Final Report

IST1999-11287 : ADVISOR

Annotated Digital Video For Intelligent Surveillance And Optimised Retrieval

Classification: Public

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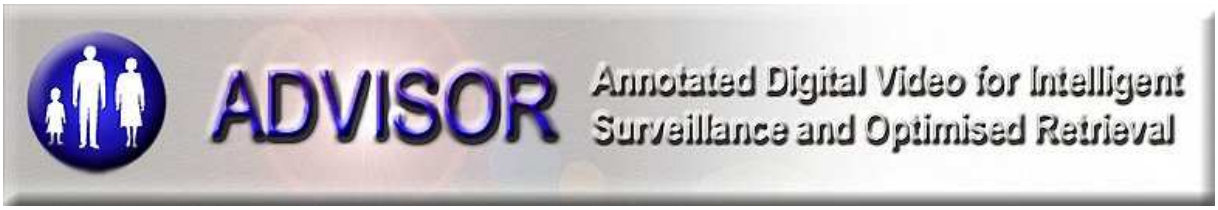

Project funded by the European Community under the "Information Society Technologies" programme (1998 – 2002)

Date: 27 May 2003

Version Number – Issue 1

Annotated Digital Video for Intelligent Surveillance and Optimised Retrieval

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MODIFICATION RECORD

Version: Draft D
Date: 20 May 2003
Author: M Naylor, C Attwood
Purpose: For review by internal partners
……..

Version: Draft E
Date: 22 May 2003
Author: M Naylor, C Attwood
Purpose: TRT Approval
……..

Version: Issue 1
Date: 27 May 2003
Author: M Naylor, C Attwood
Purpose: Release to European Commission
……..

Version:
Date:
Author:
Purpose:
……..

Abbreviations and Definitions

AV		**A**udio **V**isual
ADVISOR	-	**A**nnotated **D**igital **V**ideo for **I**ntelligent **S**urveillance and **O**ptimised **R**etrieval (this project)
CCTV	-	**C**losed **C**ircuit **T**ele**V**ision
CORBA	-	**C**ommon **O**bject **R**equest **B**roker **A**rchitecture
COTS	-	**C**ommercial **O**ff **T**he **S**helf
CROMATICA		**CRO**wd **MA**nagement with **T**elematic **I**maging and **C**ommunications **A**ssistance (a project within the 4th programme)
EC	-	**E**uropean **C**ommission
eTIP	-	**e**lectronic **T**echnological **I**mplementation **P**lan
HCI	-	**H**uman-**C**omputer **I**nterface
INRIA	-	**I**nstitut **N**ational de **R**echerches en **I**nformatique et **A**utomatique
IST	-	**I**nformation **S**ociety **T**echnologies
JPEG	-	**J**oint **P**hotographic **E**xperts **G**roup
MPEG	-	**M**oving **P**icture **E**xperts **G**roup
PRISMATICA	-	**Pr**o-active **I**ntegrated Systems for **S**ecurity **Ma**nagement by **T**echnological, **I**nstitutional and **C**ommunication **A**ssistance
RAID	-	**R**edundant **A**rray of **I**nexpensive **D**isks
STIB	-	**S**ociété des **T**ransports **I**ntercommunaux de **B**ruxelles (Brussels metro)
TCP/IP	-	**T**ransport **C**ontrol **P**rotocol/**I**nternet **P**rotocol
TMB	-	**T**ransports **M**etropolitans de **B**arcelona (Barcelona metro)
TRT(UK)	-	**T**hales **R**esearch and **T**echnology **(UK)** Ltd.
UDP	-	**U**nreliable **D**atagram **P**rotocol
VISOR BASE	-	**VI**deo **S**ensor **O**bject **R**equest **B**roker open **A**rchitecture for distributed **SE**rvices
VCR	-	**V**ideo **C**assette **R**ecorder
XML	-	E**x**tensible **M**arkup **L**anguage

Executive Summary

This document is the final report for the ADVISOR (Annotated Digital Video for Intelligent Surveillance and Optimised Retrieval) project. This project was part funded by the European Community under the Information Society Technologies programme (1998-2002). The project time scale was from 2000 to 2003, lasting 39 months.

ADVISOR was developed by a consortium of industrial and academic partners, including Thales, INRIA, Bull, University of Reading and Kingston University. The project started from some work on previous EC projects, but was the first to integrate the results of advanced video processing algorithms with an archive, search and retrieval database and a human computer interface.

During the project, new algorithms were developed for motion detection, tracking of people, and behaviour recognition. The proven algorithms for crowd monitoring were adapted from previous work on CROMATICA. A human computer interface was developed based on requirements derived from metro operator inputs.

At various points in the project, representatives of two metro companies were invited to evaluate the system from a user viewpoint and provide valuable feedback into the design. Validation tests were also completed at these stages to ensure that the technical performance was measured.

The project culminated in a successful demonstration of the system at the TMB headquarters in Barcelona, to various guests including the European Commission, project reviewers, and representatives of the Brussels and Barcelona metros.

The body of this report consists of the following sections:

- A project overview listing the main achievements of the project, and the roles of the consortium members
- The project objectives and goals at the start of the project
- The approach followed to achieve project objectives
- Project results and achievements with respect to project objectives
- A list of deliverables and other project outputs such as exhibitions, articles, and conference presentations
- Project management and co-ordination aspects
- The benefits gained from the project and exploitation plans
- Conclusions

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1 Project Overview

1.1 Main achievements of Project

The ADVISOR project has demonstrated the feasibility of using computer vision algorithms to detect unusual human behaviour and to use this to improve the effectiveness of existing security operators. It is particularly effective in a metro environment but could be adapted to other situations such as railway stations, airports and shopping malls.

For the first time, a system has been demonstrated that integrates all the capabilities of:

- Image Capture
- Behaviour Recognition
- Motion Detection
- Crowd Monitoring
- People Tracking
- Archiving, Search and Retrieval
- Human Computer interface
- Communications over an IP infrastructure

1.2 Consortium Composition

The ADVISOR consortium consisted of the following partners:

- Thales Research & Technology (UK) Ltd. (TRT(UK))
- Institut National de Recherches en Informatique et Automatique (INRIA)
- Vigitec
- Bull
- Kings College London (between 2000-2001)
- Kingston University (between 2001-2003)
- University of Reading

In addition, the consortium was supported by the Brussels Metro (STIB) and the Barcelona Metro (TMB).

1.3 Roles of Partners

The key roles of each partner are listed in this section. Each of the partners also had a more general role in assisting with other work packages, such as management, dissemination and integration.

1.3.1 Thales Research & Technology (UK) Ltd.

- Project Co-ordinator
- System Design
- System Integration

- Test Bed and Demonstrator hardware
- Camera calibration
- Capture Module
- Dissemination
- Validation

1.3.2 INRIA

- Vision Algorithms
- Supervised Learning
- Scene Model Construction
- Motion Detection Module including Blob Tracker
- Behaviour Recognition Module

1.3.3 Vigitec

- User requirements capture
- Human Computer Interface Module
- Evaluation with end users

1.3.4 Bull

- Archive, Search and Retrieval Module
- Contribution to Vision Algorithms

1.3.5 Kingston University

- Crowd Monitor Module
- Supervised Learning

1.3.6 University of Reading

- People Tracker Module
- Camera Calibration

2 Project Objectives

This section states the project objectives as determined at the start of the project.

2.1 Goal

The goal of ADVISOR is to improve the management of public transport networks through better exploitation of data from CCTV cameras. This will be achieved by harnessing the latest developments in computer vision technologies to address issues of passenger safety and crowd management central to the successful promotion of increased use of public transport in the future. The adoption of these new technologies by public transport operators will create new opportunities to develop further services for more efficient management of the transport environment.

2.2 Objectives

The principal objective of ADVISOR is to demonstrate the benefits of computer vision for reducing the workload on metro staff who rely on CCTV surveillance to assist them in the management of the transport network. Two further objectives will be to develop new management services for the operators, based on CCTV surveillance, and to demonstrate how a system such as ADVISOR should be specified and procured in the future.

2.3 Operational Goals

The specific goals for the ADVISOR project are to demonstrate the following capabilities, which are relevant to the overall goal of enhancing public transport operations through better use of CCTV.

- Computer-Assisted incident detection: ADVISOR will provide timely indication of anomalous events (e.g. crowds forming, flow of people stopped, entry into forbidden areas etc.) which require action from the operator in order to minimise disruption to the service.
- Post-incident analysis: Following a serious incident, there is need for post-incident analysis by specialists such as police or accident investigators. An efficient image retrieval system will be developed based on digital video coding technology.
- Quantitative analysis of behaviours: The availability of real-time, annotated digital video makes it possible to implement statistical analysis of events recorded during both normal and abnormal conditions. This analysis will provide a better understanding of the behaviours of individuals and crowds as they move through the network.
- Assessment and evaluation: ADVISOR will facilitate the specification, benchmarking, procurement and acceptance of computer-assisted CCTV surveillance systems by transport operators. This will be achieved by working closely with end users to:
  - incrementally develop a set of functional requirements; and
  - develop an assessment methodology for computer vision systems applied to surveillance.
- Market acceptability: if ADVISOR is to be commercially successful, then it must be easy to use and capable of being easily re-configured and scaled for different sites. ADVISOR will be developed using open standards for distributed processing, image coding and transmission. This allows development to be independent of the particular size and configuration of the End-User systems. ADVISOR will include a Human Computer Interface (HCI) designed in consultation with the End Users.

