Video Surveillance and Monitoring Integrated Feasibility Demonstration Specification Document (1998)

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Contents

1 Overview

This document presents the goals, capabilities, demo scenarios, and hardware components currently envisioned for the Video Surveillance and Monitoring (VSAM) Integrated Feasibility Demonstration (IFD).

The purpose of the IFD is to demonstrate a working prototype system for video surveillance and monitoring that:

1. provides real-time capabilities for cooperative surveillance by multiple air- and ground-based sensors
2. advances the state-of-the-art in IU functionality
3. favours video over still-image analysis

The IFD project is currently slated to run from May 1997 through December 1998, and will include two demonstrations. The first, Demo I, will take place 6 months into the project, in mid-November 1997. The second, Demo II, will take place in October 1998.

2 IU functionality

Five areas of functionality will be addressed:

- Site modeling
- Active control and coordination of sensors
- Moving target detection (MTD) and tracking
- User interface that improves operator awareness of scene
- Activity monitoring

Specific functionalities that will be addressed for Demos I and II are summarized below.

2.1 Results of the Demo I IFD effort

The 1997 VSAM demo was held successfully at CMU's Bushy Run research facility on November 12, 1997. The following sections highlight the specific technological achievements of the project to date.

2.1.1 Site modeling

The site was modeled as a combination of image-based information and a digital elevation map (DEM). The model was built in the following steps

1. An initial, low-resolution DEM and orthophoto were obtained as COTS components from the USGS.
2. The DEM was enhanced by a local terrain map generated by a laser range finder mounted on CMU's autonomous helicopter.
3. The orthophoto was enhanced by a scene mosaic obtained from the airborne sensor at the time of the demo and geo-registered to the USGS orthophoto using an affine warp.

2.1.2 MTD and tracking

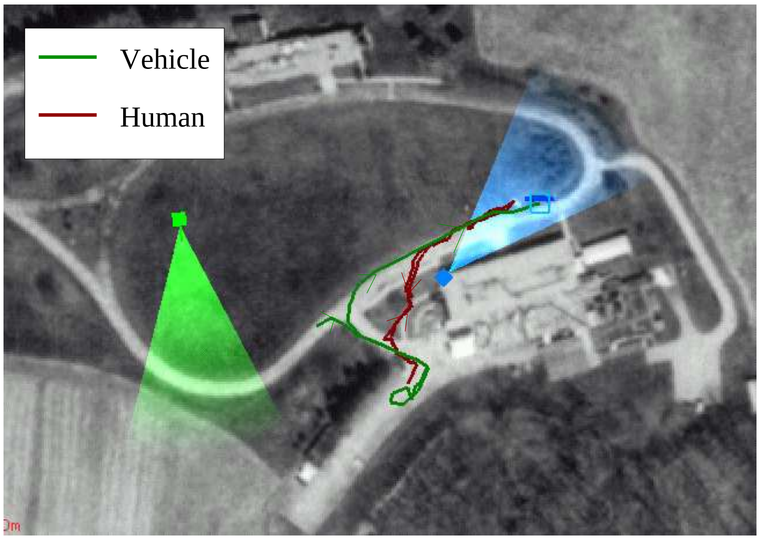

Figure 1: Synopsis of target trajectories form sensor SPU B.

- Target detection in the presence of
  - camera motion
  - varying target speed
  - cessation of target motion
  - multiple target presence
  - background motion

  This was performed using a combination of motion detection and correlation-based tracking.

- Targets were classified into "vehicle" or "human" by a combination of a simple image-based property (aspect ratio) in conjuction with a temporal consistency constraint.
- Target geolocation. This was accomplished by intersection of viewing ray with terrain model. Trajectories of targets can be calculated and displayed afterwards (see figure 1).
- Moving target detection from the airborne sensor by performing temporal differencing on a video stream stabilized by frame-to-frame affine warping.

2.1.3 Active sensor control and coordination

- Fixating an operator designated area with a single airborne sensor to compensate for airplane movement and vibration.
  This was accomplished through the use of frame-to-frame motion estimation coupled with active camera control.
- Multi-tasking airborne camera between multiple designated areas so that an operator can monitor several regions simultaneously.
  The camera automatically servo'd to aim at each area. Camera aiming was robust to uncertainties in airplane position and attitude, and was accomplished by using telemetry for coarse camera aim, followed by refinement using manual adjustment or offline image registration.
- Ground-to-air target notification was performed manually

2.1.4 User interface that improves operator awareness

The operator control unit (OCU) presented a graphical user interface that:

- Displayed the site model in 2D or 3D format displaying all sensor positions, footprints/fields of view, and target locations.
- Showed live video feeds from all sensors.
- Enabled the operator to select regions of interest and regions for ground-ground sensor hand-off
- Enables operator to control algorithm parameters.

