A Real-Time Scene Understanding System for Airport Apron Monitoring

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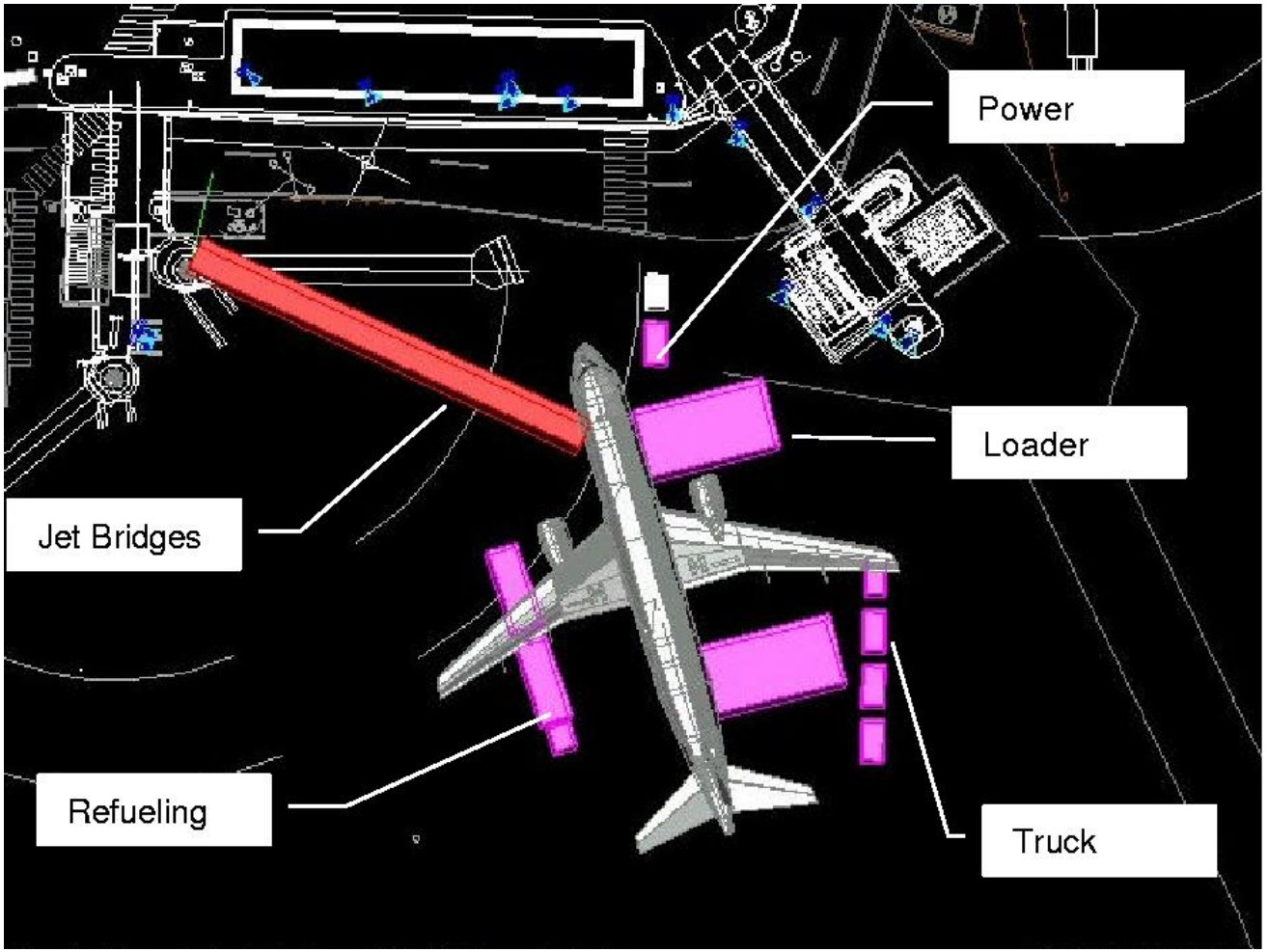
AVITRACK

Aircrafts surroundings, categorised Vehicles & Individuals Tracking for apRon's Activity model interpretation & CheckK

- **Objective:** to automate recognition of activities around parked aircraft on apron areas to improve competitiveness, safety and security

- **Scope:** develop a distributed vision system performing multi-camera visual surveillance and event recognition in real-time.