2.4 Baseline Data

The user needs analysis carried out in the CROMATICA project revealed that CCTV is widely

used in public transport operations with most operators planning to upgrade their installations. However, there is a growing problem of "information overload" with more CCTV cameras installed than can be effectively monitored by the staff available. Furthermore, facilities for recording CCTV data are either non-existent or very rudimentary. There is considerable scope for better exploitation of CCTV data to meet the growing demands on public transport operators for improvements in safety and efficiency.

Baseline data for the project will be compiled from a number of sources.

- The CONVERGE project will provide guidelines on the validation of ADVISOR.
- The INFOPOLIS project will provide guidelines for the development of the HCI, assisted by end-user feedback and experience gained in the PASSWORDS project.
- The CROMATICA/PRISMATICA (King's College and then Kingston University) projects will provide the user needs analysis and the core algorithms for monitoring crowds based on optical flow measurements in real-time.
- The AVS-PS (INRIA, VIGITEC) project will provide the core algorithms for detection and analysis of anomalous events and the development of HCI for display of annotated video.
- the results of recent work at Reading University on tracking of people will be used as the basis for the tracking algorithms.
- Bull will provide expertise on digital video technology based on experience of recent product developments.
- Thales - TRT (UK) will provide expertise on the provision of digital video services based on experience of developing service level agreements with major public transport operators.

2.5 Measures of Success

ADVISOR will be assessed through criteria, which cover:

- demonstration of computer vision techniques operating on compressed digital video inputs
- integration of the techniques via open interfaces
- demonstration of high probability of detection of anomalous events with commensurate low false alarm rate
- sustained recording of multiple video inputs in a format that allows efficient retrieval of data
- demonstration of improved performance in detection and recognition of anomalous events through learning via feed back from the operator
- quantifiable reduction in operator workload in terms of faster response to incidents and better management of CCTV resources
- an increased awareness in the operators of the flow of people through their network
- use of low cost, commercial technology

Measures of performance concern the probability of detection of anomalous events, probability of false alarm, accuracy of event classification, time taken to respond to events. These measures will be used wherever practical to quantify the assessment criteria.

2.6 Assessment and Evaluation

ADVISOR will be evaluated through two test beds, the results of which will be fed back into the design of the final demonstrator. The first test bed will be laboratory based at Thales with input supplied by PRISMATICA, TMB and STIB as video sequences of relevant events from a variety of sources. The second test bed will be designed for a site to be provided by TMB using input from a network of cameras. Synchronised recordings will be made to allow further laboratory evaluation. The demonstrator will be installed at a site to be provided by STIB where demonstrations using

live input from a network of cameras will be used to test the robustness of the system over extended periods with no prior knowledge of, or constraints on, the events that might be seen.

The end users associated with the project will be closely involved in the assessment and evaluation. Following the guidelines given by CONVERGE for the evaluation of Transport Telematics projects, the assessment will address issues under five headings.

2.6.1 User Acceptance

- Does the user understand the technology sufficiently well to be able to know what it can (and cannot) do?
- Is the user interface effective in allowing the user to make full use of the technology without needing an excessive amount of training?

2.6.2 Impact Analysis

- does the technology enable the user to undertake current tasks more effectively (in less time and with greater accuracy)?
- does the technology enable the user to undertake new tasks of operational benefit that were not previously possible?

2.6.3 Social Cost-Benefit Analysis

- to what extent does the technology improve passenger safety in public transport?
- to what extent does the technology improve the capacity of the transport system at peak times?

2.6.4 Economic Analysis

- is the technology affordable, both in terms of initial purchase and maintenance costs?
- is the technology widely available, with effective competition between suppliers?

2.6.5 Technical Analysis

- is the technology robust, in terms of maintaining a consistent level of performance in all operating environments?
- is the technology in need of or capable of further development to improve performance?
- is there a risk of obsolescence?

3 Approach

The approach followed in developing ADVISOR was as follows:

- Development of each capability by the partner with the most relevant expertise in the area.
- A deliberate decision was taken not to follow emerging standards (e.g. MPEG-7), to reduce the risk of the standards development limiting the progress of the project
- Keep each major software function separate and defined by an interface specification
- All control and data communications to use XML for ease of machine and person readability at the expense of use of more processor power.
- Use of a separate processor for each software element to minimise undesirable interactions
- Provide Open interfaces using CORBA to manage each element interconnected by sockets
- Progressively integrate the system at each stage (Test Bed 1 and 2, culminating in the Demonstrator)
- Minimise custom hardware development, to allow focus on the core problem
- Utilise software from existing sources to minimise the required effort (for example use of the Crowd monitor software developed by CROMATICA)
- Phase delivery to validation and evaluation, allowing the results to be fed into the design and implementation of the next stage.
- Separately demonstrate capabilities where integration proved to be infeasible.

In practice this approach was somewhat thwarted by events. Late deliveries from some partners meant that the project time scales became very compressed towards the end of the project, and some features needed to be omitted even with a three-month extension (see sections 6.2.3, 6.2.13, 6.2.15, and 6.2.17 below)

3.1 Comparison to alternative approaches

Other approaches were considered. For example, it was recognised that the demonstrator was very heavy and bulky, so a proposal to develop custom hardware was carefully considered. However this was rejected as the outcome would have been uncertain. In theory, this should have been nearer to a product, but processing requirements were not known at the time, and so any hardware development would have presented a high risk.

A tailored interconnection approach would have been more efficient in use of processing resources, but would not have been as flexible. It would not have been as scalable.

4 Project Results and Achievements

The project results are summarised in Table 1.

No.	Objective/Goal	Result/Achievement	Objective Met?
1	Improve the management of public transport networks through better exploitation of data from CCTV cameras	The demonstrator clearly showed the potential for ADVISOR to be used to monitor and record all camera outputs, only alerting operators when interesting events occur.	Yes
2	Demonstrate the benefits of computer vision for reducing the workload on metro staff who rely on CCTV surveillance to assist them in the management of the transport network	The demonstrator clearly showed the potential for ADVISOR to be used to monitor and record all camera outputs, only alerting operators when interesting events occur.	Yes
3	To develop new management services for the operators, based on CCTV surveillance	ADVISOR has developed the following new operator services: • Automatic detection of interesting behaviours • Complete archiving of all camera captured image sequences • Ability to randomly access, retrieve, annotate and replay image sequences	Yes
4	Demonstrate how a system such as ADVISOR should be specified and procured in the future	The ADVISOR test beds and demonstrator provided a vehicle for potential users to feedback comments on the suitability of the system. This information can be used to develop requirements for future product developments and system procurement	Yes
5	Computer-Assisted incident detection: ADVISOR will provide timely indication of anomalous events (e.g. crowds forming, flow of people stopped, entry into forbidden areas etc.) which require action from the operator in order to minimise disruption to the service	ADVISOR demonstrated detection of the following events: • Overcrowding • Blocking entry and exits • Fighting and aggression • Vandalism against equipment • Jumping over barriers (indicating people without tickets) The capabilities of an ADVISOR system are not limited to these events	Yes

No.	Objective/Goal	Result/Achievement	Objective Met?
		and others are also detected but not presented to the operator	
6	Post-incident analysis: Following a serious incident, there is need for post-incident analysis by specialists such as police or accident investigators. An efficient image retrieval system will be developed based on digital video coding technology.	The archive, search and retrieval facility is able to retrieve all images efficiently from hard disk drives using a VCR like control panel. Images can be individually stored as files for further analysis.	Yes
7	Quantitative analysis of behaviours: The availability of real-time, annotated digital video makes it possible to implement statistical analysis of events recorded during both normal and abnormal conditions. This analysis will provide a better understanding of the behaviours of individuals and crowds as they move through the network	Quantitative analysis was not actually part of a work package task, and no effort could be diverted to produce tools for such analysis. However, the system does record all the data required to perform such an analysis, in the content addressable Archive database.	No
8	Assessment and evaluation: ADVISOR will facilitate the specification, benchmarking, procurement and acceptance of computer-assisted CCTV surveillance systems by transport operators. This will be achieved by working closely with end users to: • incrementally develop a set of functional requirements; and • develop an assessment methodology for computer vision systems applied to surveillance.	End-user requirements capture was conducted by VIGITEC, and fed an evolving Functional Requirement specification.	Yes
9	Market acceptability: if ADVISOR is to be commercially successful, then it must be easy to use and capable of being easily re-configured and scaled for different sites. ADVISOR will be developed using open standards for distributed processing, image coding and transmission. This allows development to be independent of the particular size and configuration of the End-User systems. ADVISOR will include a Human Computer Interface (HCI) designed in consultation with the End Users.	The ADVISOR system has demonstrated the benefits of using scalable distributed processing. If more cameras need to be processed, then it is straightforward to add more processors. Open standards have been followed: JPEG, XML, CORBA, Ethernet Scalability is possible both ways: up and down.	Yes
10	Use of Baseline data • The CONVERGE project will provide guidelines on the validation of ADVISOR. • The INFOPOLIS project will provide guidelines for the development of the HCI, assisted by end-user feedback and experience gained in the PASSWORDS	The CONVERGE project provided guidelines on the Evaluation (not validation) of ADVISOR These projects were used to guide the development of the HCI.	Yes