The current operator interface is shown in figure 2.

2.1.5 Activity monitoring

The demonstration illustrated the use of the system for airborne detection of movement in selected areas and airborne verification of perimeter incursion detected from the ground.

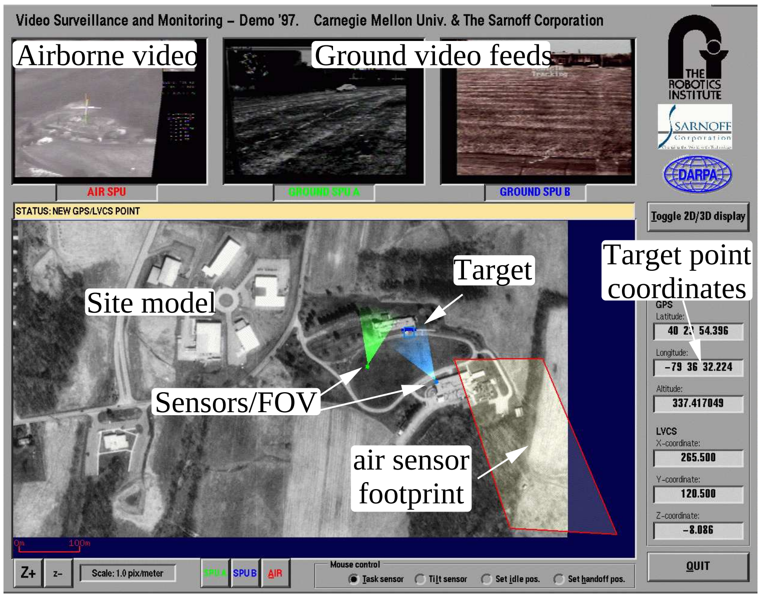

Figure 2: Current VSAM operator interface.

2.2 Goals for Demo II IFD effort

2.2.1 Active sensor control and coordination

- Robust target tracking over extended ranges of movement using multiple ground and air cameras.
  This will be accomplished by matching targets between camera views by using camera calibration and site model information to predict target position, appearance and trajectory.
- Active control of an airborne camera to track moving targets.
  This will be accomplished using the camera aiming algorithms developed for Demo I, coupled with prediction of target trajectories.

2.2.2 MTD and tracking

- Robust detection and tracking of multiple targets in the presence of camera motion/zooming using a combination of image-based approaches with temporal saliency constraints.
- Airborne tracking of single targets
- Classification of individual targets as rigid (e.g. vehicle) or non-rigid (e.g. human or animal) objects using image appearance and motion cues (both internal motion and group motion).
- Classification of targets or target motion as being either independent, or part of a formation.
- Recognition of previously seen targets by appearance and temporal salience.

2.2.3 User interface that improves operator awareness

- Enables operator awareness of targets and their previous locations. Shows specific target trajectories.
- Provides overview synopsis images/video clips which summarize activity in a highly efficient manner.
- Enables operator to designate targets to be tracked or ignored.

2.2.4 Activity monitoring

Target behaviours such as loitering and rendezvous' will be determined by observing spatio-temporal relationships between specific targets and combining them with domain knowledge.

2.3 Technology Matrix

Technology	Current capabilities	Further advancements	
Ground sensor control (handoff/ multi-tasking)	Predetermined handoff regions	3D coordinates and signatures (+ epipolar constraint)	Visibility analysis
Air sensor aiming	Video to reference image registration for landmark points	Video to reference image registration for arbitrary points	
Visualisation	Overlay current target pos. on orthophoto	Overlay target trajectory synopsis on orthophoto	Synopsis mosaic (update orthophoto with mosaic)
Target detection	Temporal change	Motion salience (temporal consistency)	
Ground-based target geolocation	Ray intersection with DEM	Refine ray intersec. e.g. Kalman filtering Domain knowledge	Multi-view triangulation
Airborne target geolocation		Video to reference image registration	
Ground based MTD and tracking	Single target step-and-stare	Single target pan/tilt/zoom	Multi-target
Airborne MTD and tracking	Stabilisation/ temporal change (detection only, user control)	Stabilisation temp. change and correlation (detection and tracking)	Auto-control of pan/tilt
Recognition of previously viewed targets		Target signature (appearance/motion)	Predicted location
Target/activity classification	Aspect ratio (human/vehicle)	Appearance based (extra categories)	Motion based

Figure 3: Proposed VSAM technologies matrix.

