Visual Traffic Monitoring

Presenters:

N. Grammalidis (Researcher C') and
T. Semertzidis (Researcher)
ITI-CERTH

UAM, Madrid
June 2008

Overview

- Introduction in Road and Airport traffic monitoring (including A-SMGCS)
- Visual airport surface movement monitoring (A-SMGCS): The INTERVUSE project
- Results of INTERVUSE project
- A case study: Prague International Airport
- A novel intelligent software-based sensor
- Road tunnel and airport parking traffic visual monitoring: The TRAVIS project
- Results of TRAVIS project
- Conclusions and future work

Road Traffic Monitoring

- **Laser technology:** A laser pulse is detected after its reflection from the vehicle. Accurate but is used only for detecting speed violations.
- **Microwave technology:** Similar principle as laser. It can also be used to detect other violations, e.g. vehicles in bus lanes.
- **Induction loops:** Coils of wire embedded in the road's surface. They detect a change of inductance in a large coil, which forms part of a resonant circuit, caused by the coil's proximity to a conductive (e.g. metal) object. Large installation, maintenance costs (asphalt has to be cut), small region
- **Magnetic sensors:** Detection of the changes of a magnetic field (e.g. the earth magnetic field) through the physical influence of a ferromagnetic object in the vicinity of it.
- **Visual detection:** Optical cameras using image processing and/or computer vision to detect moving objects, low-cost installation, larger area is monitored, different approaches

Research and commercial visual traffic detection systems

Examples of research systems (traffic data collection and/or scene understanding):

- Video Surveillance and Monitoring (VSAM, US)
- SCOCA (Trento, IT) – also capable of accident analysis
- Many more, e.g.:
  - V. Kastrinaki, M. Zervakis and K. Kalaitzakis, A survey of video processing techniques for traffic applications, Image and Vision Computing, Volume 21, Issue 4, 1 April 2003, Pages 359-381.
  - Inigo, R. M. (1985). Traffic monitoring and control using machine vision: A survey. IEEE Transactions on Industrial Electronics, 32(3), 177– 185.

Example commercial systems:

- Autoscope(Autoscope),
- QUIXOTE TRANSPORTATION (UniTrak / VideoTrak Systems), INVIS(ASCOM),
- MiTAC Integrated Highway Surveillance System,
- SMART EYE- Smart Traffic Data Sensor by Smart Systems, TRAFICON,
- CITILOG,
- EXCEL TECHNOLOGY GROUP

Introduction to Airport (Surface) Traffic Monitoring

- Air traffic management problems
- Introduction to A-SMGCS
- What sensors are used?
- Related Commercial Systems
- Related Research Projects

Air Traffic Management Problems

- Number of flights is constantly rising (traffic is doubled almost every 12 years)
- Limited airspace usage caused by restricted airways and corridors instead of free flight
- Limited traffic on ground caused by insufficient technical support with ground control systems
- Large number of operations (refuel, passenger transportations, etc) are simultaneously performed at the airport surface, even under difficult weather conditions.
- The highest risk for incidents and accidents is when the aircraft is moving on the ground

Airport Delays

Airports become air traffic management bottlenecks according to EUROCONTROL statistics

Runway Incursions (source: Federal Aviation Administration)

CALENDAR YEAR	OPERATIONAL ERRORS	PILOT DEVIATIONS	VEHICLE/ PEDESTRIAN DEVIATIONS	ACCIDENTS
1994	83	66	51	200
1995	65	125	50	240
1996	69	146	60	275
1997	69	132	87	292
1998	91	183	51	325
1999	78	182	61	321
2000	87	259	85	431

A tragic accident: Linate airport

- Place: Linate airport, Italy
- Date: 8 October 2001
- 114 passengers killed and
- 4 people at the ground lost their lives

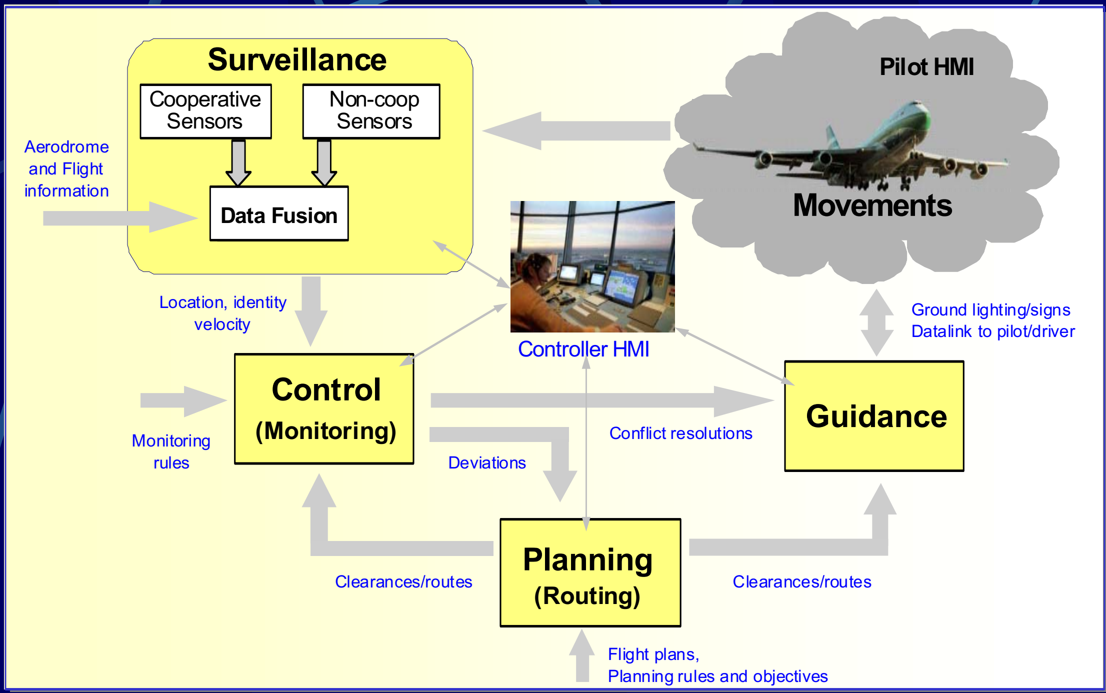
Reason:

- Limited visibility (225m).
- The airport did not have any means for surface traffic monitoring

Solution: Use of A-SMGCS (Advanced Surface movement Guidance and Control Systems)

- Surveillance
  - Level 1 – basic surveillance
- Monitoring
  - Level 2 – adds automated monitoring
- Guidance (and Control)
  - Level 3 - adds automated guidance
- Planning/Routing
  - Level 4 – adds automated planning

A-SMGCS functionalities



(Figure from EMMA IP project)

Features of A-SMGCS Systems

- A-SMGCS provides a valid tool to Air Traffic Controllers that
  - Reduces risks for life-threatening accidents
  - Improves traffic management reducing the delays at airports
- Is traditionally based on Surface Movement Radars: SMRs(primary radars) and SSRs(secondary radars)
- However, it is usually difficult to reliably cover the entire aerodrome due to
  - Reflections
  - Shadows due to buildings, equipment or other reflecting objects on the airport surface.
- Thus additional sensors ("Gap Fillers") may be needed to cover the blind spots of an A-SMGCS setup.

Present situation: Lack of A-SMGCS Systems

- A survey conducted within ISMAEL project with questionnaires to approximately 500 EU airports showed that:
  - 80% of these airports rely on human visual inspection from the control tower and
  - 40% face problems due to low visibility (visibility<400m) for more than 15days/year.

<u>Result</u>

Increase of Delays

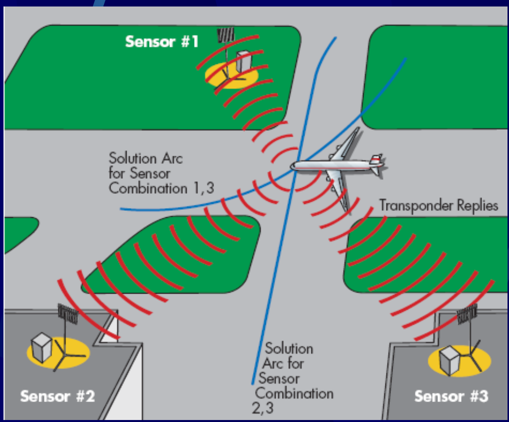
Decrease of security

Sensors used for A-SMGCS: SMR

- Surface Movement Radars (SMR) / Airport Surface Detection Equipment (ADSE)
  - Primary radars for ground surveillance (non-cooperative systems)
  - Range: 5-8km
  - Operation in X-band (8-12 GHz) or Ku-band (12-18 GHz)
  - Automatic target identification/labeling is NOT possible
  - High cost (300-500k Euro)+integration with ATC/A-SMGCS system
  - May have problems due to:
    - reflections
    - shadowing (blind spots)

Mode-S Multilateration

- Sometimes they are supported by multilateration systems that rely on Mode-S signals transmitted by the aircraft transponder.
- Multiple receivers to capture the "squitter" transmitted from the Mode-S transponder. Then, by comparing the time difference, the system calculates the position.



- However:
  - Cooperative systems (can only detect cooperative targets)
  - Aircraft transponder has to be ON: in case of a system/ malfunction or if the pilot switches it OFF, the accident risk increases

Sensors used for A-SMGCS : SSR

- Secondary Surveillance Radar (SSR) not only detects and measures the position of aircraft but also requests additional information from the aircraft itself such as its identity and altitude. These are provided in Mode-S signal by the aircraft transponder
  - Cooperative system
  - Allows automatic target identification/labeling
  - Similar problems as the SMR and multilateration, i.e.:
    - reflections
    - shadowing (blind spots)
    - if the transponder is switched off or malfunctions

Automatic Dependent Surveillance-Broadcast (ADS-B)

- Cooperative system
- An ADS-B-out equipped aircraft determines its own position using a global navigation satellite system (GNSS) and periodically broadcasts this position and other relevant information to potential ground stations and other aircraft with ADS-B-in equipment.
- ADS-B can be used over several different data link technologies (e.g. Mode-S Extended Squitter, VHF data link. etc).