No.	Objective/Goal	Result/Achievement	Objective Met?
	project. • The CROMATICA/PRISMATICA (King's College and then Kingston University) projects will provide the user needs analysis and the core algorithms for monitoring crowds based on optical flow measurements in real-time.	The crowd monitor used in ADVISOR was developed from the CROMATICA software	
11	Use of Baseline data (continued) The AVS-PV (INRIA, VIGITEC) project will provide the core algorithms for detection and analysis of anomalous events and the development of HCI for display of annotated video. The results of recent work at Reading University on tracking of people will be used as the basis for the tracking algorithms. Bull will provide expertise on digital video technology based on experience of recent product developments. Thales - TRT (UK) will provide expertise on the provision of digital video services based on experience of developing service level agreements with major public transport operators.	Input was taken from the AVS-PV project as the starting point for work on the vision algorithms and the HCI The Reading University work on people tracking was intended to be used within ADVISOR but was finished too late to be integrated Bull provided their expertise by supplying the archive, search and retrieval sub-system. TRT(UK) benefited from the support and experience of its operating company in the Transportation field.	Yes
12	Demonstration of computer vision techniques operating on compressed digital video inputs	The use of JPEG compression of quarter size images at only 5 frames per second was demonstrated to allow the vision processing algorithms to perform satisfactorily	Yes
13	Integration of the techniques via open interfaces	Standardised Open interfaces were used throughout the system for example: • Ethernet • TCP/IP, UDP • CORBA • XML • JPEG	Yes

No.	Objective/Goal	Result/Achievement	Objective Met?
14	Demonstration of high probability of detection of anomalous events with commensurate low false alarm rate	The system demonstrated an overall detection probability of 89% and a false alarm rate of 6.5%	Yes
15	Sustained recording of multiple video inputs in a format that allows efficient retrieval of data	The Archive demonstrated continuous recording of four camera inputs video and annotation data, and the ability to retrieve specific sequences based on behaviour annotations	Yes
16	Demonstration of improved performance in detection and recognition of anomalous events through learning via feed back from the operator	This was not fully achieved in the integrated system. However, the work that was done on Supervised Learning was presented. The behaviour recognition algorithms were tuned by using the results of the learning algorithm.	No
17	Quantifiable reduction in operator workload in terms of faster response to incidents and better management of CCTV resources	Although the analysis has not been performed, it is clear that in any Metro having a large number of cameras per operator, ADVISOR would offer a significant and quantifiable reduction in operator workload.	Yes
18	An increased awareness in the operators of the flow of people through their network	The flow rate of people is a primary measurement that the crowd monitoring module performs. This is presented by the system as an overcrowding alarm. As an enhancement, quantitative flow information, although not currently presented to the operator, could be suitably summarised and displayed.	Yes
19	Use of low cost, commercial technology	Use of standard PCs means that the advantages of cost reductions and capability increases can be exploited.	Yes
20	ADVISOR will be evaluated through two test beds, the results of which will be fed back into the design of the final demonstrator	Evaluations were conducted on test bed 1 and test bed 2. The results of the evaluations were used to make modifications to the design of the next stage	Yes
21	The first test bed will be laboratory based at Thales with input supplied by PRISMATICA, TMB and STIB as video sequences of relevant events from a variety of sources	Thales hosted a non-integrated series of capability demonstrations.	Yes
22	The second test bed will be designed for a site to be provided by TMB using input from a network of cameras. Synchronised recordings will be made to allow further laboratory	Owing to schedule delays, the test bed 2 was validated and evaluated at Thales Research & Technology Limited using recorded sequences	No

No.	Objective/Goal	Result/Achievement	Objective Met?
	evaluation	taken from TMB and STIB	
23	The demonstrator will be installed at a site to be provided by STIB where demonstrations using live input from a network of cameras will be used to test the robustness of the system over extended periods with no prior knowledge of, or constraints on, the events that might be seen.	The demonstrator was installed at TMB's Sagradra Familia station and the HCI remotely connected at the Sagrera dispatching centre. The system was installed for in excess of 2 weeks Installation at STIB was not feasible because the cameras had been replaced.	Yes
24	The end users associated with the project will be closely involved in the assessment and evaluation	Both TMB and STIB operators were involved in the intermediate (Test Bed 1 and Test Bed 2) and final (Demonstrator) evaluations	Yes
25	Following the guidelines given by CONVERGE for the evaluation of Transport Telematics projects, the assessment will address issues under five headings: • User Acceptance • Impact Analysis • Social Cost-Benefit Analysis • Economic Analysis • Technical Analysis	The evaluation plans and reports have followed the guidelines.	Yes

Table 1. Summary of project Results and Achievements with reference to Technical Annexe objectives.

4.1 Scientific/technological quality and innovation

Each sub-section below quotes key objectives given on the 'Innovation' section of the Contract Technical Annexe.

4.1.1 Video Archiving and Frame Annotation

'Archiving is already standard practice for Transport Operators but currently the archives are difficult to search as they are held on analogue video tapes. ADVISOR will solve this problem by:

storing video frames in digital compressed form on direct access storage devices (hard-disks) with accurate time-stamping and watermarking,

maintaining a frame annotation database tightly bound to the video frame database, and

providing efficient searching tools to retrieve appropriate frame sequences from a specific camera, at a particular time, and that contain specific events of interest. This will provide an enormous time saving, compared to manual search of traditional analogue video tape archive.'

4.1.1.1 How these objectives were met

These goals were met in results 6, 11 & 15 given in Table 1.

4.1.2 Person Tracking

'The ADVISOR person tracker will contain a detailed model of the scene geometry including the relative positions of the cameras, extending earlier work by Reading University on camera calibration and scene reconstruction from images. In the initial stages of each track, it will compile a simple 3D model of the shape and appearance of the person. With this information it will infer the 3D trajectory of the person, carry out handover, and use 3D reasoning to maintain tracking during partial occlusions. The ability to track a person automatically from one camera to another over a wide area will be a major scientific innovation in visual surveillance.'

4.1.2.1 How these objectives were met

These goals were partly met in result 15 given in Table 1. Handover of tracking from camera to camera was attempted, but as the Reading University Tracker was unavailable, and a less sophisticated type used, the handover facility was not found to be sufficiently reliable.

4.1.3 Behaviour Analysis

'ADVISOR will use a priori models of behaviour scenarios, allowing the detection of complex behaviours needed for the applications. The major innovation will be the use of the behaviour models combined with the geometric and semantic model of the site. This will allow the location of a detected person in 3D, even while the person is moving from the field of view of one camera to another. Extended, multi-camera scenarios will be considered, because the behaviour of a person can be analysed on the basis of his or her 3D motion through the site over an extended time.'

4.1.3.1 How these objectives were met

These goals were met in Results 5 & 17. A fully working and integrated Behaviour recognition module was demonstrated at the installation in Barcelona capable of recognising several types of behaviour (see Result 23). However, it did not take advantage of multiple cameras because the tracker algorithm over multiple cameras was not robust enough.

4.1.4 Supervised Learning of Behaviours

'Model based systems for inferring human behaviour from image sequences have been implemented by Y. Ivanov and A. Bobick (MIT), W.E.L. Grimson (MIT), Y. Yacoob and M.J. Black (University of Maryland and Xerox), and A. Pentland (MIT) among others. The innovation in ADVISOR will be the inclusion of feedback from a human operator who will supply his or her own classification of the observed behaviours. The system will use this information to refine the behaviour models and so reduce the number of false alarms.'

4.1.4.1 How these objectives were met

This objective was not fully achieved. However see Result 16 for a description of partial successes, and Sections 6.2.17 & 6.2.18 for more information.

4.1.5 First Integration of New Technologies

'ADVISOR will integrate for the first time the following three technologies in a single system:

tracking and behaviour recognition in image sequences;

communications networking; and

annotated image archiving.

In the ADVISOR system the image sequence processing will be monitored and directed from a central control room. The communications network will provide the essential links between the control room, the cameras and the image archive. The image annotation will be essential for recording the decisions and actions of the human operators and for efficient offline search of the archive.'

4.1.5.1 How these objectives were met

The demonstrator system installed in Barcelona met all three of these objectives fully – See Results 6, 9, 11, 15 & 23. The Human computer interface was sited 5km away from the site at which the cameras were installed and at which the video was processed – linked by a fibre LAN connection.

4.1.6 New Techniques for Transport Operators

'With the installation of the ADVISOR system transport operators, including members of the End User-group will be able to measure customer activity, detect criminal or hazardous actions, and maintain the image archives needed for efficient security and policing.'

4.1.6.1 How these objectives were met

Explicit measurement of customer activity was not attempted although the data to do so is actively recorded in the database. The detection of criminal or hazardous actions, and maintenance of the image archive was successfully demonstrated – See Results 5, 6, 9, 23 & 24.

4.1.7 Differences from previous work in the area

'ADVISOR will advance the state-of-the-art in the following important ways:

- adaptation of the existing algorithms to work with compressed digital video inputs
- extension of the algorithms to work with input from multiple cameras
- development of the algorithms to make them more robust, including 3-D modelling
- exploitation of the latest video workstation technology to achieve real-time operation
- use of the algorithms for annotating video sequences for efficient storage, search and retrieval
- improvement of the algorithms by providing learning feed-back from an operator
- encapsulation of the algorithms in a software "wrapper" to provide industry standard interfaces for ease of system integration'

4.1.7.1 How these objectives were met

All of the above objectives were fully achieved except for the 'learning from feedback' goal, which was discussed in Section 4.1.4.1, and 'input from multiple cameras', which became irrelevant when 'handover' was dropped (see Section 4.1.2.1), although the Capture, Motion Detector, Crowd Monitoring, Behaviour Recognition, Archive and HCI were multiple camera capable (see Result 15). Relevant Results include; 12 (compressed input), 11, 13 (Use of CORBA middleware), 19 (standard PCs but real time).

4.2 Community added value and contribution to EU policies

Each sub-section below quotes key objectives given on the 'Innovation' section of the Technical

Annexe.

4.2.1 Contribution to the implementation of the European Policy on Mobility

'ADVISOR will warn human operators when antisocial acts are detected or predicted, leading to more rapid and effective intervention by station staff or the police. This will reduce the occurrences of criminal or antisocial acts and increase passenger confidence and security, leading to greater use of the transportation system.