Figure 3 shows the component technologies to be addressed by the VSAM IFD team in 1998. The first column indicates the current functionality. Further columns indicate advancements proposed in the future of the project.

3 Demo II

Demo II will take place on and around the CMU campus in Pittsburgh. Some of the notional activities which will be monitored are:

- Long term activity monitoring.
  Individual targets will be monitored over large distances and periods of time through complex scenes. Domain knowledge can be added to monitoring tasks to infer behaviours of subjects. People loitering near doorways or ATMs will be detected. Vehicles, circling the block, or target rendezvous will also be detected. One specfic application example is parking lot monitoring. This task involves counting vehicles in a car park and determining when vehicles enter and exit. An extension to this task is to associate particular humans with particular vehicles allowing the system to alert the user if a theft is attempted. This work involves camera multi-tasking to track multiple people and vehicles as they move through the lot, and construction of visual activity summaries over an extended period of time. It also requires tracking objects through occlusion, either by predicting and confirming their reappearance with a single camera, or switching to another camera's view.

- Multiple target monitoring.
  The primary example is convoy monitoring. The system will be able to determine the structure and composition of a line of vehicles and use multiple ground and airborne cameras to track them over long distances and periods of time. The system will be able to alert the user to changes in the composition of the convoy, such as vehicles leaving, entering or changing order. Specific operator-designated points will be monitored from the air for detecting the presence of convoys or other formations.

Figure 4 shows the campus map of CMU's Pittsburgh campus. Vehicular demo activity will take place along the routes marked. Tentative camera placements are also indicated. The demo site is an uncontrolled urbanised area containing road networks, buildings, parking lots, doorways, alleys, and natural human and vehicular clutter.

The demo script will involve approximately three humans and three vehicles interacting with each other throught the campus. The exact script for the demo scenario is not finalised, so the opportunity exists for FREs to provide input.

4 FRE participation

A more complete specification may be found in the accompanying document: Video Surveillance and Monitoring FRE Spec Document 98-1.0. This document may be obtained from CMU by request.

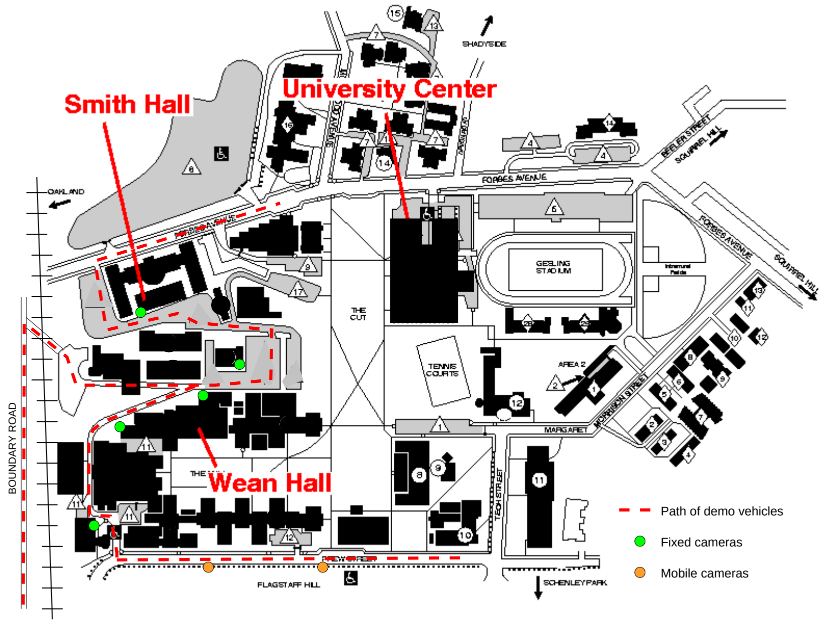

Figure 4: Map of the CMU campus showing camera placement and vehicle routes for Demo II.