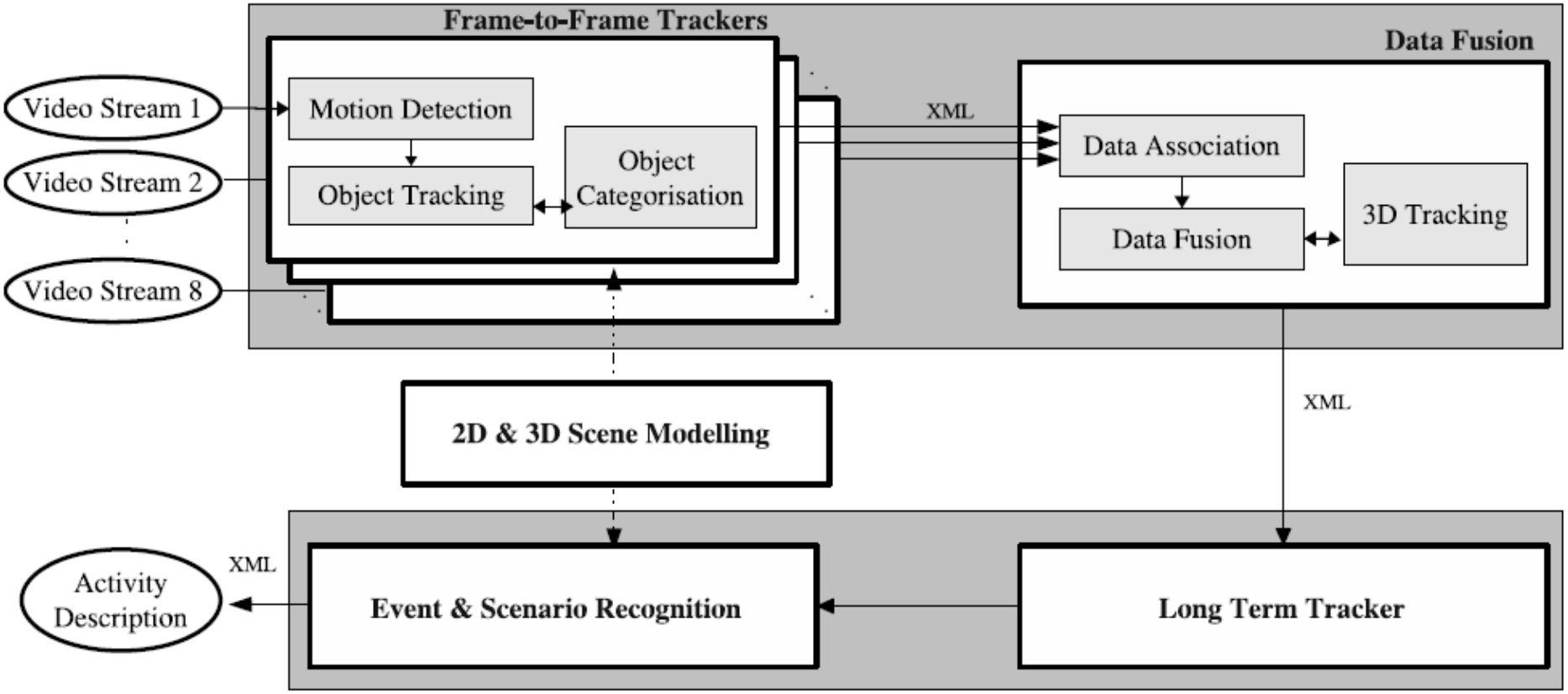
Apron E-40, Toulouse Airport, France



Application Constraints

- **The system must:**
  - Monitor and recognise the interaction of numerous vehicles and personnel
  - Operate in a dynamic environment over extended time periods
  - Operate in real-time (defined as 12.5 FPS for PAL colour images)

Architecture



Overview

- Frame Trackers (per-camera)
  - Motion Detection
  - Object Tracking
  - Object Recognition
- Data Fusion
- Long Term Tracker
- Event and Scenario Recognition

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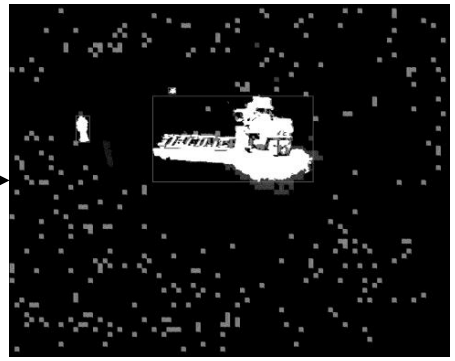
Motion Detection