Passenger safety will be increased by the computer-assisted detection of hazardous situations, for example, overcrowding or entry by passengers into forbidden areas such as the track or the edge of the platform.'

4.2.1.1 How these objectives were met

The technical achievement of the recognition of anti-social acts and behaviours provides the basis for the improvement in mobility through their future implementation, and secondary beneficial effects on perception of safety and increased public transport usage.

4.2.2 European added-value by increasing the market size

'Although ADVISOR will primarily be addressing requirements of metro operators, the capabilities to be demonstrated will have wider applicability in a number of domains where managing the mobility of people is important. These domains include airport terminals, city centres and large sporting venues.

The open architecture of ADVISOR will facilitate competition between suppliers and give end users the greatest choice when selecting intelligent video surveillance equipment '

4.2.2.1 How these objectives were met

The ADVISOR system architecture has been consistently developed with the goal of installation in a wide variety of venues. See Results 9 & 13.

4.2.3 European added-value through co-operation

'The architecture for ADVISOR will be as open as possible, partly to allow installation at different sites with different communications infrastructures and partly to allow the inclusion of software developed by companies outside the project. This will increase the value of ADVISOR to end users.'

4.2.3.1 How these objectives were met

Thales is keen to develop the ADVISOR system architecture, so that it becomes an international standard for intelligent CCTV installation. These goals are reflected in the exploitation plans. The ADVISOR system architecture has been developed to allow easy installation of additional sensors through CORBA-based software wrappers. See Results 9 & 13.

4.3 Contribution to Community Social Objectives

4.3.1 Health

'ADVISOR will be able to detect the sudden collapse of a passenger, for example fainting, and alert a human operator who can contact the emergency services. This will increase the speed of response to the emergency, especially if the collapse occurs in an area remote from other passengers. '

4.3.2 Safety

'ADVISOR will detect hazardous situations, for example, overcrowding, especially in stairwells or on escalators, and passengers too close to the edge of the platform, on the track or in other forbidden areas. Violent crimes and attacks, including attacks on staff, will be discouraged by the knowledge that all areas are under intelligent surveillance, especially as the annotated data base can be searched off line to recover a record of the attack itself, and the movements of the attacker and the victim before and after the attack. The entire data base will be audited and secure, to ensure that the images have the greatest possible value as evidence in court.'

4.3.3 Employment

'ADVISOR will increase employment in the following ways.

- It will create new, specialised jobs, for example control room operators, software and hardware experts for the installation, maintenance and upgrading of the system.
- It will make it easier for members of the public to take up employment, by making their travel safer and quicker. In particular this includes employment which requires travel at antisocial hours or in inner city areas.
- Installation of ADVISOR could influence the economic balance of the transport company, making line extensions or new stations economically feasible. Studies have demonstrated that even a 2% or 3% increase in passenger numbers has enormous financial benefits, especially when no additional trains are needed. For example, the new passengers may to travel at times when network would otherwise be almost empty, having been discouraged previously by fears about their safety.'

4.3.3.1 How these objectives were met

By delivering all the functionalities described in the Technical Annexe, which are relevant to the above cases, and demonstrating them to several European Metro companies the possibility for a future deployment of ADVISOR to create these benefits, is facilitated.

4.4 Economic development and S&T prospects

4.4.1 Consortium exploitation plan

'From a commercial point of view, it is clear that any assistance provided to operators in order to reduce their workload has a very high value, especially in applications involving thousands of cameras. It has to be considered that from this point of view that there are no efficient products available on the market. Consequently, operators will be eager to obtain the additional help provided by an automated system, acting as an intelligent assistant.

At the end of the present project, functional efficiency and economical benefits will have been demonstrated to the metro operators. However, only a prototype system will have been constructed. Therefore, the following industrial strategy has been decided, starting from the end of the project: (Table deleted).'

4.4.1.1 How these objectives were met

During the course of the project a Dissemination and Use plan was produced and updated. The electronic Technological Implementation Plan document, submitted as a draft in November 2002, contains details of the exploitation plans of each ADVISOR partner. These plans are commercially sensitive, and therefore confidential. However, it is clear that all partners are keen to exploit the technologies developed and are actively seeking to exploit the system, through further collaborations with the ADVISOR partners, Framework 6 proposals and external commercial business development.

4.5 Relations and Synergies with other projects

Clustering activities have tended to be restricted to brief formal contacts. However, the ADVISOR Test Bed 1 event served as a forum to assist the projects in determining how they might co-operate better in the future, and to validate some common decisions made.

The following projects represent projects active in the domain of machine vision. The significant differentiator of ADVISOR is its ability to store and retrieve annotated images based on search criteria.

4.5.1 VISOR BASE

(Video Sensor Object Request Broker open Architecture for distributed Services)

VISOR BASE were invited to, and attended, Test Bed 1 hosted at Thales Research. A number of useful exchanges of information took place during that day including affirmation of choices made by both projects over the best version and use of CORBA. An ADVISOR partner was also invited to, and attended, VISOR BASE steering committee meetings in France.

4.5.2 PRISMATICA

(Pro-active Integrated Systems for Security Management by Technological, Institutional and Communication Assistance)

At an early stage of the project user-group and data sharing, between the two projects was, expected. However, a requested response from the EC Project Officers for the two projects to clarify or enforce such collaboration could not be obtained. In any case, differences between the two project's timings and goals and resource allocation made the sharing of end-user groups and video data impractical. ADVISOR members did however, attend some of the PRISMATICA Steering committee meetings. In addition, VIGITEC attended each of the annual PRISMATICA End-user Group meetings. Moreover, ADVISOR had a shared partner with PRISMATICA (Kingston University) who acted as a general liaison.

4.5.3 ADVISOR

The following project is significant in that it deals with the processes of annotation, archive and retrieval although the application is not strictly related to machine vision.

ADVISOR (IST-1999-10147, i.e. NOT the ADVISOR project which is the subject of this document)

(Advanced Digital Video Storage and On-line Retrieval system)

In this project video clip start/end/camera movement detection methods were developed to improve storage and retrieval, by semi-automatic annotation based on clip boundaries. No contact was made with this project.

4.6 Implications for standardisation initiatives

The project's approach towards standardisation was to build on existing standards. Relevant standards used were: -

- Baseline-JPEG (ISO/IEC 10918-1)
- CORBA
- XML version 1.0
- 10/100-BaseT Ethernet

MPEG-7 was considered for inclusion but as the standard was not due to be completed until half way through the project (July 2001). It was therefore considered safer to develop our own content-description using validated XML-schemas. It was the intention of the ADVISOR project to take standards based components and build these into the system specification and design. It was not the intention to write new standards.

XML schemas were validated using the W3 validator website:

http://www.w3.org/2000/09/webdata/xsv

5 Deliverables and other outputs

5.1 Project Deliverables

No.	Deliverable Name	Description	WP No.	Lead participant	Security[1]
D7.1	Demonstrator	This deliverable is the physical demonstrator and remains the property of Thales Research and Technology (UK). Individual software items within the demonstrator are the property of the ADVISOR partners who developed it.	7	TRT(UK)	Pub
R0.1	Project presentation	This is a brief overview of the project as predicted at the beginning.	0	TRT(UK)	Pub
R0.2	Project management plan	This defines mechanisms for control of the interfaces between partners, in particular for communication, reporting, reviews, risk management, configuration management, release and acceptance	0	TRT(UK)	Int
R1.1	Final end user requirements evaluation report	This report provides information about the problems which the project aims to solve through their technical development. It also presents how the End-users' requirements have been captured and how these have been evaluated	1	VIGITEC	Pub
R2.1	Report on calibration, scene modelling, motion detection and tracking for a single camera.	This report provides information about the implementation of algorithms for image processing and tracking for a single camera. It presents the following tools: Crowd monitoring, Single camera calibration, Camera scene construction tool, Motion detection, and tracking of people for a single camera	2	RU	Pub
R2.2	Report on calibration, scene modelling, tracking and adaptation to changes in light level	This is the report that provides information about the algorithms for image processing and tracking for multiple cameras. It covers: Calibration of multiple cameras	2	INRIA	Pub

[1] Int Internal circulation within project (and Commission Project Officer if requested)
Pub Public document

No.	Deliverable Name	Description	WP No.	Lead participant	Security[1]
	for multiple cameras.	observing the same scene, Scene models for multiple cameras, Multiple camera tracking and adaptation to changes: illumination and static objects handling			
R3.1	Single camera behaviour recognition	This report describes the recognition of behaviours for a single camera. It includes the identification, modelling and learning of basic events and behaviours. It describes how the long term history of individuals and groups are computed to infer behaviour properties and how the models of states, events and scenarios are implemented.	3	INRIA	Pub
R3.2	Advanced behaviour recognition	This report provides information about algorithms for the recognition of behaviours for multiple cameras. It includes behaviour recognition algorithms including long term history computation, and Temporal Scenarios, learning behaviours and image annotation	3	INRIA	Pub
R4.1	Archive Specifications	This report provides information about the implementation of algorithms for data archive processing, sequence retrieval processing, operator bookmarking and audit trail processing.	4	BULL	Pub
R5.1	Operator HCI specifications	This document describes how the Human Computer Interface is positioned within the overall ADVISOR architecture. It specifies what the HCI must do, how it can be integrated into an existing security system and how it must interact with the operator.	5	VIGITEC	Pub
R6.1	Report on video interchange, software interface and CROMATICA	A report providing details of the issues arising when specifying and procuring a video capture system and suitable software or middleware. It also discusses the various design choices considered when defining the system architecture taking into account scaleablity and modularity. Finally it describes the work undertaken in adapting and integrating CROMATICA software and	6	TRT(UK)	Int