Commercial A-SMGCS systems

- NOVA9000 (Park Air Systems, Norway/US),
- STREAMS (THALES ATM, France/Italy),
- ASDE-X (SENSIS, US),
- A-SMGCS system (HITT Traffic, NL)
- SurfTrack (NESS, US/Israel)
- A-SMGCS system (Alenia Marconi Systems, IT)

Recent Research Projects based on novel sensors

- INTERVUSE (FP5 IST) – optical sensors(cameras with embedded processors) of Autoscope^{TM}, which was very successful for road traffic detection and relatively low-cost,
- ISMAEL (FP6 IST STREP) – novel developments in magnetic sensing technology, low-cost
- AIRNET (FP6 IST STREP), EGNOS/GPS low-cost platform combined with wireless telecommunication systems (CDMA, WiFi, TETRA, VDL-4) for communicating results to control center.
- SAFE-AIRPORT (FP6 IST STREP), rotating directional microphone arrays.
- Design of an A-SMGCS Prototype at Barajas Airport / Airport surface surveillance based on video images: work by EPS Universidad Carlos III de Madrid.
- AVITRACK project (FP6 AERO STREP): Aircraft surroundings, categorised Vehicles & Individuals Tracking for apRon's Activity model interpretation & CheckK
- EMMA FP6 IP (European airport Movement Management by A-SMGCS)

Comparison of A-SMGCS technologies

Technologies/Characteristics	Visual	Magnetic	Radar (primary)	GPS	Multilateration
Installation cost	Low	Medium	High	Low	High
Operation cost	Low	Low	Medium	Low	Medium
Ease of installations/ modifications	Easy	Medium	Hard	Easy	Hard
Influence from weather conditions	Yes	Temperature-dependent	No	No	No
Active detection (need for cooperative targets)	No	No	No	Yes	Yes
People detection	Yes	No	No	No	No
Target identification	No (maybe class)	No (maybe class)	No	Yes	Yes

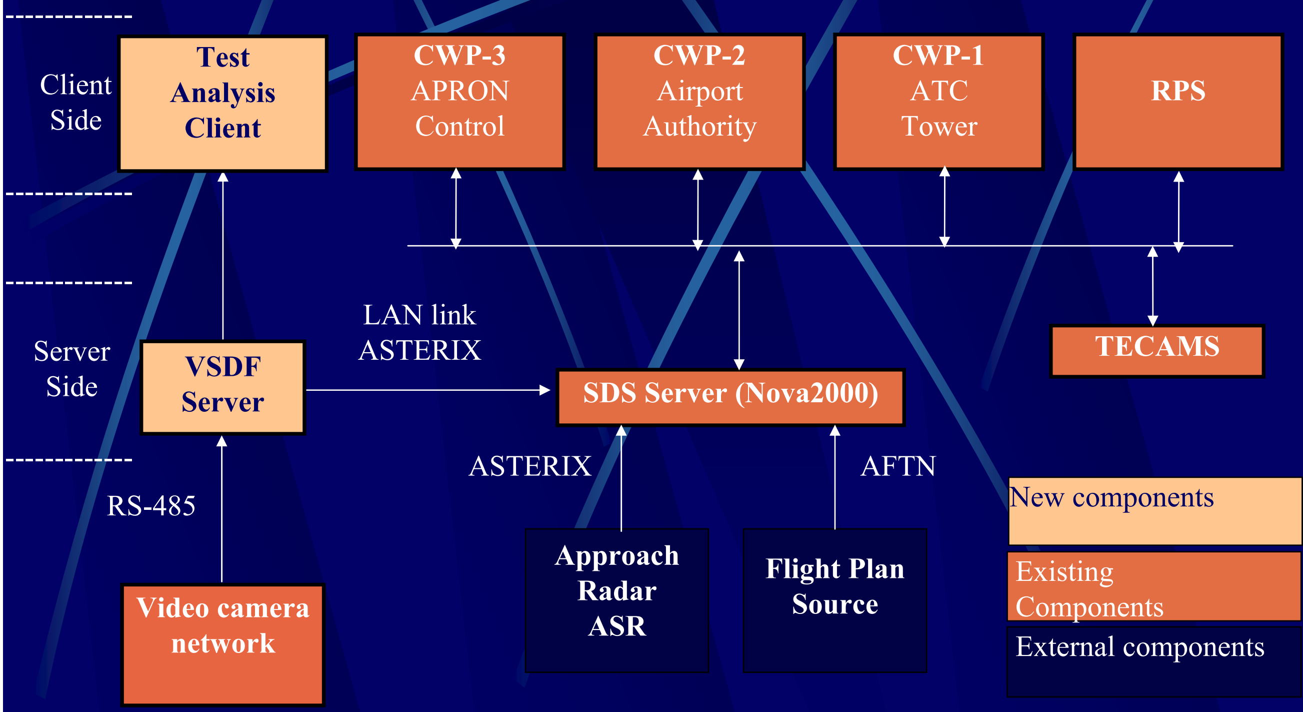
Airport surface monitoring using intelligent optical sensors: The INTERVUSE project

- EC-funded
- Objective: AGMGCS using a network of Intelligent optical sensors with
- Partners:
  - **Center for Research and Technology Hellas (CERTH) / Informatics and Telematics Institute** (Greece, Coordinator),
  - **Park Air Systems** (Norway),
  - **DataCollect Verkehrsdatentechnik GmbH & Co.KG.** (Germany),
  - **Mannheim Airport,** (Germany),
  - **DFS Deutsche Flugsicherung** (Germany, sub-contractor of CERTH),
  - **“Macedonia” Airport of Thessaloniki** (Greece, not an official partner)

Project Objectives

- Provide a new position sensing technology for A-SMGCS by combination of ATC radar tracking, flight plan processing, state vector extraction based on video cameras.
- Correlate and fuse these data to generate a synthetic ground situation display in an integrated SMGCS-ATC controller working position.
- Develop and test two prototype systems at two European airports: Mannheim and Thessaloniki.
- Study of the usability of the system as:
  - a low cost solution for A-SMGCS tasks at smaller airports (Mannheim tests)
  - solutions for limited A-SMGCS tasks (Thessaloniki tests)
  - contributions for larger A-SMGCS solutions at large airports to cover blind spots like hidden yards or taxiways

System Architecture



Autoscope Solo® Wide Area Video Vehicle Detection System

- Autoscope® system uses machine vision technology and an embedded processor to produce highly accurate traffic measurements:
  - speed data
  - estimation of traffic statistics (e.g. volume)
  - vehicle classification
- Detection of incidents in highways.

- Each camera can be individually configured with Virtual Detectors
- Virtual Detectors: "Regions of Interest" that can detect local motion (target presence) using contrast recognition and learned patterns.
- All cameras are addressable by a unique IP address and are linked using serial cables (RS-485 similar to RS-232 but suitable for larger distances up to 1Km)

Demonstration of Camera functionality (Thessaloniki Airport)

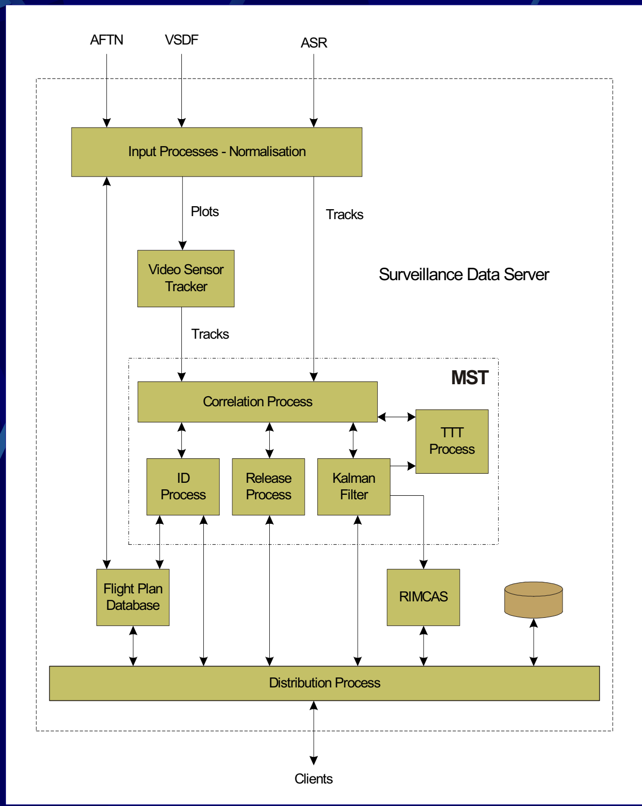
- **Camera 1**
- **Camera 2**

Video Sensor Data Fusion

- Periodically polls the event data (VD states) from the cameras (constant cycle),
- Processes the data received to detect and avoid possible false alarms
- Forms the observations (plots) that contain:
  - The time of the event
  - The ground position and size of the target (uses calibration)
  - Additional information (e.g. velocity)
- Sends observations to the tracker of the system (SDS) in ASTERIX format (radar data exchange standard)
- Supports an optional visualization window, which shows VDs and observations on an airport map.

The Surveillance Data Server

- Based on NOVA2000
- Interfaces to VSDF, ASR, and flight plan data sources; Additional interfaces are available for SMR, MLAT, ADS-B
- Performs data fusion, correlation, and multi-sensor target tracking using Kalman filtering
- Distributes data to the controller working positions and other clients



Controller Working Positions

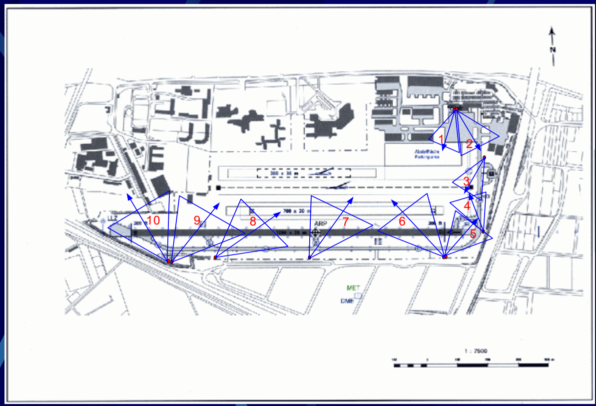
- A main traffic situation display window showing the movement area along with the tracked surface movement targets
- An inset window showing the traffic situation in the air

- Arrival and Departure flight plan lists with manual labelling capability
- A vehicle list with manual labelling capability
- Windows for presentation of alerts and status information

Two Prototype Systems

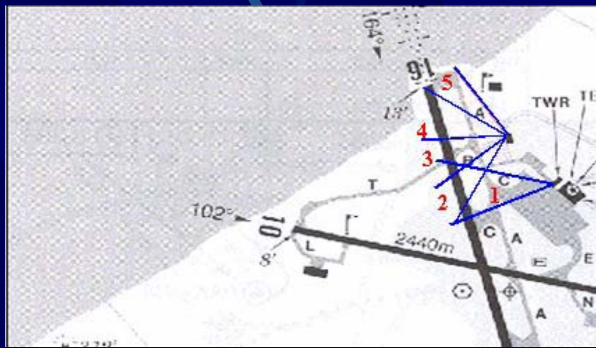
Site 1: Mannheim Airport

- All the area of the airport was covered
- Ten cameras were installed
- There were gaps between cameras.