Video data feed

Motion Detection



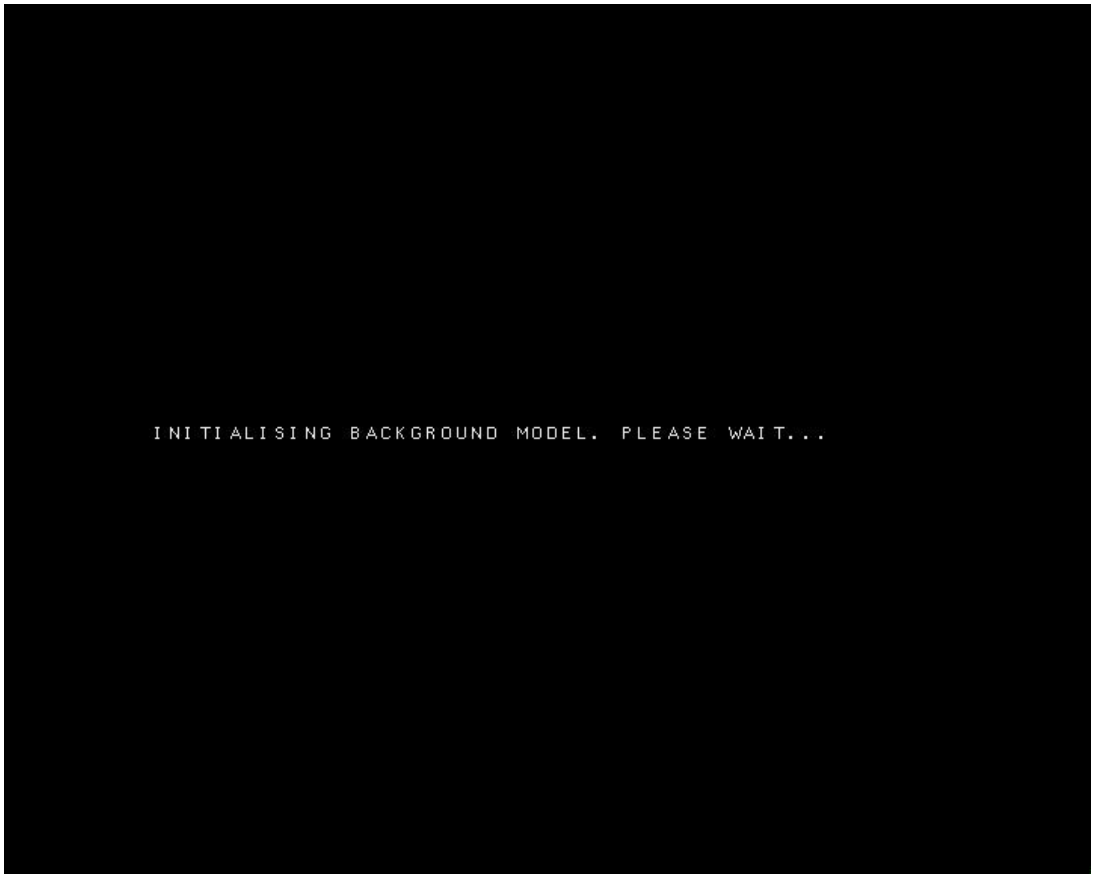
2D blobs

Motion Detection

- Background subtraction using pixel-wise Gaussian background model in normalised RGB colour space
- Object based background layering to allow moving objects to be differentiated from stationary objects.
- Shadow and highlight suppression module based on work of Horprasert *et al* (ICCV'99)

Motion Detection Result

Motion Detection



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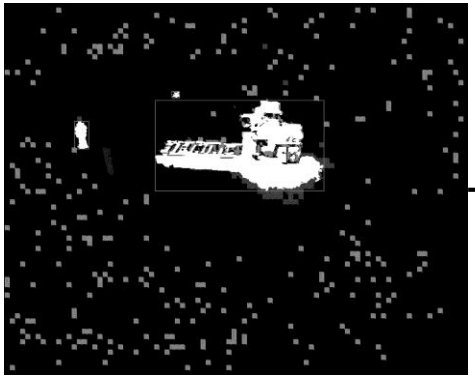
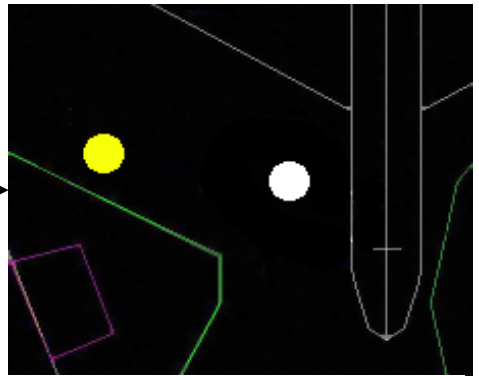
Object Tracking



2D blobs

Object Tracking

2D tracks



3D localisation

KLT Tracking

1. **KLT interest points:** generated for object regions.
   - Each point has object membership in frame t-1.
   - Each object contains >1 features.

2. **KLT algorithm:** Track points to current frame t

3. **KLT features:** Match to frame t motion regions and handle interactions.

4. **Replenish** KLT interest points and continue.

KLT Tracking II

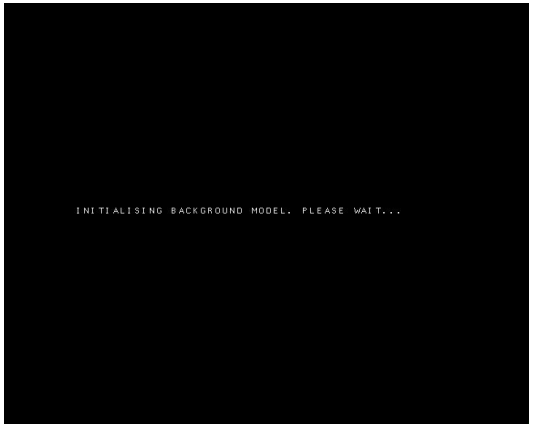
- **Match function:** determines if motion region correspondence is
  - One-to-one (tracked)
  - One-to-many (split)
  - Many-to-one (merge)
  - One-to-none (missing)
  - None-to-one (new)

- When merging, an object's state is predicted by fitting a translational motion model to the tracked points.

