrated and correlated sensor simulations for coordinated multiple crew rehearsals.

ABOUT THE AUTHOR

Dale Fawcett is working as the System Engineering Manager for the Special Operations Forces (SOF) Aircrew Training Sytsem (ATS) program at Loral Defense Systems - Akron. He is responsible for system engineering on the Talon I and Talon II Weapon System Trainers (WSTs) and Mission Rehearsal Devices. Mr. Fawcett has previously worked as the Software Project Engineer on F-15E WST. In that position, he was responsible for the development and integration of the operational and support software and for the EO/IR and radar data bases for the F-15E WST. He has also worked on the R&D development of the Loral DRLMS and previously on the Reference Scene Generation Facility for the Army Pershing II Missile System. Mr. Fawcett holds a BS in Mathematics from Bucknell University and a MS in Systems Management from the University of Southern California.