Figure 5 shows the proposed system for 1998 with tap points for FREs (or other interested parties). The IFD will accept data from FREs (or other parties) in the form of

- Site model data
  - USGS/NIMA orthophotos, DEMS, topographic maps
  - Custom images/DEMS (in a format TBD)
  - Cultural/domain/target database entries (in a format TBD)
- Video data
  - Live video
  - VHS/S-VHS video tape
  - Movie files (in QT, SGI or MPEG format)
  - Image sets (.gif, .jpeg, .ppm, .pgm)

Five levels of FRE participation in Demo II have been considered of which four will be supported in 1998

1. Sensors - FREs provide sensors for IFD testbed
2. Live taps - IFD provides live video taps during the demo which the FREs can use as inputs to their systems

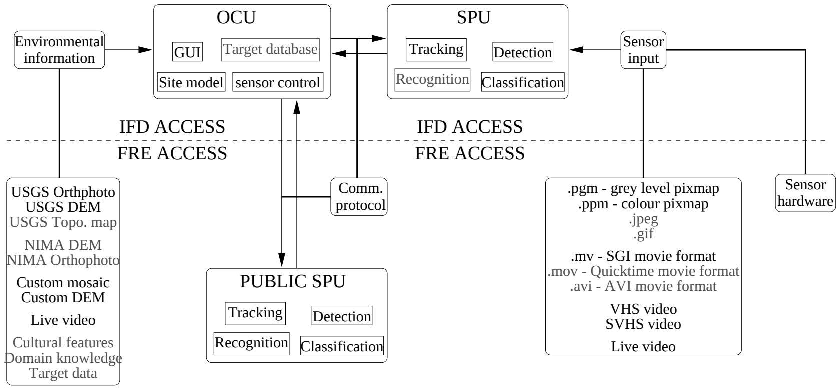

Figure 5: Proposed logical system infrastructure with tap points for FREs. Items in dark gray were used in the 1997 VSAM IFD demo. Items in light gray will become available for the 1998 demo.

3. Parallel system - FREs can set up their systems in parallel with the IFD. Output can also be shown in parallel. (Assuming FREs do not absorb critical band-width or line-of-sight at the demo site).

4. FRE SPU - IFD (in collaboration with interested FREs) will publish an SPU-OCU comm protocol and FREs can provide a complete SPU to be integrated with the IFD testbed system.

5. FRE algorithms (not supported in 1998) - FREs can provide algorithms which are integrated into IFD SPUs.

A list of approximate dates for FRE participation is given below:

Feb. 16, 1998	First publication of FRE participation spec.
Apr. 16-17, 1998	VSAM workshop III – Finalise FRE spec.
May 15, 1998	FRE's inform IFD if they intend to participate in '98 IFD demo.
Jun. 12, 1998	Demo planning workshop. FRE participation is mandatory for FREs with levels 2-4 of participation.
Aug-Sep (TBD), 1998	Various FRE participation days/weeks
Oct 8-9, 1998	Proposed DEMO II

5 VSAM schedule 1998

Proposed VSAM dates:

Jan. 1998	Start NVL AWR process for new hardware
Feb. 16, 1998	First publication of FRE participation spec.
Apr. 16-17, 1998	VSAM workshop III (Benning), Finalise FRE spec.
May, 1998	Install VFE-200 on Islander
Jun. 12, 1998	Demo planning workshop (NVL), initial FRE deliverables
May, 1998	Install VFE-200 on Islander
Jul. 1, 1998	Begin preparation of demo infrastructure
Sep. 28, 1998	Completion of on-site infrastructure, freeze system
Oct 8-9, 1998	**Proposed DEMO II**

Proposed flight schedule, which will change in consultation with other users of Islander:

May 18-22	Fly at NVL
Jun. 8-12	Fly at NVL
Jul. 6-10	Fly at NVL
Jul. 20-24	Fly at NVL
Aug. 3-7	Fly on site
Sep. 7-11	Fly on site
Sep. 28 - Oct 7	Fly on site
Oct 8-9, 1998	**Proposed DEMO II**

Important dates:

Apr. 1	IEEE WACV deadline
Jun. 22-26	IEEE CVPR 98 (San Diego)
Oct 8-9, 1998	**Proposed DEMO II**
Oct. 19-21	IEEE WACV (Sarnoff)
Nov. 21-23	DARPA IUW

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