- To detect splitting of objects the intra-object interest points are robustly clustered using translational motion models.

Object Tracking Result

Object Tracking Result



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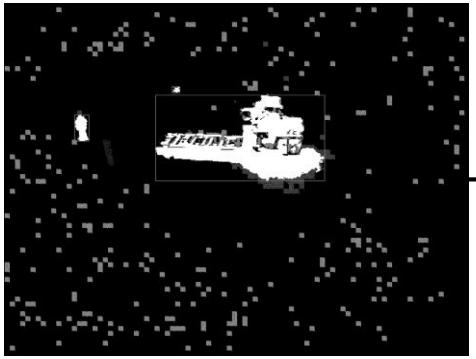
Object Recognition

2D tracks



2D blobs

Object Recognition

Aircraft	**0.1**
Transporter	**0.7**
GPU	**0.1**
Service Vehicle	**0.1**
Person	**0.0**
Other	**0.0**

Per track category vectors

Object Recognition

- Multi-stage classifier combining efficient bottom-up and expensive top-down classifiers:
  - Stage One: classify main object types (people, vehicles, aircraft etc) using a GMM trained on efficient descriptors (3D width/height etc)
  - Stage Two: for vehicle type, classify sub-type (loader, tanker etc) using textured 3D models fitted using NCC and SIMPLEX search within the parameter space.

Object Recognition Result

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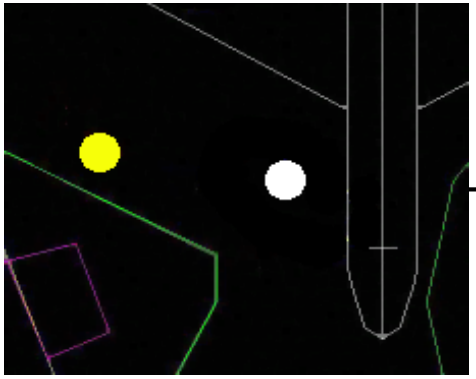
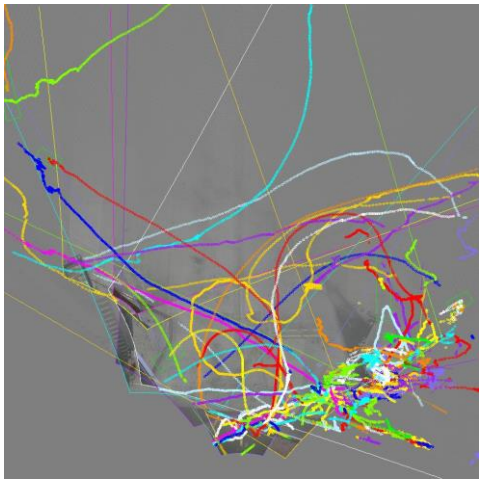
Data Fusion