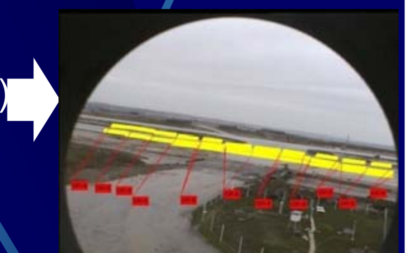
Site 2: Thessaloniki Airport

- Only a part of the main taxiway was covered (800m)
- Five cameras were installed
- There were no gaps between cameras.



Lessons Learned

- The cameras should be installed as high as possible and close to the area to be surveyed to reduce shadowing and occlusion effects and improve calibration accuracy
- One way to avoid occlusions is to place detectors ONLY at the road closer to the sensor (lower in image)
- VSDF constraints can be defined to resolve specific problems, however errors may still occur.



- The VSDF algorithm handles traffic in roads and crossings, but has problems with more complex movements (e.g. APRON), when target tracks are not predefined
- Camera movements/oscillations should be avoided
- The existence of sky in the camera's field of view should be avoided since Autoscope sensors are sensitive to sudden illumination changes.

Lessons Learned (2)

- The FoV of the sensors should cover the entire monitored TWY/RWYs using small overlaps, so that
  - efficient use of the cameras is made
  - gaps (blind spots) are reduced or completely avoided.
- Design of VD configuration:
  1. The ground length of detectors is determined by the resolution requirement (approximately 15m).
  2. Detectors are non-overlapping and consecutive detectors are adjacent, so that the probability of detection at any time instant is increased.
  3. Adjusting the detector width is the ONLY means to control its sensitivity. The smallest possible width is selected that results to (almost) no false alarms, within a certain time period. This "optimal" detector width may depend on the existing wind conditions and the efficient mounting of cameras. Some algorithmic details about Autoscope VDs are still unknown (commercial product).
  4. Local adjustments may be required for some detectors, depending on the camera viewing angle and/or their image content.
  5. VDs can be placed in rows parallel to the road to be combined with OR operations to increase robustness to false alarms

TEST RESULTS

- False detection error: 1.5%
- Missed detection error: 4%
- Theoretical obtainable accuracy 7.5m
- Possibility to discriminate between targets which are separated by 15m or more
- Good Performance for velocities between 0 and 100km

Conclusion

The results indicate that the INTERVUSE technology can achieve most of the performance requirements of an SMR

Strengths

- Lower cost
- Higher update rate
- No radiation
- Configurable setup
- Passive system
- (Optional) Provision of video image(s)

Weaknesses

- Limited coverage
- Detection problems in heavy fog
- Problems/False detections
  - due to occlusions
  - due to sudden illumination changes
  - Targets not moving for a long period (e.g. 2mins)

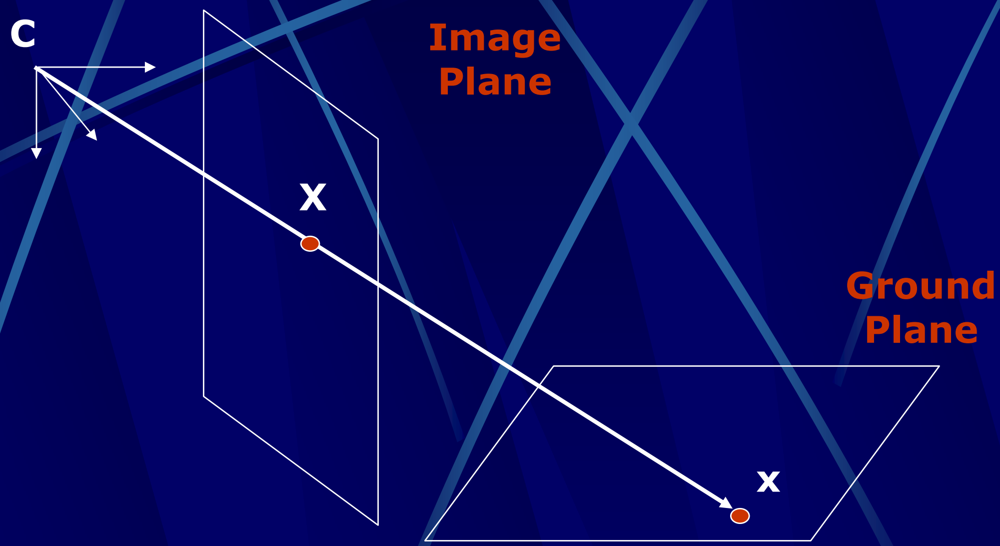
More Details on Video Sensor Data Fusion module

- Camera Calibration
- The VSDF Software
- VSDF Demonstration

Camera Calibration

- For each camera, a function to convert ground to image coordinate and vice versa is estimated.
- Calibration is used to create a VSDF configuration file, which contains the ground coordinates of the four corners of each detector.
- The detector centers (in ground coordinates) are then used for producing VSDF observations.

Camera Calibration



- If **X=**(X,Y,1) **and x=**(x,y,1) (projective coordinates) and **C** is a projective camera then **x** and **X** are related by an homography **M** (3x3 matrix with 8 degrees of freedom – scale is arbitrary)**:**

X=Mx

Camera Calibration (2)

- We fix scale by setting $M_{33}=1$

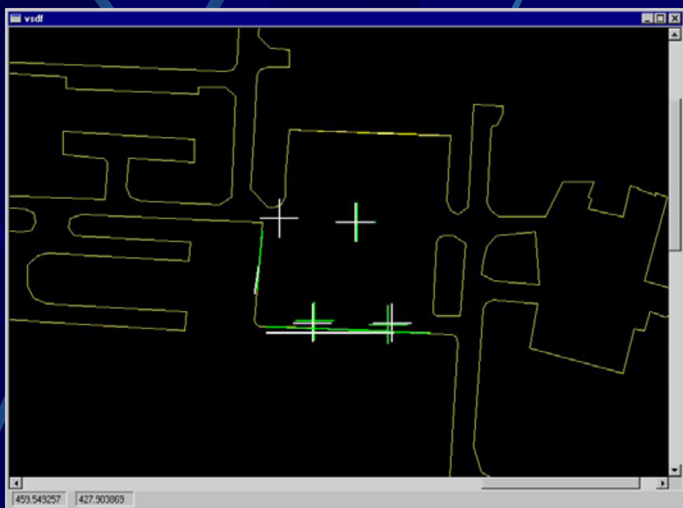
$$M = \begin{bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & 1 \end{bmatrix}$$

- $n \geq 4$ corresponding points **(X,x)** are marked both on the map (ground coordinates) and the image.
- Calibration is then achieved by solving an over-determined system of *n* equations and 8 unknowns, using least squares estimation.

[1] K.J.Bradshaw, I.D. Reid and D.W. Murray, “The Active Recovery of 3D Motion Trajectories and Their Use in Prediction,” IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. 19, No. 3, March 1997, pp 219-233.

Camera Calibration (3)

- Line correspondences are usually easier to mark and may also be used, if available. Each line correspondence results to two additional equations (same as point correspondences).

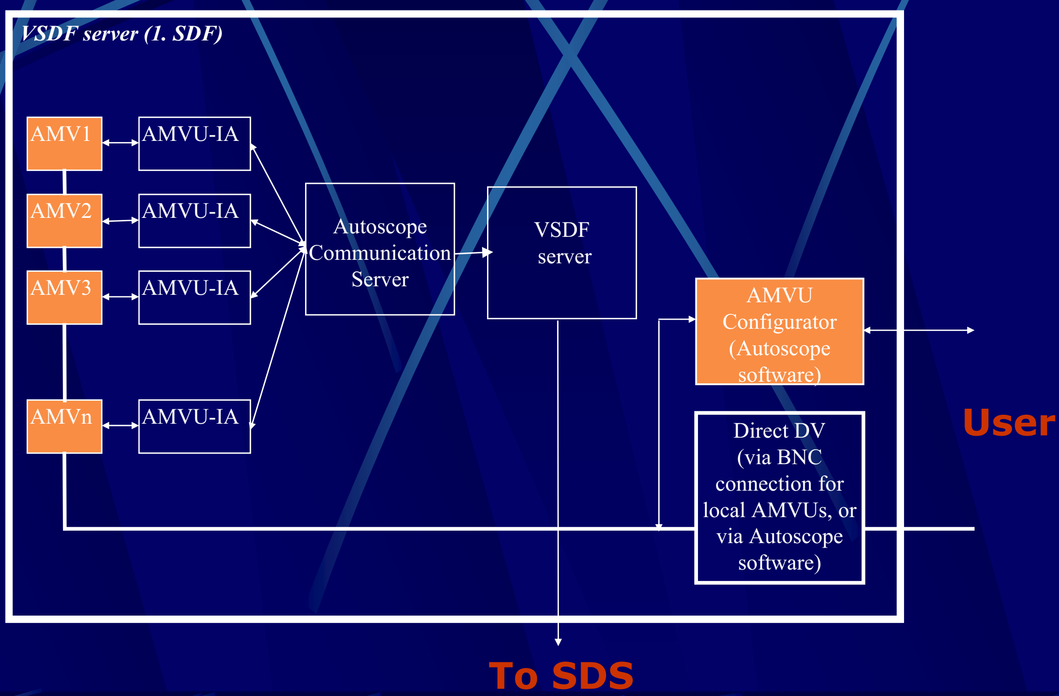


- Visualization of point and line correspondences (green) and calibration results (white).

VSDF Server Overview

- Collects data about the state of detectors from all Autoscope sensors (AMVUs).
- Processes this data in order to extract a set of observations (plots). The position and size of each observation is estimated.
- The final results of the VSDF process are encoded in ASTERIX Cat.10 format and sent to the SDS for further process (tracking).
- An optional visualization window of inputs (VD states) and outputs (observations) is also supported.