No.	Deliverable Name	Description	WP No.	Lead participant	Security[1]
		hardware.			
R7.2	Report on Test bed 1 and Test bed 2	This is split into two volumes. The first describes the presentation and demonstrations made of test bed 1 progress. The second is the report of the validation of Test Bed 2. It includes the data used, the validation process employed, the results and an analysis of the results.	7	TRT(UK)	Pub
R7.3	Report on technical validation of demonstrator	This report describes the final validation of the demonstrator system. It includes the data used, the validation process employed, the results and an analysis of the results.	7	TRT(UK)	Pub
R8.1 R8.2	Evaluation Plan and First Evaluation report	This is the evaluation Plan and first evaluation report. It provides the plan (criteria and methodology) to evaluate the ADVISOR results at different stages of the project as well as the report of the first intermediate evaluation performed by the end users	8	VIGITEC	Pub
R8.3	Second Evaluation report	This is the second evaluation report for the ADVISOR project. It provides the second intermediate evaluation performed by the end-users associated with the project: STIB (metro of Brussels) and TMB (metro of Barcelona)	8	VIGITEC	Pub
R8.4	Final evaluation report	This is the Final Evaluation Report for the ADVISOR project. It provides the report of the final evaluation performed by the End-users according to the Evaluation Plan (Deliverable R8.1)	8	VIGITEC	Pub
R9.1	Dissemination and Use Plan	This describes the developing views of Consortium members and how they intend to publicise the work of the project in the first instance and how those partners who have the appropriate commercial infrastructure intend to take forward the work of the ADVISOR project and exploit the outcome commercially. The document is superceded by the eTIP (R9.2)	9	TRT(UK)	Int
R9.2	Technological	This describes the plans for, and the	9	TRT(UK)	Pub

No.	Deliverable Name	Description	WP No.	Lead participant	Security[1]
	implementation plan	achievements of the use and exploitation of the results of ADVISOR. It supersedes the Dissemination and use plan.			
R9.3	Final Report	This is the current document.	9	TRT(UK)	Pub

5.2 Other Outputs

Date	***Title***	***Number of persons attended + other information***
2nd May 2001 to 4th May 2001	Automatic Congestion Detection System for Underground Platforms. Authors: B. P. Lo and S. A. Velastin.	Presented at the "2001 International Symposium on Intelligent Multimedia, Video and Speech Processing" Kowloon Shangri-La, Hong Kong. Permission to present this paper was granted by the EC.
19/07/2001	Advisory Users Group meeting. Held at KCL	Presentation of ADVISOR project and discussions between ADVISOR and PRISMATICA.
4/09/2001	The Application of Colour Filtering to Real-Time Person Tracking	Reading University: N. Siebel and S. Maybank: Presentation of a poster. In Proceedings of the 2nd European Workshop on Advanced Video-Based Surveillance Systems (AVBS'2001), Kingston upon Thames, UK, pp. 227-234, September 2001.
4/09/2001	2nd European Workshop on Advanced Video-Based Surveillance Systems (AVBS'2001), Kingston upon Thames, UK, September 2001	F. Cupillard and F. Bremond Presentation of a paper: Tracking Groups of People for Video Surveillance.
October 2001	On the use of colour filtering in an integrated real-time people tracking system	Reading University: Book chapter `On the use of colour filtering in an integrated real-time people tracking system'. In P. Remagnino, G.A. Jones, N. Paragios and C. Regazzoni (eds.) Video Based Surveillance Systems: computer vision and distributed processing, pp. 167-175. Kluwer Academic Publishers.
December 2001.	Real time tracking of pedestrians and vehicles.	Reading University: N. T. Siebel & S. J. Maybank. Paper in Proc. 2nd IEEE International

Date	***Title***	***Number of persons attended + other information***
		Workshop on Performance Evaluation of Tracking and Surveillance (PETS2001), Hawaii, 9 December 2001. No paper version. ISBN 0-704914-40-9 (DVD).
4-8 February 2002	International Conference in Central Europe on Computer Graphics, Visualisation and Computer Vision WSCG'2002. Plzen, Czech Republic	F. Bremond: Presentation of an article: Human Behaviour Visualisation and Simulation for Automatic Video Understanding.
25-26 March 2002	3rd Sino-Franco Workshop on Multimedia and Web Technologies. INRIA Sophia, France	M. Thonnat and F. Bremond: tile of the presentation: Representation, Recognition and visualisation of Human Behaviours for Video Interpretation.
9-10 April 2002	Workshop on temporal reasoning at Pleumeur-Bodou, France	INRIA: T. Vu, F. Bremond and M. Thonnat: title of the presentation: Representation and Recognition of Human Behaviours for Video Interpretation.
2nd June 2002	PETS 2002 Journal paper 'Latitudinal and longitudinal process diversity'	Reading University: attendance at the workshops of `PETS'2002' Preparation and submission of an article to the Journal 'Software Maintenance and Evolution', special issue on Process Diversity in Software Maintenance and Evolution. Title of paper: Latitudinal and longitudinal process diversity.
24th May 2002 to 4th June 2002	CVPR2002 `Fusion of Multiple Tracking Algorithms for Robust People Tracking'	Reading University: preparation of a poster for the presentation `Fusion of Multiple Tracking Algorithms for Robust People Tracking' at CVPR2002. Presentation of the poster at the conference.
24-25 September 2002	Seminars	Presentation of the Reading work on ADVISOR in seminars at the University of Hamburg (24th) and the University of Kiel (25th).
2002	ECCV2002 Fusion of multiple tracking algorithms for robust people tracking.	Reading University: Paper in, Proc. 7th European Conference on Computer Vision, ECCV 2002, vol. IV, pp. 373-387, ISBN 3-540-43748-7.
21- 26 July 2002.	*European Conference on Artificial Intelligence ECAI'2002*	INRIA : presentation of an article : T. Vu, F. Brémond and M. Thonnat, Temporal Constraints for Video Interpretation, In the proceeding of the *15-th European Conference on Artificial Intelligence (ECAI'2002)*, *W9: Modelling and Solving Problems with Constraints*, Lyon, France, 21-26 July 2002.
16-18 September 2002	*Conference on Knowledge-Based Intelligent Information & Engineering Systems* (KES'2002)	INRIA: presentation of the article : T. Vu, F. Brémond and M. Thonnat, Video surveillance: human behaviour representation and on-line recognition, *The Sixth International Conference*

Date	Title	Number of persons attended + other information
		on Knowledge-Based Intelligent Information & Engineering Systems (KES'2002), Podere d'Ombriano, Crema, Italy, 16, 17 & 18 September 2002.
3-4 December 2002	*Workshop on Applications of Computer Vision*, Orlando USA	INRIA: presentation of the article : F. Cupillard, F. Brémond and M. Thonnat, Group Behaviour Recognition With Multiple Cameras, In *IEEE Proc. of the Workshop on Applications of Computer Vision*, Orlando USA, Dec 3,4 2002.
26 February 2003	*IEE Symposium - Intelligent Distributed Surveillance Systems (IDSS)*, London, UK	S. Velastin organised and chaired this event. F. Brémond made an oral presentation of the article: Behaviour Recognition for Individuals, Groups of people and Crowd and made a poster presentation of the article: Reference Image for a Visual Surveillance Platform. M. Valera (KU) presented article: "An Approach for Designing a Real-Time Intelligent Distributed Surveillance System". B. Lo (KU) presented article: "An Intelligent Distributed Surveillance System For Public Transport". S Velastin was interviewed by TF-3.
1-3 April 2003	*3rd International Conference on Computer Vision Systems ICVS 2003,* Graz, Austria.	T. Vu made an oral presentation of the article: Automatic Video Interpretation: A linear method for temporal scenario recognition.
1-3 April 2003	*3rd International Conference on Computer Vision Systems ICVS 2003*, Graz, Austria.	N. Moenne Loccoz made a poster presentation of the article: Recurrent Bayesian Network for the Recognition of Human Behaviours from Video.
2003	Ph.D. Thesis. 'Design and Implementation of People Tracking Algorithms for Visual Surveillance Applications'.	Awarded to N. T. Siebel. School of Systems Engineering, The University of Reading, UK.
March 2003	SECURA Exhibition, held in Brussels and dealing with safety and security equipment and services	VIGITEC participated as an exhibitor at SECURA in Brussels and dealing with safety and security equipment and services. ADVISOR documentation was made available and discussed.
11th March 2003	Thales Digital Video Symposium – Chateau Les Mesnuls, France.	ADVISOR presented by G. Stott of TRT to audience of 70 Thales workers in the field of video processing.
14 May 2003	Thales Research and Technology Workshop	M Naylor presented: "Experiences with XML in the ADVISOR Project" to a group of Thales UK software engineers and managers.
May 2003	InfoPol Exhibition, held in Kortrijk (B)	VIGITEC participated as an exhibitor at InfoPol, dealing with equipment and services for law enforcement. ADVISOR documentation was made available and discussed.