Per-camera 2D tracks



Per-camera 3D localisation

Data Fusion



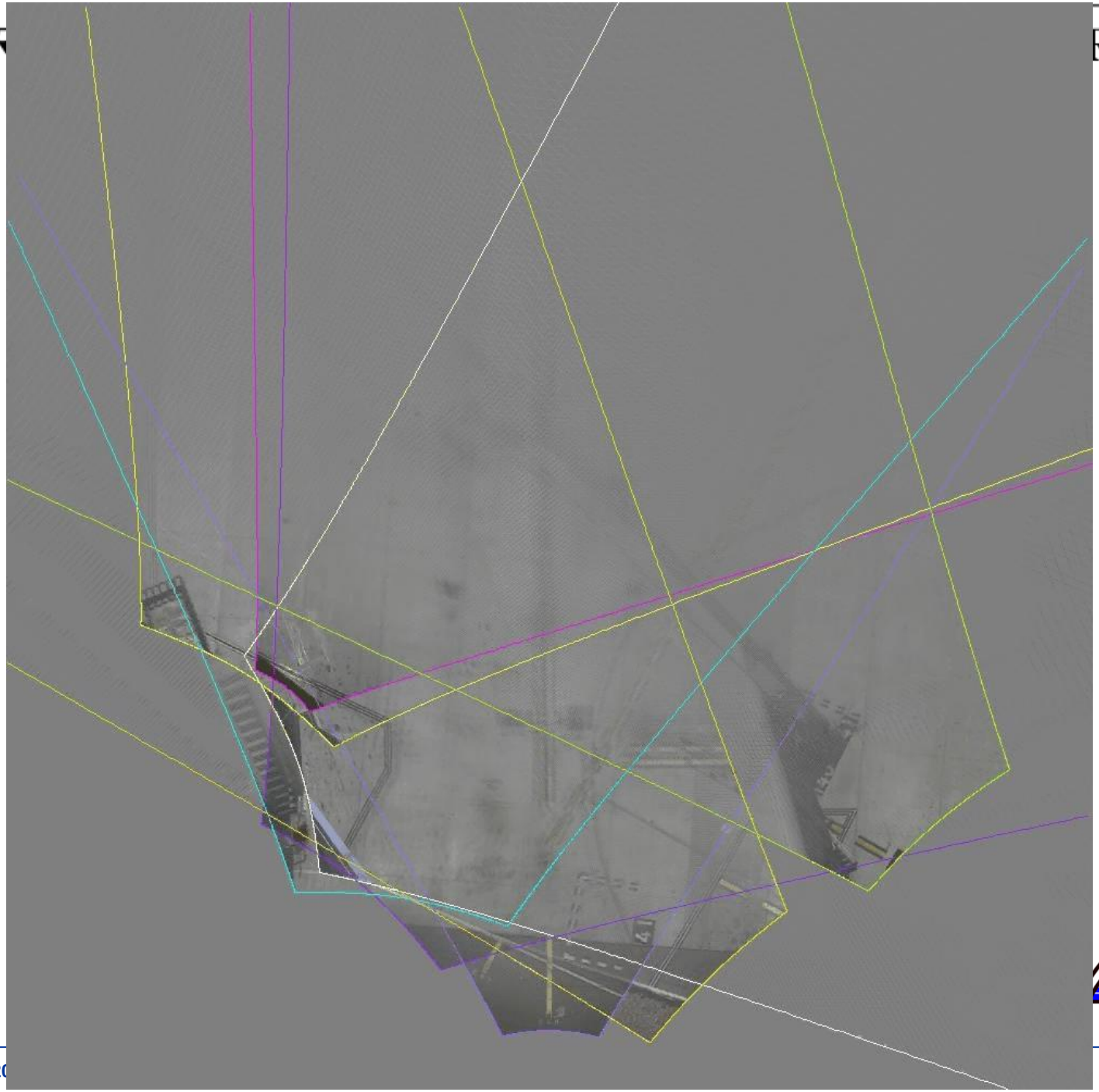
3D fused tracks

Data Fusion

- Discrete Nearest Neighbour Kalman Filter approach with constant velocity

1. Validation gate used to limit the potential matches between tracks and per-camera measurements.
2. Data association: nearest neighbour per camera to a track.
3. Fusion of associated measurements.
4. Kalman filter update of each track state with fused measurement.
5. New candidate tracks from remaining measurements.

Data Fusion Result



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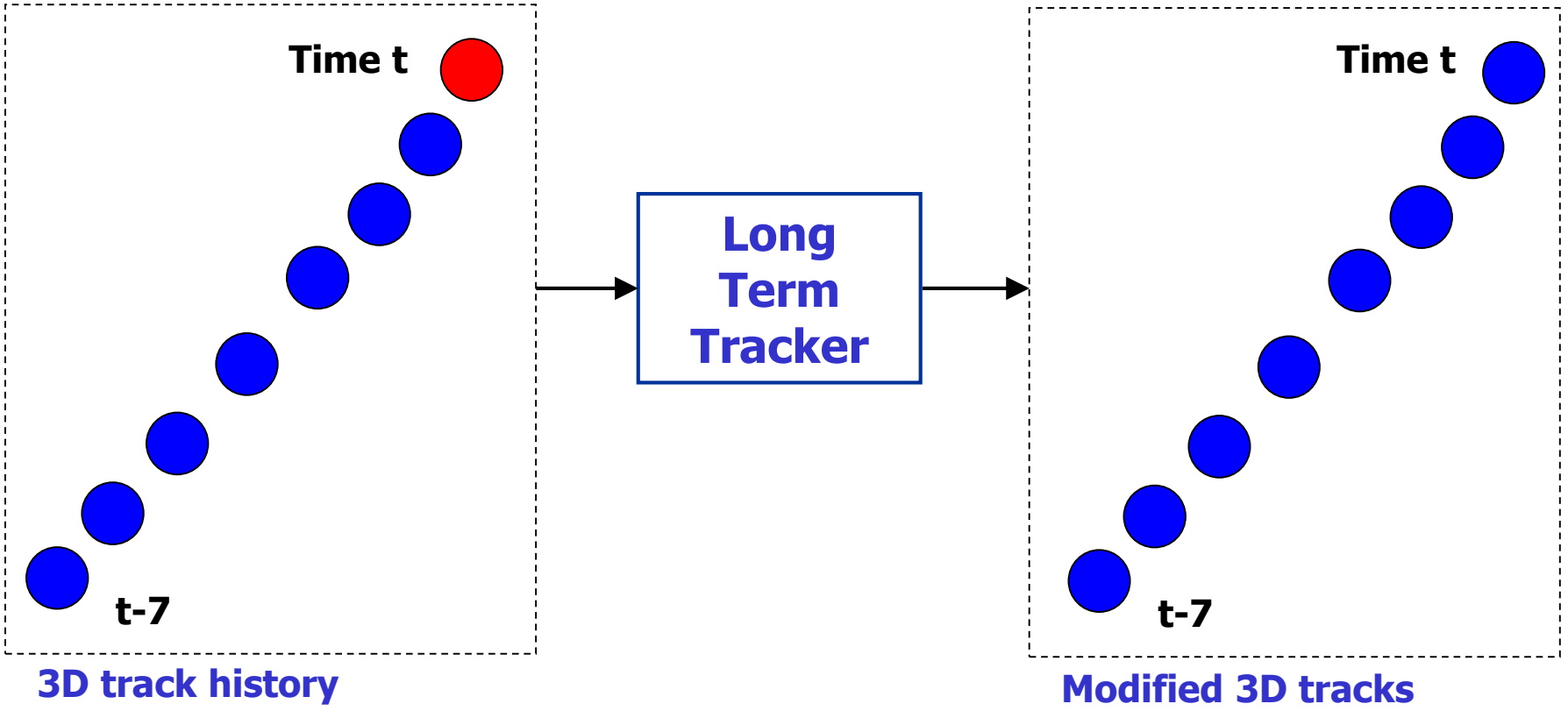
Long Term Tracker