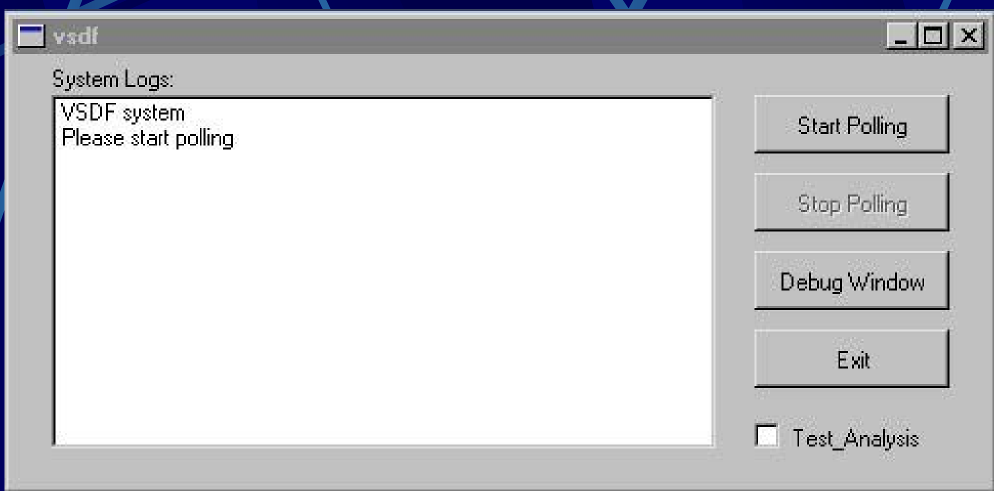
VSDF Server Architecture



VSDF software

- Win32 multi-threaded application
- Developed using Microsoft Visual C++ and Autoscope SDK
- The Qt library was used for the user interface (so that future porting to UNIX is easy).
- Consists of three threads:
  1. The User Interface Thread (UIT).
  2. The Worker Thread (WT), which is responsible for the main tasks of VSDF (polling, forming of observations, encoding and transmission of outputs as ASTERIX Cat10 messages).
  3. The Optional Visualization Window Thread (DWT).

User Interface

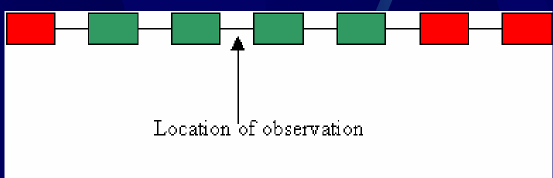


Polling of Virtual Detectors

- Polling is based on polling functions from an Autoscope SDK.
- Polling System Limitation: New data can be provided by polling only after 1sec has passed from the previous polling, which causes some problems, when higher update rates are needed.

Forming of observations

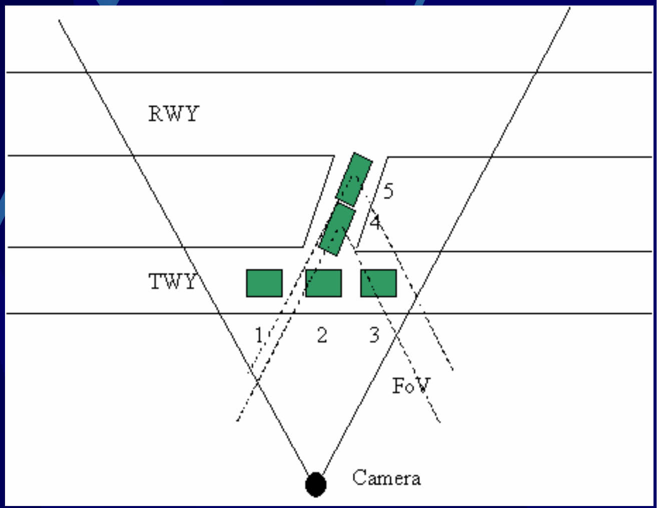
- In each polling cycle, a vector containing the (binary) states of all VDs is updated.
- Using this vector and topology-related “constraints” specified in a configuration file (designed for each airport), observations are formed.
- “VD Chains” are defined in the configuration file. Each chain is a sequence of consecutive detectors (even from different cameras), that are adjacent.
- Within each chain, each sequence of activated consecutive detectors produces EXACTLY ONE observation.



consecutive activated detectors

Additional constraints to handle occlusions

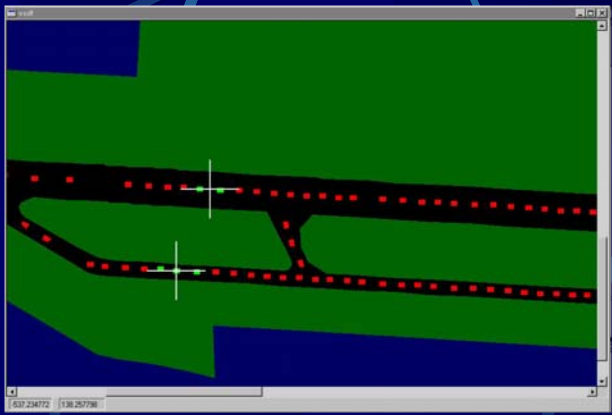
- In this example setup, the tail of an aircraft passing from TWY may activate 4,5 leading to false results
- Thus, an activation in the intersection layer is ACCEPTED ONLY IF NO detectors of the main layer (1,2,3) are activated.
- This constraint correctly resolves occlusions from a plane at the TWY, however it still fails when two planes exist (one at the TWY and one at the intersecting road).



Encoding into ASTERIX Cat10 messages and transmission to SDS

- For each observation a data packet is generated and transmitted (via UDP) as an ASTERIX Cat10 message
- This message includes:
  - The position of the observation in Cartesian co-ordinates
  - The estimated target size using the distance between the first and the last activated detector
  - The time and date obtained by the VSDF clock when sending the message
- In addition, to inform the SDS server about VSDF status, a periodic system status data message is generated and transmitted

Visualization Window



- This (optional) local visualization window is implemented as a separate thread, so as to be fully independently from the core VSDF procedures.
- This tool provides a real time display of the status of all VD's on an airport map (Green=activated, Red=inactivated, Yellow=activated, but ignored by VSDF, grey=Not used, off-line).
- Observations sent to SDS are shown as white crosses.
- The user may zoom in or out to observe any airport section.

Demonstration (Mannheim Airport)

Demonstration (Thessaloniki Airport)

Conclusions / Future work

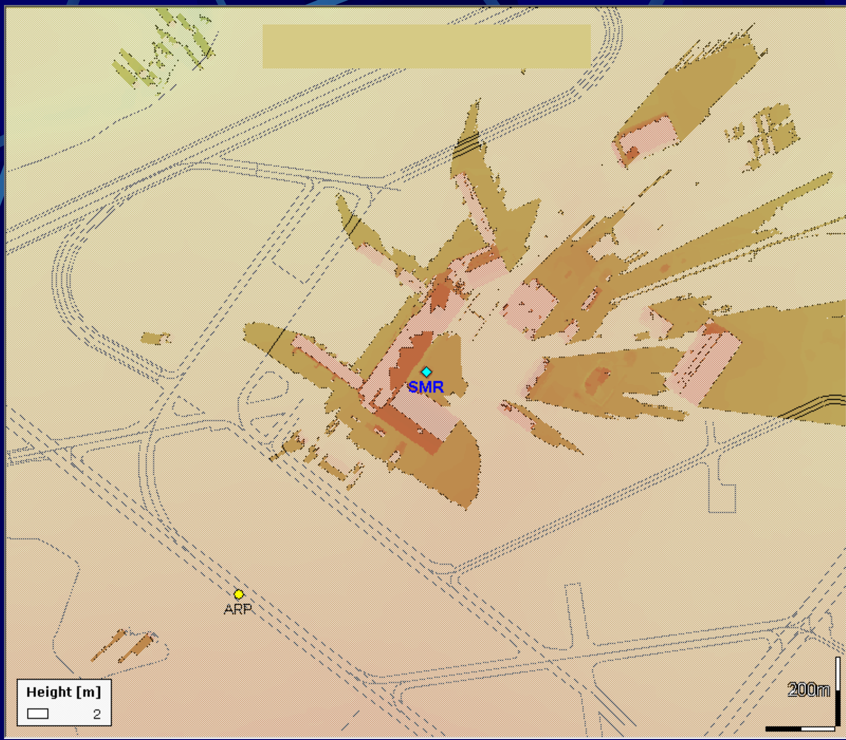
- Fully configurable - Configuration files are pre-defined for each airport
- Resolution is related to the detector lengths
- Sensitivity/Accuracy is related to detector widths
- Future extensions:
  - Porting to UNIX
  - Use of tracking algorithms to improve accuracy
  - Other applications with Autoscope sensors or other sensors

A Gap-filler case study: Prague airport

- Test of Gap-filler system at Prague International airport within FP6 EMMA IP project (European airport Movement Management by A-SMGCS, http://www.dlr.de/emma/)