5.3 Articles Published , Press coverage, development web sites, etc.

Date and Type	***Details***
March 2000, CORDIS Project Summary	Summary of Test Bed 1 & 2 and Demonstrator with details of functionality.
December 2000, Press Article (Internet)	Press Article in Forbes Magazine (USA). Article title "Who (Gonna) Dunnit", by Michael Katz. A fairly lightweight description with some minor inaccuracies about the programme. Some sensational extrapolations at the end. http://www.forbes.com/premium/archives/purchase.jhtml?storyURL=/forbes/2000/1211/6615216a.html&_requestid=137
December 2000, Press article.	Article in Metro Magazine (UK). Metro is free to users of the London Underground. The article is one paragraph.
December 2000, Press Article.	Press Article in Computer weekly. One paragraph plus picture of a surveillance camera.
August 2001. Press Article.	Article on advanced video surveillance in the Belgian national newspaper "De Morgen" (in Dutch language) where ADVISOR partners, past and current activities, are described.
August 2001. Press Article.	Article on advanced video surveillance in the Belgian national newspaper "La Meuse" (in French) where ADVISOR partners, past and current activities, are described.
August 2001, Press Article.	The Advisor project was referred to in the following magazine article. S.J. Maybank 2001 A thousand eyes are watching. SecurityOz, issue 12, July/August 2001, pp 102-103.
September 2001. Workshop Paper.	INRIA scientific paper on Detection and Tracking of Groups of People has been accepted by the 2nd European Workshop on Advanced Video Based Surveillance.
September 2001. Press article	An article on advanced video surveillance in "l'expresso" (in Italian language) cited ADVISOR and described ADVISOR activities.
October 2001. Television	VIGITEC: Visit of people from Belgian Television to VIGITEC to explore possible co-operation and participation to a TV programme
31 October 2001. Press briefing	Reading University: S.J. Maybank took part in a Press Briefing on Visual Surveillance, held at the New York Academy of Sciences (NYAS), and organised by the NYAS and IEEE Spectrum magazine. The Press Briefing was summarised in the IEEE newsletter `The Institute', January 2002, vol. 26, no. 1. See also: http://www.nyas.org/scitech/sum/mtg_01_1031.html
January 2002. Television programme	INRIA: Generation of MPEG videos for Belgian television sent to VIGITEC
February 2002. Conference paper	INRIA: T. Vu, F. Bremond and M. Thonnat: Presentation of an article at the International Conference in Central Europe on Computer Graphics, Visualisation and Computer Vision WSCG'2002

Date and Type	***Details***
Journal paper.	Reading University: An article accepted by the Journal 'Software Maintenance and Evolution' (vol. 15, pp. 9-25, 2003). This paper describes part of the work carried out at Reading on the ADVISOR project.
21- 26 July 2002. Conference Paper	INRIA : presentation of an article : T. Vu, F. Brémond and M. Thonnat, Temporal Constraints for Video Interpretation, In the proceeding of the *15-th European Conference on Artificial Intelligence (ECAI'2002)*, *W9: Modelling and Solving Problems with Constraints*, Lyon, France, 21-26 July 2002.
16-18 September 2002 Conference Paper	INRIA: T. Vu, F. Brémond and M. Thonnat, Video surveillance: human behaviour representation and on-line recognition, *The Sixth International Conference on Knowledge-Based Intelligent Information & Engineering Systems* (KES'2002), Podere d'Ombriano Crema Italy, 16, 17 & 18 September 2002.
3-4 December 2002 Workshop paper	INRIA: F. Cupillard, F. Brémond and M. Thonnat, Group Behaviour Recognition With Multiple Cameras, In *IEEE Proc. of the Workshop on Applications of Computer Vision*, Orlando USA, Dec 3,4 2002.
26 February 2003 Workshop paper	INRIA: F. Cupillard, F. Brémond and M. Thonnat, Behaviour Recognition for Individuals, Groups of people and Crowd for *Distributed Surveillance Systems (IDSS)*, London, UK.
26 February 2003 Workshop paper	INRIA: F. Tornieri, F. Brémond and M. Thonnat, Reference Image for a Visual Surveillance Platform, In *Distributed Surveillance Systems (IDSS)*, London, UK.
26 February 2003 Workshop paper	KU: M Valera, S. Velastin: " An Approach for Designing a Real-Time Intelligent Distributed Surveillance System", In *Distributed Surveillance Systems (IDSS)*, London, UK.
26 February 2003 Workshop paper	KU: Benny Lo, Sergio A Velastin, Maria Alicia Vicencio-Silva and Jie Sun: "An Intelligent Distributed Surveillance System For Public Transport", In *Distributed Surveillance Systems (IDSS)*, London, UK.
1-3 April 2003 Conference paper	INRIA: T. Vu, F. Brémond and M. Thonnat, Automatic Video Interpretation: A linear method for temporal scenario recognition, for the *3rd International Conference on Computer Vision Systems ICVS 2003,* Graz, Austria.
1-3 April 2003 Conference paper	INRIA: N. Moenne Loccoz, F. Brémond and M. Thonnat, Recurrent Bayesian Network for the Recognition of Human Behaviors from Video, for the *3rd International Conference on Computer Vision Systems ICVS 2003,* Graz, Austria.
9-15 Aug 2003: Conference paper	INRIA: T. Vu, F. Brémond and M. Thonnat, Automatic Video Interpretation : A novel algorithm for temporal scenario recognition for *the International Joint Conference on Artificial Intelligence 2003,* Acapulco, Mexico.

Date and Type	***Details***
9-11 March 2003: Filming of a documentary video	A documentary (lasting 11.5 min) was shot during the evaluation of the ADVISOR system at Barcelona. A DVD is available from INRIA or Thales. The video is also available at the web site: `http://www.inria.fr/multimedia/Videotheque-fra.html`

6 Project Management and co-ordination aspects

6.1 Performance of the consortium

In general the consortium performed well. All Steering committee meetings and Technical meetings were well attended. A healthy debate was held on all issues and generally resulted in a satisfactory outcome.

There were some staffing problems, particularly at Reading University and Bull. The problem at Reading prevented the people tracker from being integrated into the system. The problems at Bull were resolved and caused little damage to the project.

Communication was hampered to some extent by language difficulties at the working level. However, patience helped to resolve these, much to the credit of those involved. Email was found to be an excellent means of communication, with the telephone being used only when very interactive discussions were required.

Consortium members were always willing to travel, to help resolve integration problems. Towards the end of the project, the whole consortium made a great effort to bring the project to a successful conclusion, culminating in a successful evaluation, validation, demonstration and final review in Barcelona.

6.2 Problems encountered and solved

This section describes the main problems that were encountered during the project and how they were solved.

6.2.1 TAO CORBA Audio-Video (AV) Streaming Service

Serious limitations and bugs were found with the AV-streaming service of TAO CORBA. These led to its eventual replacement with Sockets. The same problem was found by the IST VISORBase project.

6.2.2 Integration of Software developed for LINUX

Much of the vision processing software was developed in a LINUX environment. There were many problems with porting this to Windows 2000. Amongst these were differences with libraries, compilers, and memory management. The net effect of this was that source code developed on Windows would often not compile and would then crash when installed in the system.

This problem was largely, but not completely, solved by a trial build and test of the software using a Windows machine prior to each delivery.

Compilation of the Reading People Tracker under Windows was achieved. Linking and running were not achieved.

6.2.3 People Tracker

The people tracker developed by the University of Reading suffered delays due to the lack of resources. This caused it to be excluded from the test bed 2 integrated system. INRIA substituted a blob tracker that they had developed, and this, although not as sophisticated, proved to be adequate for the behaviour recognition algorithms.

This decision was a one way path, and the People Tracker was never integrated into the demonstrator. However the completed work was reported in a PhD thesis by Nils Siebel. The

source code for the People Tracker is publicly available at
http://www.cvg.cs.rdg.ac.uk/~nts/PeopleTracker

6.2.4 XML parser in HCI

The HCI was developed using Microsoft Visual Basic. Although an XML parser was available for this, it proved to be too slow to process the XML in real time. A decision was taken to produce a customised parser, specifically for the task, and this performed well. At the time there was an apparent threat to the project schedule because of this problem, but it turned out that other software was on the critical path.

6.2.5 Performance Issues with Test Bed 2

Test bed 2 exhibited performance problems with more than two cameras. This limited the scope of validation and evaluation that could be performed at that stage. The problems were resolved before the demonstrator by speed optimisation of the motion detection and behaviour recognition software, and upgrading the Athlon processors from 1.2 GHz to 1.8 GHz.

6.2.6 Archive trace files

Trace files created by the archive were not removed by the database purge, and slowly caused the hard disks to fill without warnings. This caused the archive performance to degrade slowly. The problem was resolved temporarily by deleting the files, and permanently by suppressing the creation of the trace files.

6.2.7 Sequence Data Collection

In order to develop the behaviour recognition algorithms, and ultimately to demonstrate the system, it was necessary to capture a large number of example behaviours. Not surprisingly, the metro operators did not have enough archive material for this to be used. In any event, the archives were from various stations, and a scene model would have been needed for each example. This was not feasible.

The problem was solved by using actors to reproduce the required behaviours in different ways and different places. For safety reasons, this could only be done at night, after the stations had closed, and so lacked the normal background.

6.2.8 Demonstration data collection: sequence digitisation, morphing sequences

The data that had been captured from acted sequences was recorded at different times, and because of this, there were differences in the required background files. This is an unusual situation for the system, and for the system to function correctly, the sequences had to be concatenated by “morphing” them into each other.

6.2.9 Configuration control

During the development of test bed 2, it was difficult to separate bug fix releases from those that were intended to add functionality, because the algorithm development was attempting to advance the functionality, yet the integration was attempting to establish a fixed baseline to enable validation and evaluation. These were often in conflict. This was only solved at the demonstrator releases, when the functions were completed.

6.2.10 Demonstration requirements definition

The ADVISOR system had been specified as a four camera input system and had been developed as such. However the requirements for the demonstrator had not been fully

considered. In order to demonstrate the system, a mixture of "live" camera data, and recorded sequences was needed. This necessitated a change to the capture and playback software to enable these to be mixed. Additionally the HCI was required to demonstrate automatic switching from live images to images displaying alarm data.

This problem was solved by re-writing the ADVISOR Playback tool to allow input of up to four cameras plus four sequences played back from hard disk drive. A new disk (73 GB) was purchased to support the demonstration requirements.