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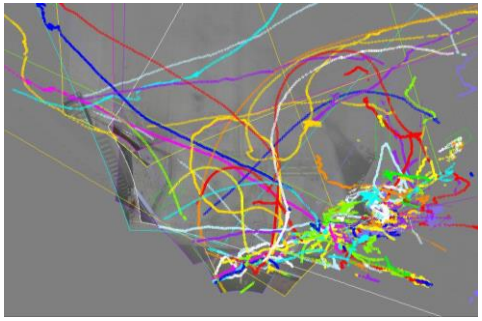
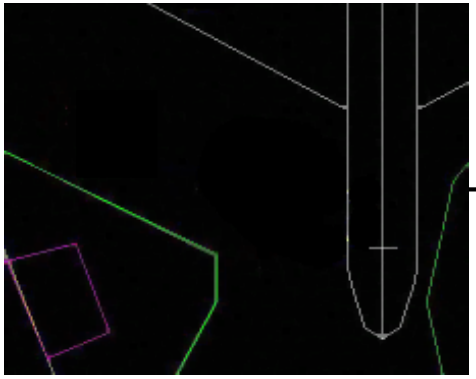
Event and Scenario Recognition

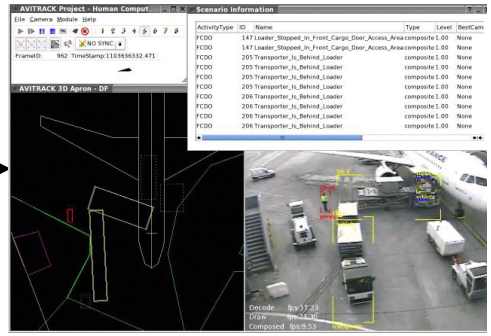


3D tracks



Contextual knowledge / Event Models

Event and Scenario Recognition



Recognised apron activities (displayed by HCI)

Event and Scenario Recognition

- **Approach:** Event Recognition based on
  - a priori knowledge of the observed environment
  - models of events predefined by application domain experts
  - spatio-temporal reasoning based on temporal constraints propagation

3D Scene Model of the Observed Environment

- **Definition:** a priori knowledge of the observed empty scene
  - **Cameras** e.g. intrinsic, extrinsic parameters
  - **3D Geometry** of moving/static objects and ground plane zones e.g. location, shape, volume
  - **Semantics**:
    - type (e.g. object, zone)
    - characteristics (e.g. appearance)
    - function (e.g. seat)

3D Scene Model of the Observed Environment

- **Purpose:**
  - keep the interpretation independent from the sensors and the sites: many sensors, one 3D referential
  - provide additional knowledge for activity recognition

Video Event Representation: Video Event Model

- We have defined four types of video events:

primitive state	**composite state**
primitive event	**composite event**

- A video event is constituted by three parts:
  - **Physical objects:** all real world scene objects
  - **Components:** list of states and events
  - **Constraints:** symbolic, logical, spatio-temporal relations between components or physical objects

Video Event Representation

- **States:** describe situations characterising one or more objects defined at a time instance or a stable situation defined over a time interval
  - **Primitive State**: a measurement computed from the tracking module output (e.g. a person is inside a zone)
  - **Composite State**: a combination of primitive states

Video Event Representation

- **Examples of states:**

A person is inside the Equipment Restricted Area (ERA) zone

The Ground Power Unit (GPU) Vehicle is stopped in GPU access area

Video Event Representation

- **Events:** activities containing at least a change of state values between two consecutive times
- **Primitive Event:** corresponds to a change of primitive state values

