Surveillance Angels

Valedictory Lecture

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Abstract

The use of sensor networks has been proposed for military surveillance and environmental monitoring applications. Those systems are composed of a heterogeneous set of sensors to observe the environment. In centralised systems the observed data will be conveyed to the control room to process the data. Human operators are supposed to give a semantic interpretation of the observed data. They are searching for suspicious or unwanted behaviour. The increase of surveillance sensors in the military domain requires a huge amount of human operators which is far beyond available resources. Automated systems are needed to give a context sensitive semantic interpretation of the observed kinematic data.

As a proof of concept two automatic surveillance projects will be discussed in this paper. The first project is about a centralised system based on the AIS-Automated Identification System which will be used to monitor ship movements automatically. The second project is about a decentralised system composed of a network of cameras installed at a military area.

There is a need for a surveillance system along the coast of Europe. There is an increase of illegal drugs transport from the open sea, intrusion of boat refuges, illegal fishing, pollution of the sea by illegal chemical and oil pollution by ships. An automated sensor system is needed to detect illegal intruders and suspicious ship movements. Vessels fitted with AIS transceivers and transponders can be tracked by AIS base stations located along coast lines or, when out of range of terrestrial networks, through a growing number of satellites that are fitted with special AIS receivers. AIS data include a unique identifier of a vessel and kinematic data such as its position, course and speed. The proposed system enables identification, and tracking of vessels and to detect unwanted or illegal behaviour of ship movements. If ships violate traffic rules, enter forbidden areas or approach a critical infrastructure an alert will be generated automatically in the control room. Human operators start an emergency procedure.

The second project is about a network of cameras installed at a military area. The area is monitored by multiple cameras with non-overlapping field of views monitored by human operators. We developed an automated surveillance system. At the entrance gate the identity of visitors will be checked by a face recognition system. In case of intruders, unwanted behaviour, trouble makers the emotional state of the visitor will be assessed by an analysis of facial expressions using the Active Appearance model. If unwanted behaviour is detected an alert is send the control room.

Also license place of cars will be recognized using a system based on Neocognitron Neural Networks. Moving objects as persons and vehicles will be detected, localized and tracked. Kinematic parameters are extracted and a semantic interpretation of their behaviour is automatically generated using a rule based system and Bayesian networks. Cars violating the traffic rules or passing speed limits or entering forbidden areas or stopping/parking at forbidden places will be detected. A prototype of a system has been developed which is able to monitor the area 24 hours a day, 7 days a week.

Chapter 1
Intelligent surveillance

In his inaugural lecture in 2010 Professor Rothkrantz introduced the concept of a guardian angel. An angel is an animation of software agents. An agent is able to perceive its environments, to reason about context and observations and to take appropriate actions and finally is able to evaluate the impact of its actions. The goal of a personalised guardian angel is to care of the safety of guarded person. Every human observer has a digital counterpart, taking care of its wellbeing and taking care of the communication with other parts of the system. In case of threat or dangerous situations the guardian angel has to take actions to protect the guarded person. A surveillance angel is another member of the community of angels. The main task is to monitor an environment and to detect unusual events. An angel is like agents an autonomous object communicating with other angels in its virtual angel world.
The last three years our research was focused on surveillance angels. The concept surveillance angels in a military context can best be illustrated with drones, such as a ScanEagle [1] (see Fig 1). A drone is an unmanned aerial vehicle (UAV), equipped with high definition cameras and able to survey large areas from the air. A drone can be considered as a flying camera system or as a flying angel. A drone can be launched from the ground or from a ship by human operators, and is navigated by human operators in the control room. Actions as launching a missile from a drone will be initiated by human operators. Video recordings are transmitted from the drones to the ground station and the semantic interpretation of these recordings in the given context is again done by human operators. So a drone is under control of human operators and many operators are needed. Human operators in the control rooms are supposed to survey video data 24/7 and to give a semantic interpretation of the observed data. In case of suspicious or unwanted behaviour they start an alert procedure.
Nowadays many military researchers are involved in projects to design autonomous drones. Such an intelligent drone is modelled as an agent and should be able to monitor the environment, to detect and track objects and to reason about their behaviour and to choose appropriate actions. Such a drone should also be able to evaluate its own behaviour. The design of autonomous drones is under discussion. Especially if such a drone will be permitted to launch its own missiles is a topic of ethical debates. We are used to the battle of drones in war games and agents in cyber war. But a battle of the angels in the real world is still far beyond our dreams and not a topic of our research.