6.2.11 STIB camera changes

Following recording of many sequences at STIB Brussels Yser station, the cameras were changed. It was infeasible to perform demonstrations there without repeating much of the work. It was therefore decided to limit the demonstrations to TMB Barcelona.

6.2.12 Late delivery of software to test bed 2

Test bed 2 became a moving milestone, mainly because of lateness of the software deliveries. An attempt was made to stop this by applying a "guillotine" in September 2002. This had limited success, as the system did not work well enough to validate properly and to evaluate at all. Therefore, it was decided to allow some further controlled updates to allow these tasks to be performed.

6.2.13 Multiple camera tracking algorithm

The multiple camera tracking algorithm performs the fusion of tracking data coming from several cameras then tries to obtain coherent and global tracks of people. Although it has been shown to be feasible, it was not able to be integrated. The main reason was that the cameras were spaced too far apart for the image resolution of ADVISOR. The tracking algorithm was not robust enough with distant objects to allow this to be demonstrated.

6.2.14 Budget redistribution

A consequence of some of the technical and staffing problems experienced during the early years of the project was that Thales and INRIA needed to spend more than the allowed budget to ensure satisfactory project completion. Other partners were under spent. This problem was resolved by carefully planning the remainder of the work, and requesting a re-apportionment of the EC budget. This was granted by the Project Officer. Although Thales and INRIA still had to contribute additional funds to the project, this approach helped significantly.

6.2.15 Watermarking

We did not implement watermarking techniques in ADVISOR because the available technologies were not able to add watermarks in the image quickly enough. We planned to add watermarks at the level of the Capture PC that digitises 4 cameras at 5 frames/second, meaning a total of 20 frames/second. In the state of the art, the watermarking technologies need at least 100milliseconds to process 1 frame, allowing only 10 frames/second to be watermarked. So the state of the art technology was not sufficient. Two possible solution approaches were envisaged: to increase the PC speed or to develop and optimize our own watermarking algorithm. Due to Bull staffing problems, neither of these two solutions could be undertaken.

6.2.16 Using recorded video to allow system evaluation and presentation

The ADVISOR demonstrator has been tested by feeding it with 4 live video cameras. This configuration was not shown during the demonstration because of the low probability of alarms being generated during the actual presentations. The behaviours of interest occur infrequently in the metro and to demonstrate alarm detection with a reasonable chance of picking-up an incident

during a demonstration the ADVISOR system would have to be installed on all the 800 cameras or so available in Barcelona metro. This was clearly not possible during ADVISOR project. During the final review the ADVISOR system was run with 7 video inputs (4 from live cameras and 3 from recorders showing events or behaviours of interest). The motion detection module and the behavior recognition module were actively processing 1 live camera input and 3 recorded inputs among the 7 inputs. The remaining three were digitised and multi-cast to the HCI, to allow automatic switching between cameras (when an alarm occurs) to be shown.

6.2.17 System learning by operator interaction

In ADVISOR it was planned for the human operators to have the possibility to give a feedback to the ADVISOR system in order to tune and to improve performance. For example, learning could have been used to decrease the crowd size threshold at which to alert operators to overcrowding behaviour.

To implement such feedback, the ADVISOR system needed to be fully integrated and working. However, this was completed at a late stage of the project. After the ADVISOR system was integrated, a CORBA/XML links from the HCI to the behaviour recognition module was scheduled to be added, which implied a change of the ADVISOR architecture. Unfortunately, we did not have enough time to realise this work.

6.2.18 Learning of events/behaviours

Two works on events/behaviours learning have been realised in ADVISOR. A first work has been done by INRIA to learn fighting behaviour using a Bayesian network in a pre-processing stage. This work has been published at the International Conference on Vision Systems (ICVS03), has been reported in ADVISOR deliverable R3.2 and has been demonstrated at the ADVISOR annual review in September 2002. This work was successful and we used the analysis performed during the learning stage to tune parameters of the behaviour recognition for the ADVISOR demonstrator, to recognise fighting behaviour. The second work has been done by Kingston University to learn crowd dynamics using CROMATICA output and has also been reported in ADVISOR deliverable R3.2 and demonstrated at the ADVISOR final review. Due to staffing problems at Reading, who should perform some work on behaviour learning, Kingston agreed to start some work on behaviour learning but at a later stage (July 2002). Thus there was not time enough to use the work of Kingston to improve the performance of the ADVISOR demonstrator.

7 Outlook: Benefits and Exploitation Plans

This section provides an overview of each partners assessment of the benefits obtained from the project and its future plans for exploiting these benefits. Further details are provided in the Technological Implementation Plan.

7.1 Thales Research & Technology Ltd

7.1.1 Benefits

ADVISOR has provided TRT(UK) with the opportunity to integrate a demonstrator of a state of the art vision processing system. This system, although a research demonstrator, has the potential to be developed into a product in the next few years. Thales intends to demonstrate the ADVISOR system to all interested parties with a view to further development taking place.

Thales has also learned lessons from managing such an international project and from the technology created by the project.

7.1.2 Achievements & Exploitation

Thales' three main achievements were:

7.1.2.1 Development of Software wrappers and a Generic System Design

A key problem in managing large software-based EC consortia is the integration of software modules, developed under a variety of operating system environments, and non-standard libraries, at different partner sites. A system design specification was generated at Thales that defines an interface, which 'wraps' software running in each module. Within this wrapper layer TAO CORBA then acts as broker between requests from one software module or object, and all others connected to the same ORB. The 'wrapper' layer adds a standardised interface specification, which allows current and future applications to link to each other with well defined I/O pathways. In this way, software developers are able to produce software which can exchange data freely with other software modules.

This architecture facilitates the ability to 'Plug-in' 'best of breed' algorithms. ADVISOR used its own defined XML Schemas to pass and store scene content descriptions, as MPEG-7 was awaiting approval. MPEG-7 is now accepted, and future development will use it. The wrapper layer provides an interface that defines precisely the outputs and inputs that any module will send or can receive. Improved versions of existing sensors, or completely new sensors can therefore be added with minimal additional effort. Only the core of the alarm-handling component needs updating. The experiences of the project provide a firm base for future development of large-scale systems and standards-based video content description.

7.1.2.2 Exploitation of COTS PC hardware

ADVISOR started with the premise that commercial off the shelf PC hardware could be used to support real-time video processing, by networking separate PCs to provide the necessary computational power to support multiple camera processing. TRT(UK) has demonstrated the feasibility of this approach, with a low numbers of cameras (<5).

7.1.2.3 Camera Calibration

3D computer vision with monocular cameras requires the derivation of the precise transformation from a camera's local co-ordinate system to a world co-ordinate system of the scene viewed by the camera. Using this transformation, objects identified in the 2D image plane can be located with respect to the world co-ordinate system – this allows, for example, the position of people on

the ground surface to be estimated. Recovering this transformation typically requires a large set of correspondence points (2D image co-ordinates coupled to 3D scene co-ordinates). An efficient Tool for deriving the required correspondence points was created using a modified version of scene models used in behaviour recognition. These scene models describe the type and position of objects viewed by one or more cameras, in 3D world co-ordinate system. By presenting a scene model as a wire frame model overlaid on a typical image from a specific camera, the user of the tool, has first to approximately align the model and the scene using simple slider controls which modify the rotation and translation parameters of the camera model. When the wire-frame model is approximately correctly overlaid, the user simply clicks on model 2D vertices and drags and drops a tie-line that indicates the correct position for that point in the scene. The tool extracts the necessary correspondence pairs and solves the transformation. The tool allows both implicit (simple linear transformation model) and explicit (parameterised transformation with lens distortion coefficients) camera models to be built. The process of calibrating a camera (around 100 point pairs) can be completed in under 15 minutes.

The camera calibration algorithms and tools are being exploited for other vision processing projects.

7.2 INRIA

7.2.1 Benefits and Achievements

7.2.1.1 Building an operational system processing from pixel level up to the recognition of behaviours.

This system has a semi-automatic set-up. A configuration file is defined for each camera. This file contains the 3D scene model specifying the zones of interest and the calibration of the camera. Although there are still improvements to be made to ease the set-up process, the ADVISOR system was still able to successfully configure five cameras from both Brussels and Barcelona metros.

7.2.1.2 A working Behaviour recognition Module

The efficacy of the behaviour recognition module was shown. The behaviour recognition module has been demonstrated and evaluated on four long videos (each lasting over seven hours) containing interesting and normal behaviours. It has also been demonstrated on one live video at a Barcelona metro station. The behaviour recognition module has a high rate of correct recognition (89%) on the recorded sequences. The behaviour recognition module managed to recognise 25 blocking behaviours out of 27, 30 fighting behaviours out of 35, 7 jumping over barrier behaviours out of 8, 4 vandalism behaviours out of 4 and 2 overcrowding behaviours out of 2. The behaviour recognition module has low rate of false alarms (6,5%) on the recorded sequences. There were 0 false alarm for blocking, vandalism and overcrowding behaviour, 1 false alarm for jumping over barrier behaviour and 4 false alarms for fighting behaviour.

There are limitations due to the inability to model all aspects of human behaviour (e.g. the description of accurate gestures is not yet formalised), the position of cameras (e.g. activity only partly in the field of view of the cameras may not be detected) and tracking errors (e.g. tracking an individual in a crowd is still an open issue).

7.2.1.3 Use of Artificial Intelligent techniques in a real-time system

Artificial Intelligence techniques were developed to operate within an operational real time system. The knowledge-based formalism defined in ADVISOR has eased the process of extracting a machine usable description of interesting behaviours from definitions given by security experts.