  - **Example:** The Ground Power Unit (GPU) Vehicle enters in the GPU access area

Video Event Representation

- **Composite Event:** corresponds to a combination of states and events i.e. a *scenario* representing an apron activity

Composite_event (Aircraft_Arrival_Preparation,
Physical objects((p1 : Person), (v1 : Vehicle), (z1 : Zone), (z2 : Zone) (z3 : Zone), (z4 : Zone))
Components((c1 : Composite_State GPU_Arrived_In_ERA(v1,z1))
(c2 : Composite_Event GPU_Enters_GPU_Area(v1,z2))
(c3 : Composite_State GPU_Stopped_In_GPU_Are(v1,z2))
(c4 : Composite_State Handler_Gets_Out_GPU(p1, v1,z2, z3))
(c5 : Composite_Event Handler_From_GPU_Deposites_Chocks (p1,v1,z2,z3,z4)))
Constraints((v1->Type = GPU)
(z1->Name = ERA)
(z2->Name = GPU_Area)
(z3->Name = GPU_Door)
(z4->Name = Arrival_Preparation)
(c1 before c2) (c2 before c3) (c3 before c4) (c4 before c5)(c4 during c3) (c5 during c3)))

Scene Understanding Result

SCENARIO AIRCRAFT_ARRIVAL_PREPARATION_SCENARIOS

Vehicle: GPU

Person: Handler

Zones: ERA, GPU_Access, Arrival_Preparation

Dynamic Zone: GPU_Door

Vehicle_Arrived_In_ERA

Gpu_Enters_Gpu_Access_Area

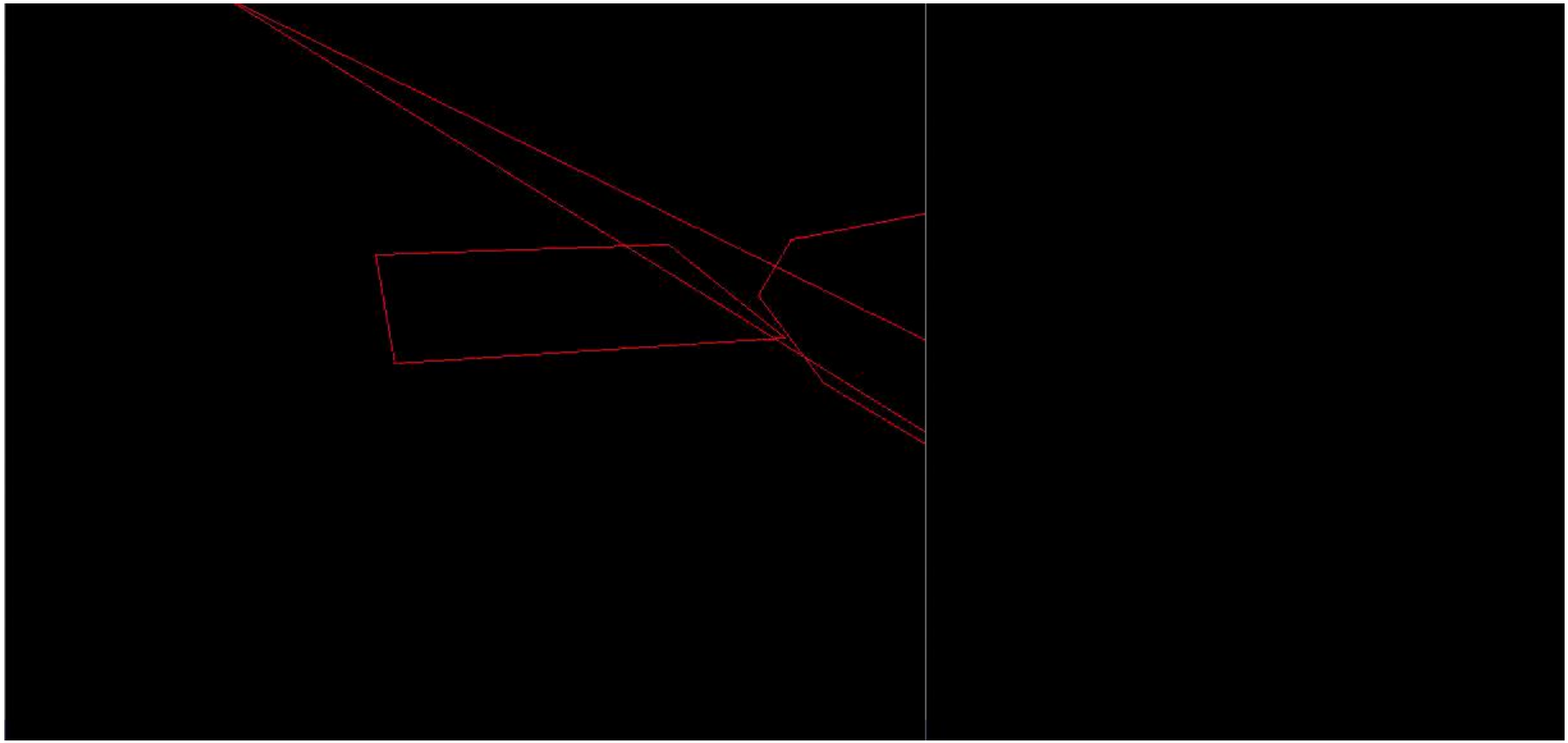
Gpu_Stopped_In_Gpu_Access_Area

Handler_Gets_Out_Gpu

Handler_From_Gpu_Deposites_Chocks_Or_Stud

Preparation of the Aircraft Arrival

Scene Understanding Result



Baggage Loading at the front of the aircraft

Video Event Recognition Algorithm

- **Algorithm in three parts (see VU *et al*, IJCAI'03)**

1. primitive state recognition
2. primitive event recognition given an event template
3. composite state or composite event recognition

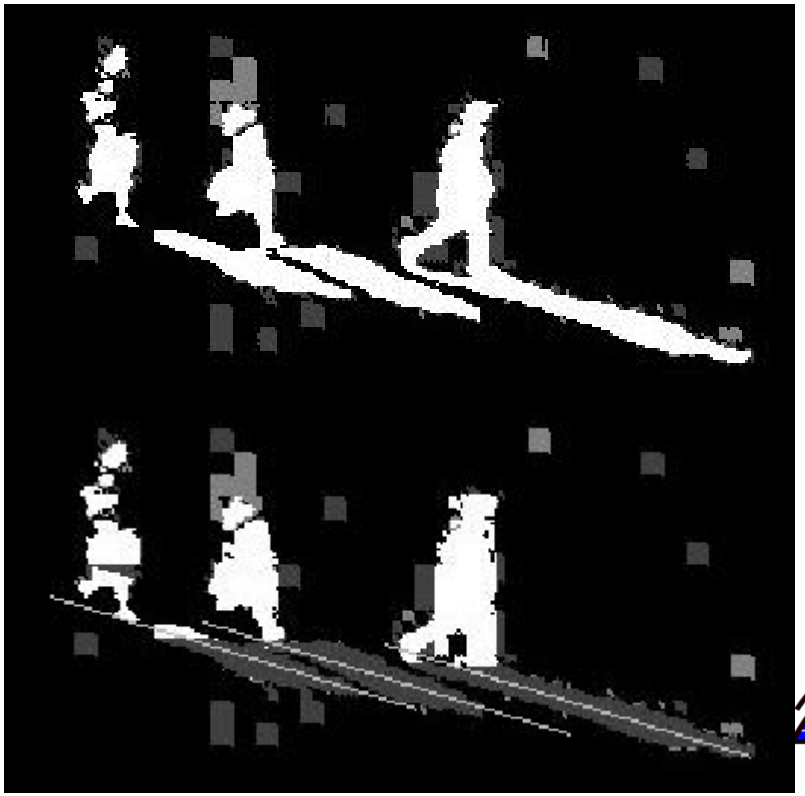
Scene Understanding Results

- **Video Event Modelling:**
  - 28 video events
  - “Aircraft Arrival Preparation”, “Baggage Loading” and “Tanker Arrival” operations
- **Video Event Recognition** tested on 8 video sequences (1899-3774 frames)