Prague Airport Layout

SMR Shadow Areas

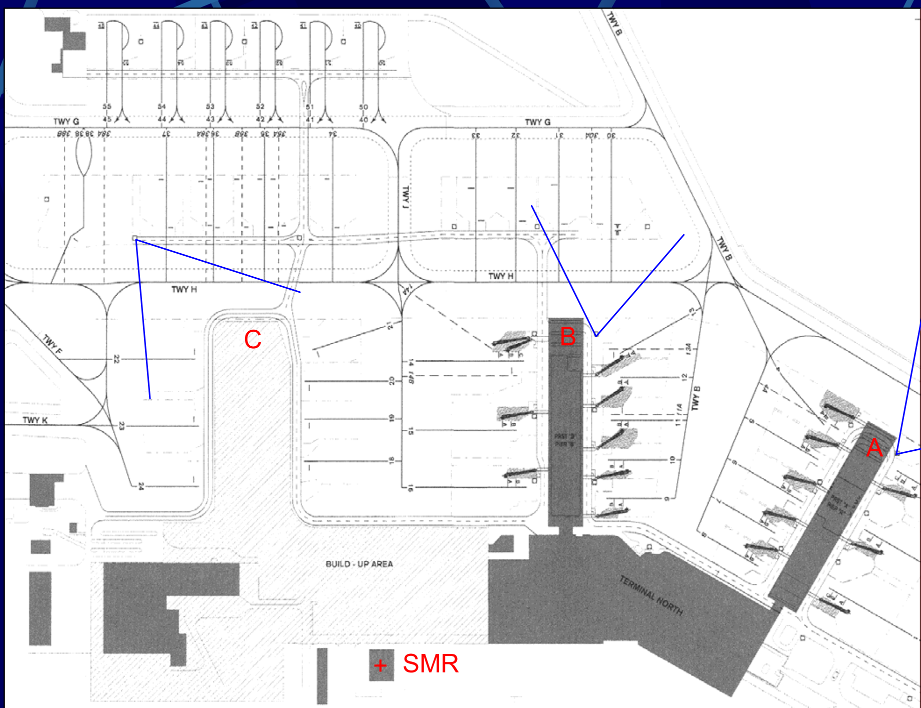


SMR Blind Spots

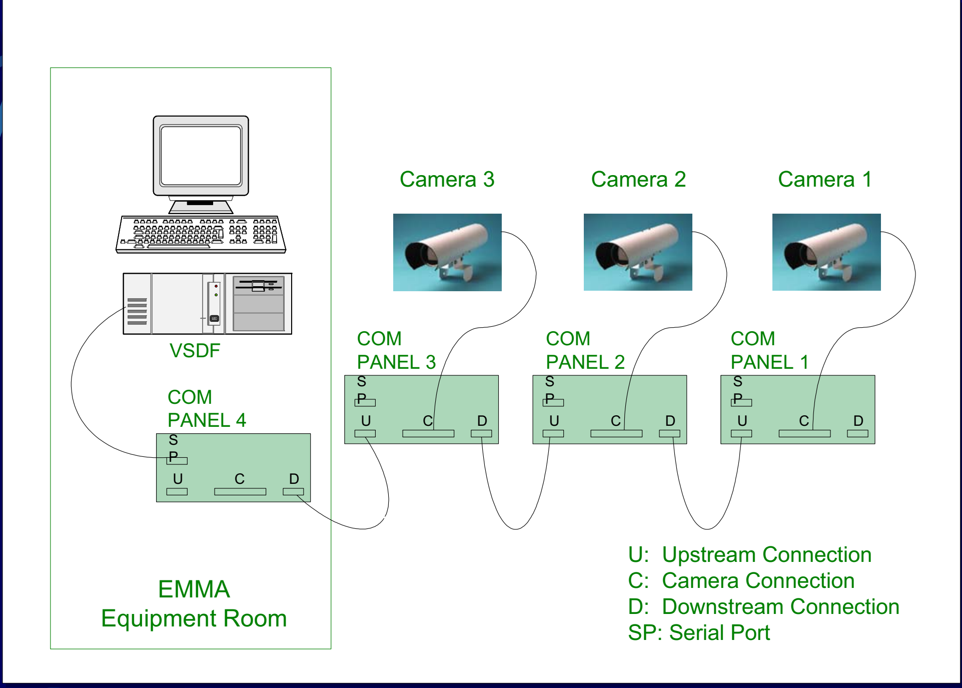
View North from Tower

Installation Positions for Cameras

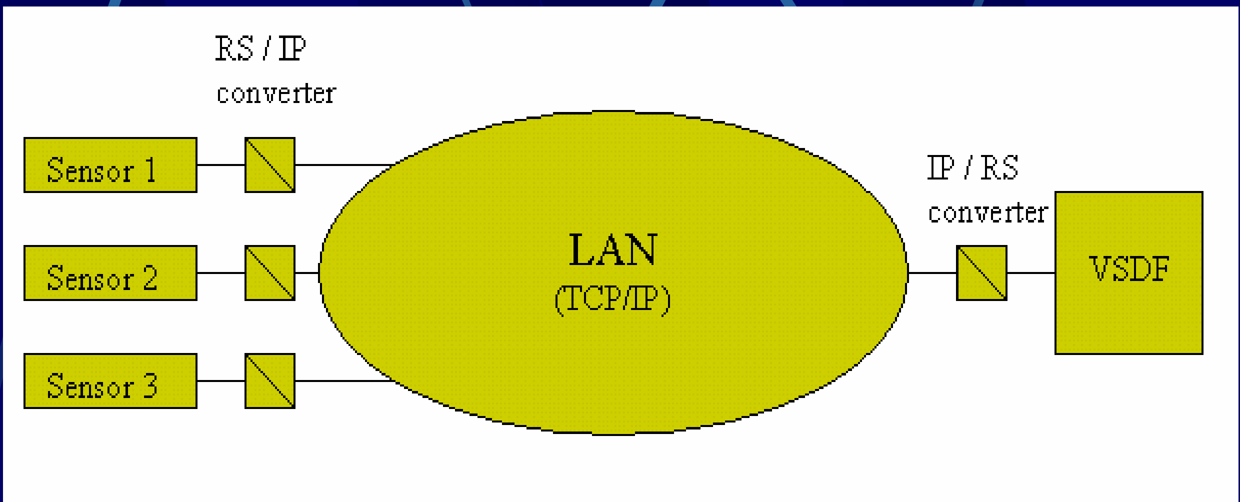
Camera Locations amd FOVs



VSDF Implementation (standard RS-485 connections)

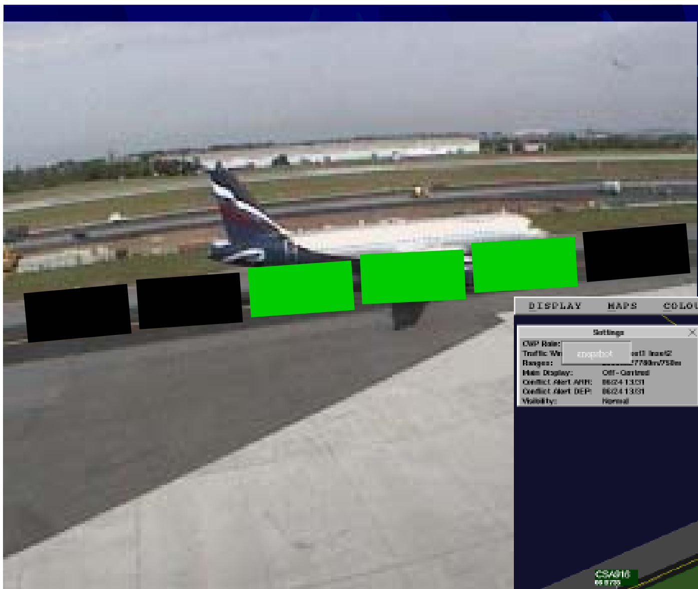


VSDF Implementation (using RS-485 to IP converters)



Final VD setup

Experimental Results



A novel software sensor inspired by Autoscope

Objectives:

- To design and implement software-based detection system (using PCs)
- To achieve similar (and even better) performance as Autoscope sensors
- To decrease costs
- To support ANY camera (even very low cost ones)
- To employ state-of-the-art background detection algorithms for improved results
- To generalize Autoscope “Visual Detector” concept with general polygon shape (instead of rectangular)

Background extraction and update

- Four background extraction methods were studied and supported:
  - Mixture of Gaussians (KaewTraKulPong and Bowden)
  - Bayes Technique (Li et al)
  - Fast Reliable background subtraction and update (Lluis-Miralles-Bastidas)
  - Non-parametric Model for Background Subtraction (Elgammal et al)
- They were tested against important factors, such as complexity, illumination changes, shadows.

Mixture of Gaussians model

- The probability density function for each pixel is modeled as an adaptive mixture of Gaussian distributions.
- The Expectation-Maximization (EM) algorithm is used to fit the Gaussian mixture model. This is an iterative process that guarantees convergence to a local maximum.
- The Mixture of Gaussians model:
  - Copes well with illumination changes
  - Is robust to slowly moving objects in the background
  - Requires adjustment of a small number of parameters

Bayes algorithm

- A Bayes decision rule is applied for the classification of background and foreground from selected feature vectors.
- Stationary and moving background objects are identified by selecting suitable features for each category
- As a result, foreground objects are also identified.
- Various strategies have been proposed for gradual or at-once learning of background features.
- The high computational cost of the method and the need for high memory resources render the algorithm inappropriate for real time applications

Lluis-Miralles-Bastidas algorithm

- Fast and simple background estimation and update algorithm, based on a moving average.
- Optimization of results by using and estimating the "background noise level" and by calculating automatically an optimal threshold.
- Suitable for indoor or outdoor scenes with small environmental changes (wind, illumination).
- Fast adaptation in foreground changes giving advanced sensitivity in detection of moving objects.
- Low computational cost.

Non-parametric modeling

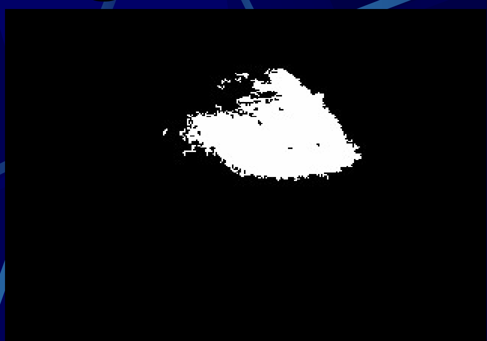
- The Probability Density Function (pdf) of the background for a pixel is modeled from its N most recent values, using a kernel function (e.g. a Gaussian)
- The variance of each kernel function is estimated
- A pixel is classified as background if the probability to belong to background is higher than a total threshold T, which is properly adjusted.
- Optional shadow removal by studying color and illumination information for each pixel.
- Memory requirements may decrease by using a Lookup Table for probability calculations

Evaluation of Background Extraction Results

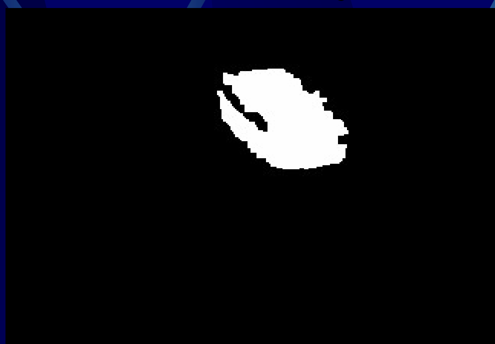
Road traffic sequence

Airport sequence

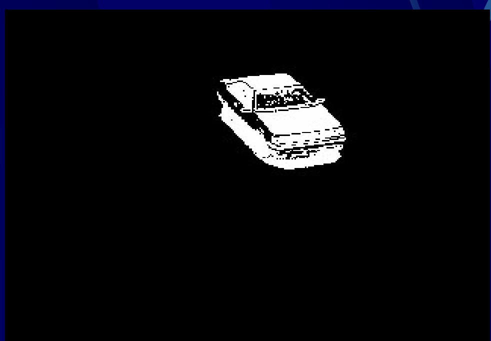
Background extraction (Road)



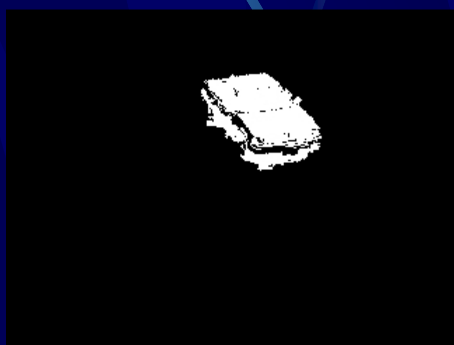
Mixture of Gaussians



Bayes



Fast technique (Lluis)



Non parametric model + shadow suppression (Elgammal)

Background extraction (Airport)