The learning techniques used in ADVISOR comprised methods to tune parameters of complex

modules. In particular, these techniques were needed for the behaviour recognition module because of the large numbers of parameters and the large variety of behaviour instances.

7.3 Vigitec

7.3.1 Benefits & Achievements

7.3.1.1 Knowledge Gained

VIGITEC benefits from the project through the knowledge gained about:

- public transport companies (especially metros) point of view on various safety and security issues (problems encountered, current way of management, perception, policy, etc.)
- how to adequately transform metro company's requirements first into specifications and second, into daily operators operational tools that would be very well accepted
- some new ergonomic rules of design for Human Computer Interfaces
- new programming methods (modularity, interconnectivity, multi-languages, etc.)
- XML programming
- current state-of-the-art in behaviour recognition

7.3.1.2 Experience

VIGITEC benefits from the project through the experience acquired about:

- optimised software decompression of images
- programming multilingual versions of an application
- interactive communication with database
- required processing power to achieve such a type of intelligent detection, recognition, storage and exploitation
- the way to translate technical results into visible outcomes to the users (wording of understandable messages, overlays and other sort of information)

7.3.2 Exploitation

VIGITEC, as a commercial company, will exploit the project results in:

- developing efficient further marketing activities towards public transport
- influencing strategic decisions on further company's software development
- improving quality and efficiency of company's software development, especially for what concerns Human Computer Interfaces and image recording
- including ideas, concepts and some code into a new company's starting software development programme called ITeo ®, and related to video surveillance of public places (wherein public transport).

7.4 Bull

7.4.1 Benefits & Achievements

The main difficulties in the implementation of the Archive subsystem reside in the large number of objects, associated with a large volume of data, that are to be stored, and in the real-time constraints that are to be met during the indexation process. Although designed with larger configurations in mind, the Archive implementation is tailored to fit the final Demonstrator requirements (to support four simultaneous streams of five images per second each). For performance reasons, raw data (the digital images coming from the four cameras and generated by the Capture module, and their associated annotations issued by the Behaviour Recognition module) are not stored directly in the relational database. Instead they are stored in file system directory structures, optimised to facilitate their efficient streaming to remote Human Computer Interface modules.

To implement the retrieval facility offered to remote operators, relevant information is extracted on the fly both from the image header (spatio-temporal data such as camera location, date and time) and from the associated annotation (semantic data such as alarm type). This information is then used as keys in the indexation process to build the relational database that is used for retrieval operations.

Another functionality of the Archive module is the dialogue with one or several remote HCI modules.

Each HCI may issue requests to retrieve "interesting" video sequences based on a combination of spatio-temporal and semantic criteria. Once selected, up to four video sequences are sent, with their associated annotations, to the HCI in forward or backward streaming mode and at various image rates under the remote operator's control. A specific dialogue protocol has been designed to support operators' requests and these VCR-like operations. XML structured formats have been chosen to code the data exchanged with the Behaviour Recognition module (annotations) and with the HCI module (operator's requests, bookmarks, and VCR controls).

The Archive module has been successfully demonstrated via the HCI PC during the final ADVISOR project evaluation, validation and demonstration sessions in Barcelona. The search and retrieval functionality was found to work as specified, through the controls provided on the HCI.

However, it appears that to support larger configurations, several optimisations have to be explored to extend the global I/O throughput and the capacity of the storage subsystem. In its current configuration, the Archive uses standard SCSI hard disks, the use of external dedicated storage subsystems using RAID technology should be considered to improve its overall performance. It might be also a good idea to use a database organisation that allows isolation of the indexation process from the search and retrieval process.

Another way to improve the performance of the Archive that could be further explored, is to avoid storing images that do not contain interesting information.

7.4.2 Exploitation

For a commercial product, more sophisticated manual or automatic content management tools must be developed to comply with the legislation of the different countries where the ADVISOR system will be installed.

Another issue to be addressed in a commercial product is the addition of a watermark in the images in order to prove their integrity when video sequences are used as evidence in court. A paper study shows that the main problem is the demanding processing time of the watermarking algorithms, which implies a special effort of software optimisation or the use of dedicated hardware.

7.5 Kingston University

7.5.1 Crowd Monitoring Module

Before the ADVISOR project started, Kings College London had developed (as part of the EU-CROMATICA project) a crowd monitoring sub-system to detect situations of interest in underground stations such as overcrowding, congestion, stationary objects, intrusion and counter-flow. The system used a specially-developed hardware consisting of a PC, a frame grabber and a specialised board that was used for fast (up to 25 frames/second) calculation of image motion vectors (optical flow) based on a chip originally designed as part of an MPEG-2 encoder. The frame grabber captured images passing them to both the PC and the motion estimation board. The motion vectors were then sent to the PC where substantial additional processing took place (e.g. filtering, background estimation, region merging, etc.) to display the results on through a dedicated user interface. The system was limited to processing a single video source. For ADVISOR, it was decided that such a system was not sufficiently scalable for an ADVISOR system that had to handle many cameras at the same time and where the image capture process occurred remotely. Moreover, the specialised MPEG-2 chip had been taken out of production. Therefore it was decided to completely re-implement the system on a general-purpose DSP (Digital Signal Processor) card so that each card can handle one or more video sources with minimal PC host intervention (except for communication with the rest of the ADVISOR system). The card chosen was the Sollatek's STM-1300, based on a Philips TriMedia Video DSP. Each card runs software known as a "Crowd Monitoring Module" (CMM). A PC can have typically five such cards and tests were conducted at the end of the project with a PC hosting ten CMMs. This demonstrated scalability. All the software and hardware previously available from CROMATICA had to be totally re-designed (e.g. motion vectors are now calculated by software on the DSP board as well as all of the subsequent image processing). Software was also written to interface to the networking architecture of the ADVISOR system. The module was then incorporated into the complete system and shown to work well with recorded and live data (the latter shown in the final demonstrator in Barcelona). Finally, some design concepts developed in the project were harmonised with those developed as part of the concurrent EU project PRISMATICA so as to minimise undesirable divergence. For example, PRISMATICA also used a networking approach based on CORBA and a version of the CMM was derived to integrate it as part of a PRISMATICA system.

7.5.2 Learning Methods

Visual Surveillance data in general and ADVISOR data in particular capture events occurring in public spaces. More specifically, metro areas witness events which are recurrent in such domain: train passengers populate metro platforms, get on and off trains, then stand, sit or walk about waiting for the next train to arrive on the platform. The nature of the data lends itself very well to data mining techniques. Information can indeed be extracted from those data and analysed to infer patterns of typical motion.

A preliminary study on how to extract patterns and create models was conducted during the last year of life of the ADVISOR project. Two techniques were proposed. The first technique studies the main directions of motion of crowd moving on a metro platform. It builds a histogram of orientations and identifies the main orientations corresponding to the maxima of the built histogram. The second technique creates a spatial-temporal model of the dynamics of a metro scene. The model is built on the basis of the output generated by the motion detection algorithm (MDA). The MDA extracts regions of detected motion and an accumulator is used to keep track of the amount of motion over time in the entire field of view of the camera filming the scene. The accumulator is then used to calculate an estimate of the probability density function (PDF) of motion in the field of view (FOV). A mixture of Gaussian components (EM) then approximates the PDF. Such components can be employed to assign semantic labels to the various regions of the

camera FOV. In addition, the EM can be employed to estimate the main trends of motion in the scene by keeping track of transitions of crowd from between regions.

7.6 University of Reading

The project has resulted in a fully working version of the Reading People Tracker running on the Linux operating system. The tracker is in a good state for commercial exploitation. The source code for the tracker is publicly available on the University web site:

http://www.cvg.cs.rdg.ac.uk/~nts/PeopleTracking/

The tracker will be used in future research projects in CCTV surveillance.

The Reading People Tracker is fully described in Nils Siebles' PhD thesis available at http://www.cvg.cs.rdg.ac.uk/~nts/#publications.

8 Conclusions

The ADVISOR project was formulated to bring together the disciplines of leading edge machine vision algorithm development and practical implementation of real time systems. In this respect, ADVISOR has represented a very significant step along the road from laboratory techniques to commercial product development. This transition has not been without its problems, but in general these have been solved, except where such problems were of a fundamental nature and would have required major changes to the system design. Where work could not be integrated into the system, it has been separately demonstrated and documented, so that it will be possible to integrate it in a future development. The people tracker and supervised learning algorithms are examples of this.

The work that has been performed represents the current state of the art in machine vision technology for behaviour recognition of individuals, groups and crowds. The ADVISOR system addresses a market segment where there is an obvious and growing need for products. The next challenge will be to exploit that need by taking the results of ADVISOR and disseminating them to end users, and planning and developing products that can be derived from ADVISOR. Although ADVISOR was a success, it is not clear that the current ADVISOR specification is sufficient to meet users' requirements.

Further work that will need to be performed to address real world applications includes:

- Behaviour recognition needs to be broadened to include more possible behaviours and to include supervised learning algorithms controlled by the operators
- An improved person tracker, perhaps based on the Reading people tracker will need to be integrated to allow the recognition of more types of behaviours
- More use needs to be made of multiple cameras, and to achieve this, better quality images will be required. This would also be required to meet the requirements of providing satisfactory evidence in court.
- The capture of images needs to be capable of inserting a digital watermark to ensure that the images can be used in legal proceedings
- The size of the equipment needed to implement a system must be reduced, so that the cost of installation and maintenance will be more acceptable
- Tools must be developed to reduce the installation and maintenance costs of scene modelling and camera calibration
- Improvements will need to be made to the archive, search and retrieval to cope with a larger scale deployment

The consortium members are interested in performing further work in this area, should the opportunity arise, and work is underway to actively market the ADVISOR type of system.