    - True Positive : 49
    - False Positive : 0
    - False Negative : 0

Disclaimer: Situations where the tracking module misdetects objects were not addressed

Further Work

- **Motion Detection**: Explicit handling of ghosts and *strong* shadows in visual tracking



Further Work

- **Object Tracking**: added an estimate of the probability of unobstructed observation
- **Object Recognition**: implemented simulated annealing method for top-down model fitting to reduce the likelihood of local maxima detection
- **Object Recognition**: evaluated use of local features (WSMM, harris-laplace) and descriptors (SIFT, NCC) in a bottom-up classifier (currently, a KNN based approach)

Further Work

- **Data Fusion**: Implemented a JPDA filter and extended the validation gate in the standard filter to include location, velocity and category in formation.

- **Data Fusion**: Implemented an epipole based data association algorithm for tracking people off the ground plane.

Further Work

- **Long Term Tracker**: Handling of track ID changes, fragmented tracks, lost tracks and track category confusion.
- **Event and Scenario Recognition**: 58 video events defined and subsequently recognised on representative test data

Future Work

- **Object Tracking**: explicit occlusion analysis to aid reasoning on the congested apron
- **Object Recognition**: improve the robustness of the bottom-up classification stage when objects are interacting
- **Data Fusion**: use particle filter based tracking to improve performance in presence of noise or highly manoeuvering targets
- **Event and Scenario Recognition**: allow uncertainty handling when the tracking result is unreliable

Future Work

- The AVITRACK System: application in other VS domains

Thank you

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- **Website:** www.avitrack.net