Mixture of Gaussians

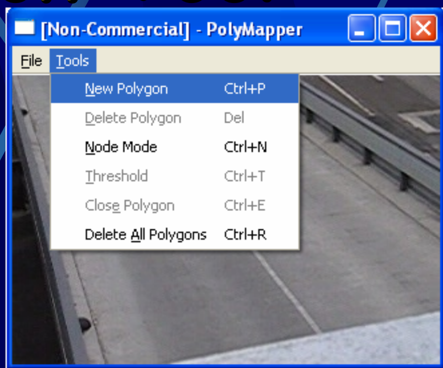
Bayes (Li)

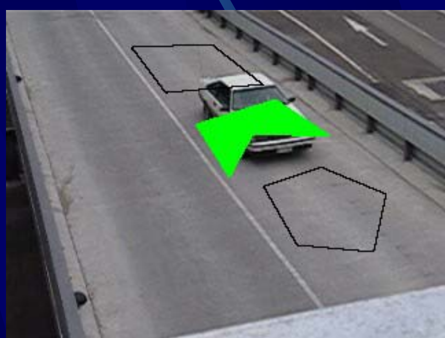
Fast technique (Lluis)

Non parametric model (Elgammal)

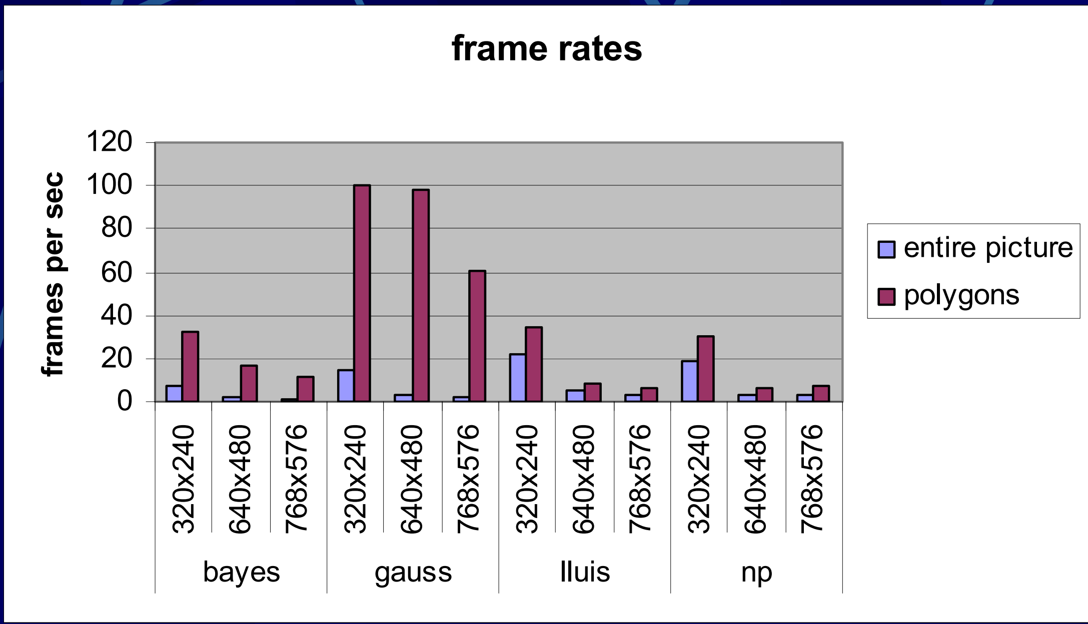
The "PolyMapper" configuration Tool

- A tool for off-line configuration of regions of interest was developed. It allows the user:
  - to define polygons of any shape and size depending on the scene structure and the user needs.
  - to adjust a threshold (sensitivity indicator) for each polygon.
- PolyMapper was built using the Qt library and can run under both Windows and Linux.





Comparison of execution times



Conclusions and future work

- Occlusions: Always a MAJOR issue in computer vision applications
- Weather (Fog/Rain/Snow) may cause problems, but:
  - In relatively light fog, since the camera is closer to the target than the tower controller, it may still provide useful info to him
  - Even in more heavy fog, the camera software may still recognize small changes in pixel values, that are invisible to the human eye.
- Shadows: can be significantly suppressed by Autoscope or simple shadow suppression algorithms
- Research on efficient background update: A VERY DIFFICULT task since all target have to be continuously and accurately detected (need to avoid their incorporation into background).
- Camera stabilization is very important
- RS-485 support / Network of sensors needs to be supported for the new sensor
- Exploitation activities for the new sensor

Centre for Research and Technology Hellas (CERTH) -
Informatics and Telematics Institute (ITI)

TRAVIS –
An Efficient Traffic Visual Monitoring System

Outline

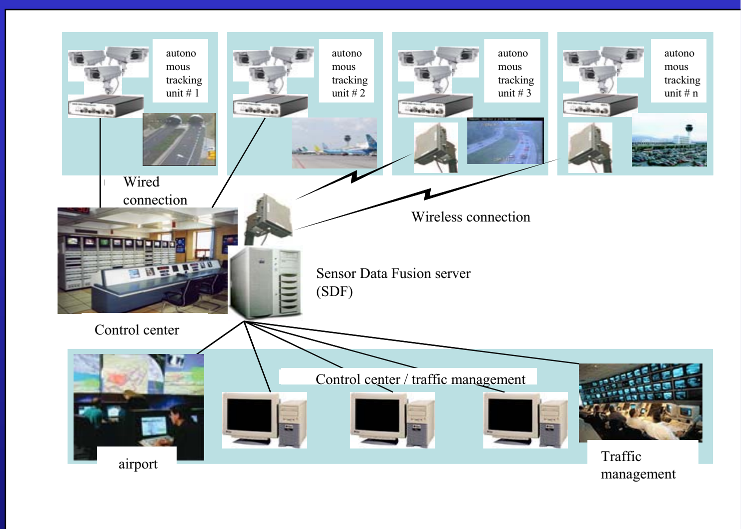
- Introduction
- System Architecture
- System modules and algorithms
- Pilot applications
- Experimental results
- Demo videos
- Conclusions

Aims of TRAVIS system

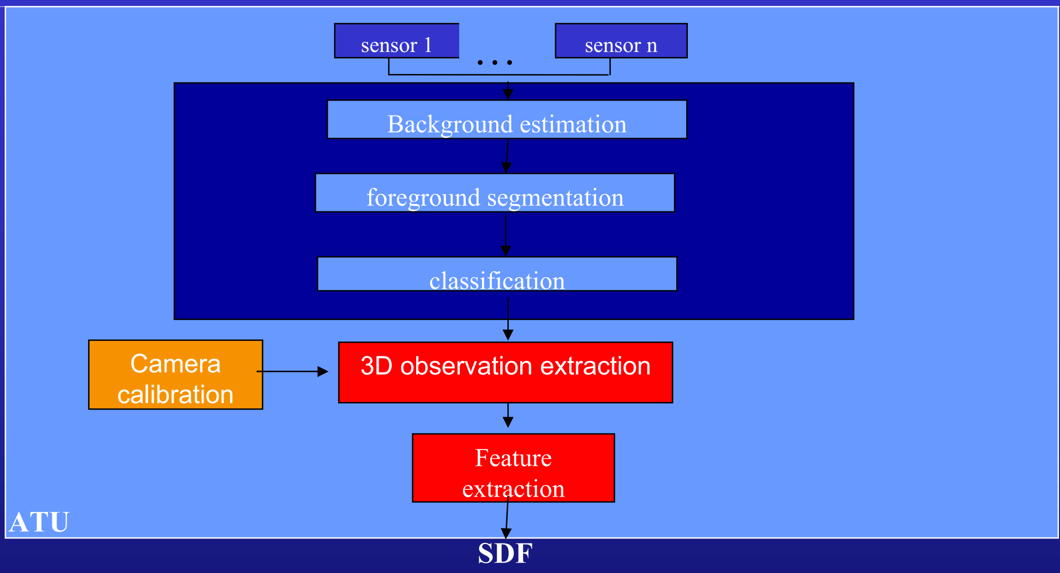
- The fundamental goal is a moving target tracking system, based on a network of cameras.
- A fully scaled and parameterized system for use in a broad field of applications
- Two prototypes were developed:
  - A tunnel monitoring system able to trace events that can lead to accidents. Installed at a tunnel near Piraeus harbor.
  - An alternative A-SMGCS for control of movements occurring at the aircraft parking area (APRON). Installed at Macedonia airport of Thessaloniki, Greece

TRAVIS System Architecture

- Scalable network of Autonomous Tracking Units
  - Video sensors
  - Detect foreground objects
  - Send results
- Sensor Data Fusion server (SDF)
  - Fuse observations from remote ATUs
  - Track moving objects
  - Visualize moving objects



Autonomous Tracking Unit



Background extraction techniques

- Four background extraction methods are supported:
  - Bayes Technique (Li et al)
  - Mixture of Gaussians (KaewTraKulPong and Bowden)
  - Reliable background subtraction and update (Lluis-Miralles-Bastidas)
  - Non-parametric Model for Background Subtraction (Elgammal et al)
- They were tested against crucial factors, such as complexity, illumination changes, shadows.
- Based on experimental results, the Non-parametric Model for Background Subtraction seems to be the most efficient one.

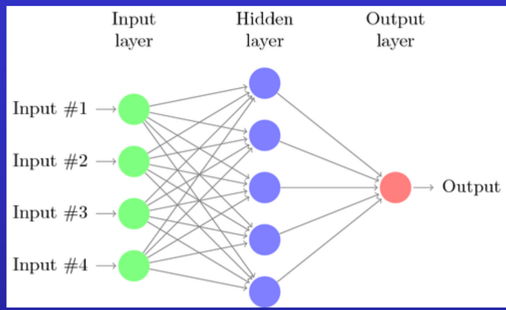
Classification

- Targets are classified in four categories :
  - Human
  - Car
  - Large vehicle (track, bus)
  - Airplane (Airport) / Motorcycle (Tunnel)
- For the implementation of classifier a Back Propagation Neural Network was used.

Classification

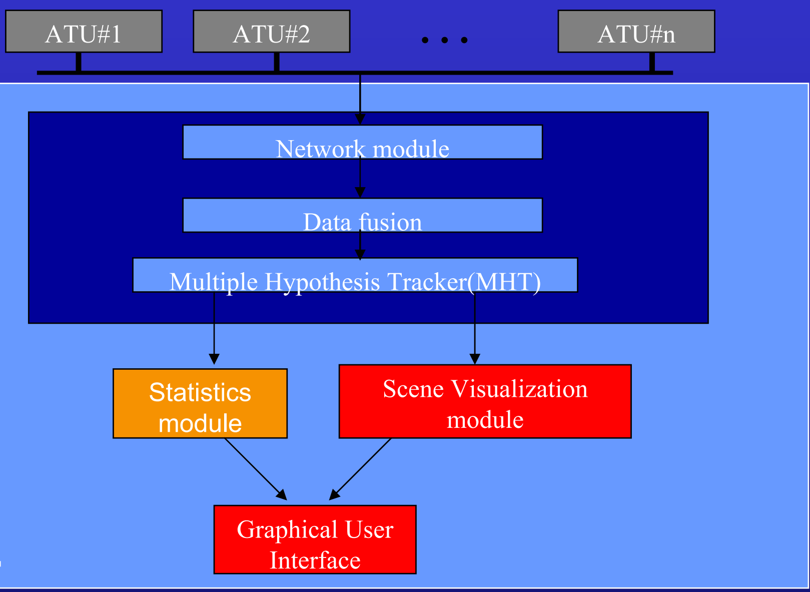
- The inputs of the Neural network in use are nine features of the observation:
  - The size of the major and the minor axis of the bounding ellipse of the observation in ground plane which are indicative of the size of the target.
  - The 7 Hu moments of the blob, that describe the shape of object and have the advantage of being independent of translations and rotations of the object.

Classification



- The Neural Network has one hidden layer with 100 nodes and an output layer with 4 outputs.
- Every output is the probability the observation to belong to this class.
- These four values are normalized to have a sum of one.
- For the training of the Neural Network, frame sequences from “Macedonia” airport of Thessaloniki and a tunnel near Piraeus harbor were used.

Sensor Data Fusion server (SDF)



Sensor Data Fusion server (SDF)

- Collects information from all ATUs using a constant polling cycle
- Produces fused estimates of the position and velocity of each moving target
- Tracks the moving targets using a multi-target tracking algorithm (Multiple Hypothesis Tracking – MHT)
- Produces friendly User Interface that:
  - Generate a synthetic ground situation display and provide alerts when specific situations (e.g. accidents) are detected.
  - Present the moving targets in real time
  - Present statistics of the observed scene
  - Give control to the User on the system as a whole

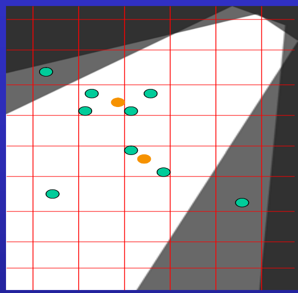
SDF server – observation fusion

- Two fusion techniques
- Grid – based technique
  - Separate the overlap area (in world coordinates) in cells
  - Observations belong to the same cell or to neighboring cells are grouped together
  - Fused observations are produced be averaging the parameters
- Foreground map fusion technique
  - Each autonomous tracking unit determines the pixels in each video sensor that are also visible by other video sensors
  - For these pixels foreground probability maps are generated
  - These maps are then transmitted to the SDF, where they are fused together (warped to the ground plane and multiplied together)

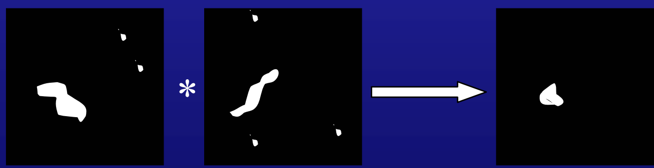
SDF server – observation fusion

2 modes / fusion techniques

- Grid-based fusion



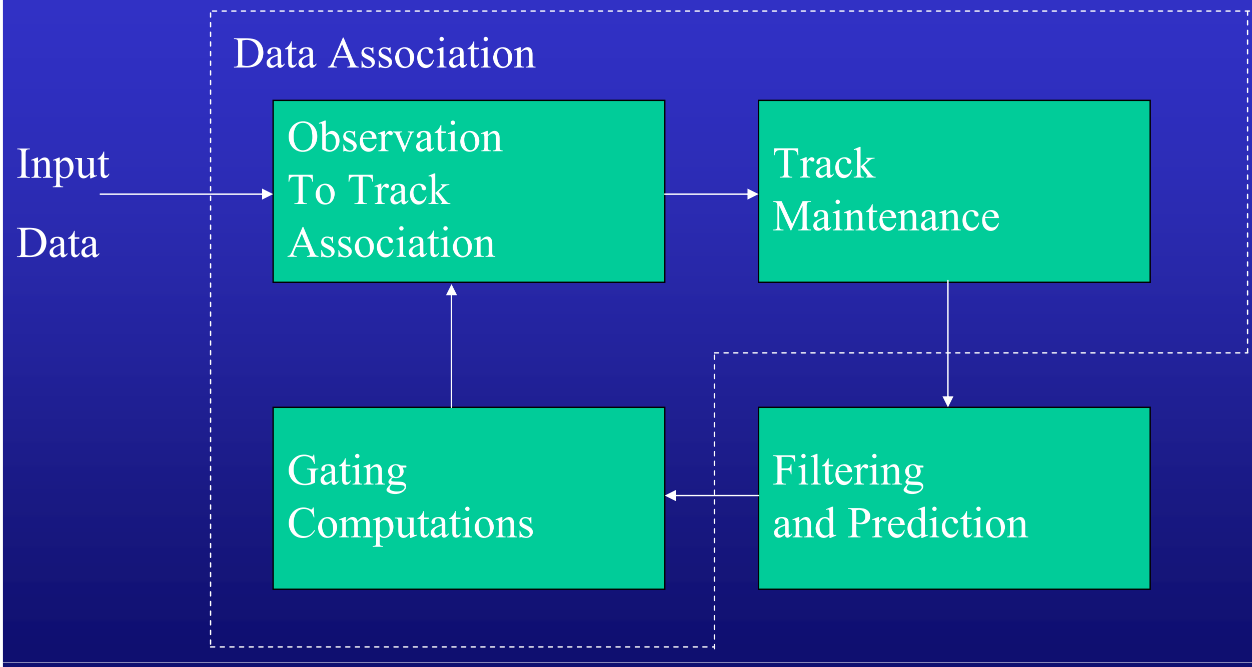
- Foreground map fusion



Multiple Hypothesis Tracking

- MHT is a statistical data association algorithm that has significant advantages:
  - Automatic track initiation
  - Automatic track termination
  - Track continuation – even in the absence of measurements (temporary occlusions)
  - Explicit modeling of spurious measurements (false alarms)
  - Explicit modeling of Uniqueness constraints: A measurement may be assigned to only one track and a track may be the source of only one measurement.

Multiple Hypothesis Tracking



Multiple Hypothesis Tracking

- An efficient implementation of MHT using a fast algorithm to generate the k-best hypothesis [Cox96] is used.
- Slight delay is introduced, since a decision (selection of the best hypothesis) is delayed for N time instants (usually N=2,3).
  - If N=0, no delay is introduced and the algorithm behaves exactly like GNN (nearest neighbor).
- Any Kalman filter model may be easily implemented.

SDF server – statistics

- Statistics per lane and per object class (Person, Car, Large vehicle, Motorcycle. Other)
- Minimum, Maximum and Average Velocity estimation
- Traffic flow (Vehicles/h)
- Traffic density (Vehicles/km)
- Vehicle counters

- Real time presentation of statistics and recording for post processing and analysis

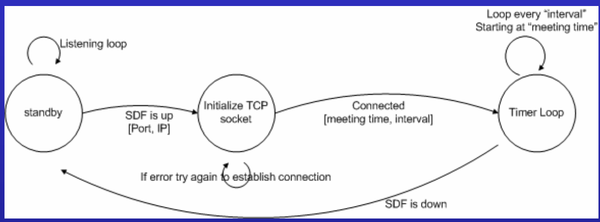
Data exchange and control

- Client – Server based architecture. TCP/IP network
- Use of Network Time Protocol to synchronize the interconnected computers (ATUs) with SDF clock
- Appointment algorithm to have millisecond synchronization in frame capture
- Remote control of ATU network through SDF software using a UDP signaling channel
- Data packets contain plain text data or text and foreground maps depending on the operation mode

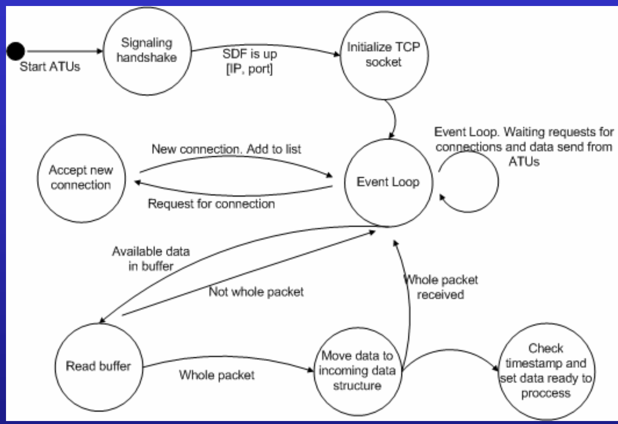
UAM, Madrid June 2008

Data exchange and control

ATU



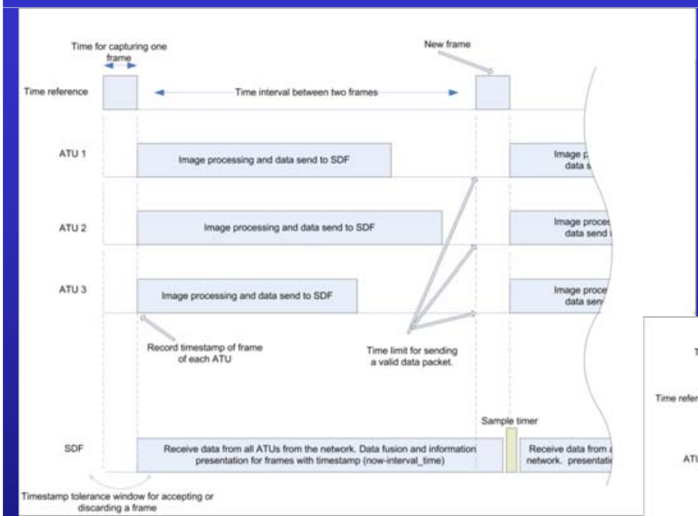
SDF



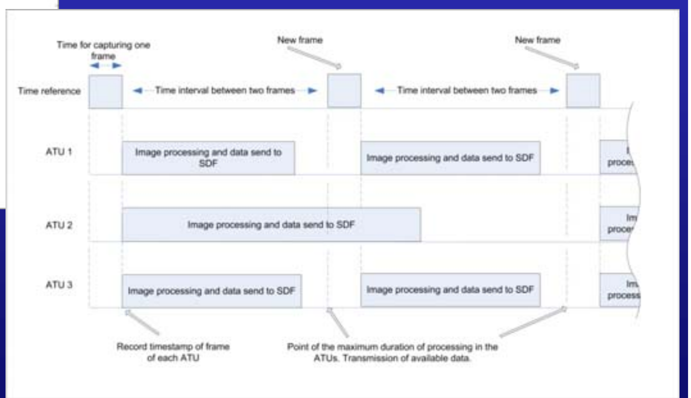
ATU data packet →

Mode (1 byte)	Packet size (2 bytes)	ASCII size (2 bytes)	timestamp (8 bytes)	ASCII observations (t_size bytes)	Deflated foreground map (im_size bytes)

Synchronization maintenance



Capture cycle and processing time window with no delays

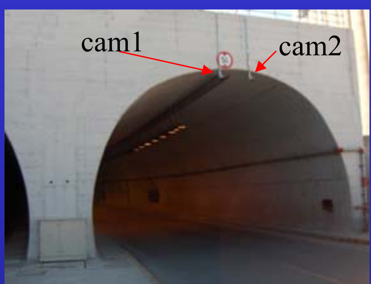


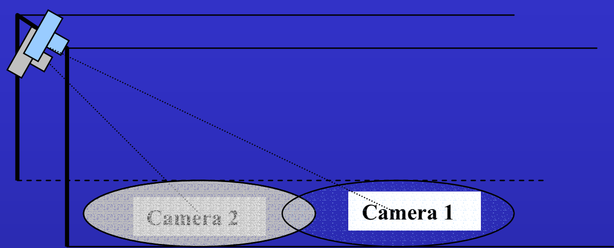
ATU 2 exceed the given time for processing and data transmission

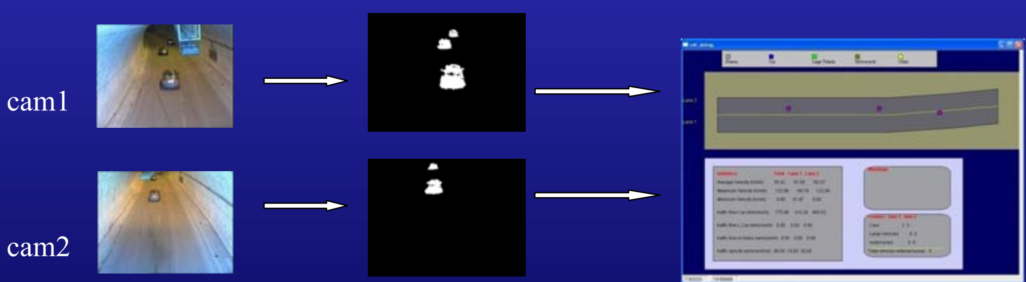
Secondary video streaming system

- Secondary backup system from each ATU to control center
- On Demand video streaming to assist:
  - Human operators
  - Decision makers
- Every ATU is able to stream:
  - Compressed video
    - Using unreal media streaming server
  - A number of compressed images (JPEG, JPEG2000)
    - Supported by the hardware of the Frame Grabber

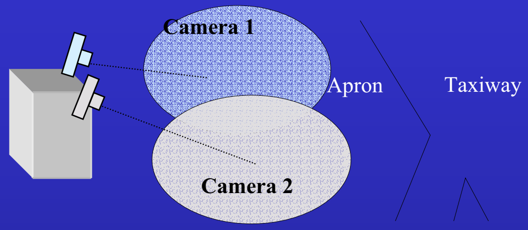
Pilot applications - tunnel

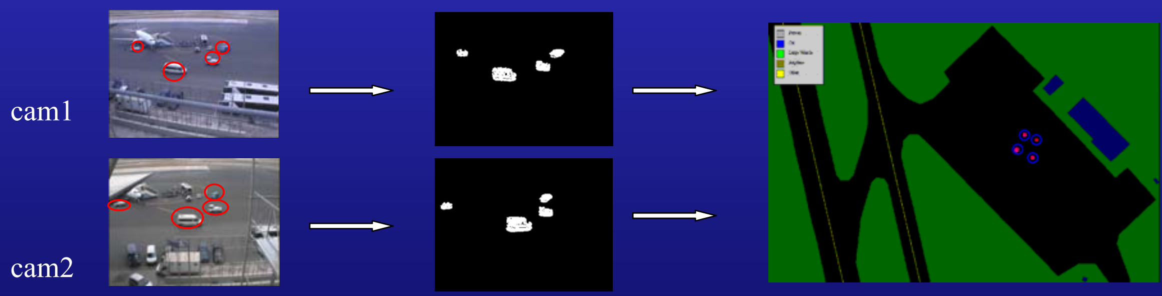






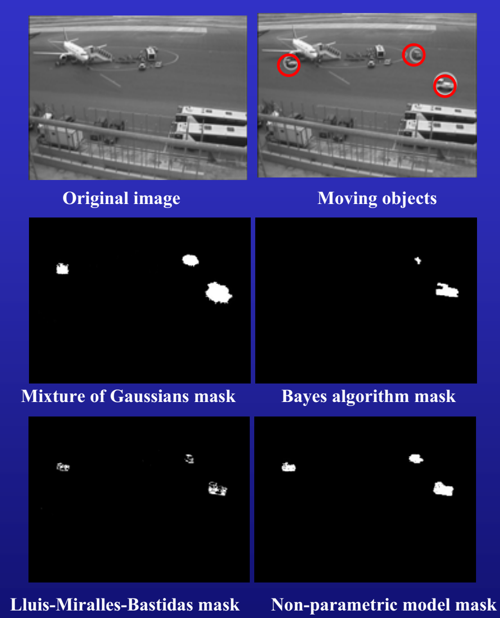
Pilot applications - airport





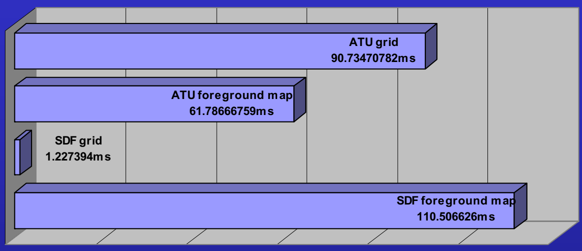
Experimental results

Method	Resolution	Time(s)	FPS
BAYES	**320x240**	0.13	7.68
	640x480	0.59	1.68
	768x576	0.73	1.38
GAUSS	**320x240**	0.07	14.38
	640x480	0.29	3.39
	768x576	0.39	2.59
LLUIS	**320x240**	0.05	22.19
	640x480	0.19	5.16
	768x576	0.28	3.63
NON- PARAMETRIC	**320x240**	0.054	18.57
	640x480	0.35	2.83
	768x576	0.38	2.65

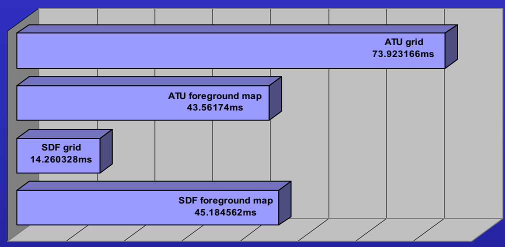


Experimental results

Tunnel installation:
fusion times grid-foreground map

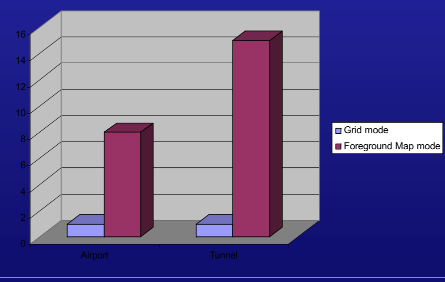


Airport installation:
fusion times grid-foreground map



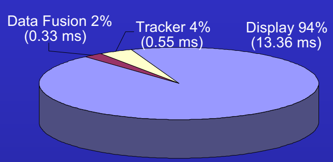
Bandwidth usage per mode for each pilot installation

- Grid mode ~ 1KByte / frame
- Foreground airport ~8 Kbytes / frame
- Foreground tunnel ~15 Kbytes / frame

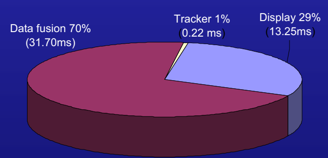


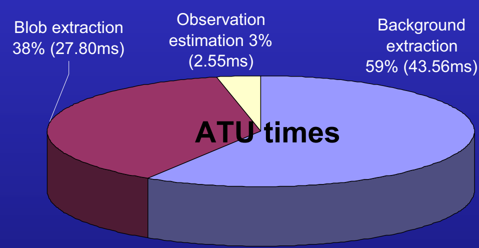
Experimental results

SDF times (Grid mode)



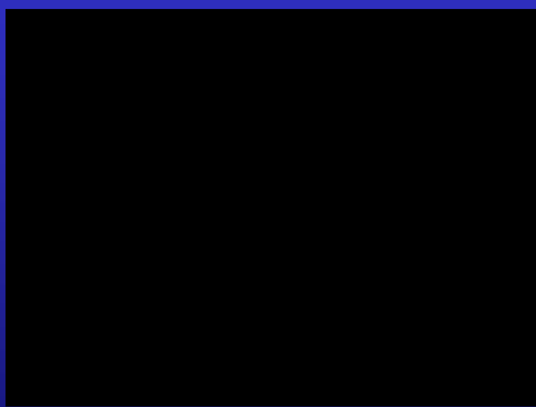
SDF times (Foreground map mode)





Demo videos - tunnel

Demo videos - airport



SDF

Conclusions

- Scalable
- Easily maintainable – remotely controlled
- Modular – able to integrate new algorithms
- Based on COTS parts
- Aimed for a broad field of applications
- The non-parametric modelling method seems to provide improved background extraction results in terms of accuracy and time efficiency
- Two data fusion techniques were examined, resulting to a trade-off between efficiency, bandwidth and computational complexity.

UAM, Madrid June 2008

Future work

- Support for additional efficient background extraction algorithms
- Research on background update algorithms to solve problems caused by local and global illumination changes
- Hardware implementation of ATUs based on DSP / FPGA technologies
- Implementation of ATU as Web Enabled Sensor, for use in service oriented architectures
- Exploitation of TRAVIS products (by VRSENSE spinoff company

Centre for Research and Technology Hellas (CERTH) -
Informatics and Telematics Institute (ITI)

Thank you for your attention

Questions?

Nikos Grammalidis
Electrical and Computer Engineer, Ph.D.
Centre for Research and Technology Hellas
Informatics and Telematics Institute
E-mail: ngramm@iti.gr

Theodoros Semertzidis
Electrical and Computer Engineer
Centre for Research and Technology Hellas
Informatics and Telematics Institute
E-mail: theosem@iti.gr

UAM, Madrid June 2008