Photo Netherlands Ministry of Defence

Fig.1: ScanEagle launched from HNMLS Rotterdam

Our research was not limited to flying angels. Our main focus was surveillance angels, or on intelligent sensor surveillance networks. Nowadays we can observe surveillance systems on many places to survey military people, military objects as buildings, harbours, vessels and installations. Via the sensor network the guarding operators in the control room are supposed to detect intruders, attackers, violence and unwanted behaviour and special events. The increase of surveillance systems in the military domain requires an exponential growth of the number of human operators which is far beyond available resources. So there is a need to automate the sensor systems.
A surveillance system must be able to detect and track moving objects, classify these objects and detect some of their activities. Human operators are able to give a context sensitive interpretation

of moving objects based on their lifelong experience or special training. In chapter 3 we will report about our research activities in the area of analysis of human behaviour. We will discuss analysis of body movements as gestures and facial expressions. But we start in chapter 2 with the analysis of tracks on annotated maps. We will show that it is possible to detect unwanted behaviour using only tracks of moving objects. Objects violating traffic rules or behavioural rules, entering forbidden areas can be decided on track analysis. The use of specific knowledge rules, historical analysis of tracks and annotated maps enables context sensitive semantic interpretation of recorded tracks and kinematic features. At the end of the research projects human operators will be replaced by an automated surveillance system. A prototype of the system has been developed and is currently used as a decision support system.
Our research challenge can be defined as follows:

Research challenge
Is it possible to design a surveillance system composed of a network of smart sensors that are able to generate a context sensitive semantic interpretation of observed events?

The developed system should be able to perform:

- Auto Surveillance (deviation of speed, direction route, boundary crossing).
- Protection of critical infrastructures such as strategic, military harbours and installations against piracy, terroristic attacks and intruders.
- Anomaly detection (unwanted behaviour, violation of traffic rules).
- Generating alerts and alarms after probabilistic)/deterministic reasoning/processing of the observed AIS data.

The outline of this paper is as follows. In the next chapters we will discuss the cases 1 and 2 which are an application of our surveillance systems.

Chapter 2
Case 1 A Monitoring System of a Military Harbour Using Automatic Identification System (AIS)

Fig. 2: The Atlantic wall (green line)

During the second World War Nazi Germany expected an invasion from the Allied Forces from the seaside. Especially the Channel between Great Britain and France was a dangerous area. To protect Europe against an invasion from the Atlantic Ocean and North Sea an extensive system of coastal fortification called the Atlantic Wall was built along the Western Coast of Europe [2] (see

Fig. 2). Military guards were supposed to monitor the open sea 24/7. A huge amount of military observers were needed to cover the whole area.

There is no longer a need for protection against large scale invasion of Allied Forces but protection against invasion by terrorists, drugs criminals, refuges and illegal persons. Nowadays ship movements along the coast of Europe and the North Sea are monitored by the AIS system [3,4,5] (see Fig. 3). The network of human observers is replaced by sensor networks. Vessels fitted with AIS transceivers and transponders send at regular times a message with their identity, position, speed and heading. These data can be tracked by neighbouring vessels AIS base stations located along coast lines or, when out of range of terrestrial networks, through a growing number of satellites that are fitted with special AIS receivers. No complex pattern recognition algorithms are needed to localise vessels as long as the AIS system is on. Switching of the AIS system is not permitted. The AIS system was designed for safety reasons. Even in bad weather conditions vessels are able to localise each other to avoid collisions and to provide help if needed. For safety reasons even small ships have an AIS system nowadays.

The AIS system enables military Command and Control centres to get full awareness of the situation on open sea. The position and tracks of vessels are displayed on computer screens monitored by human operators. Monitoring ship movements 24 hours a day during 7 days a week requires a lot of human resources. The surveillance job is of high importance but not very challenging. Intrusion of ships in forbidden areas, violation of the traffic rules and suspicious ship movements have be detected by the human operators. The event will be analysed and in case an alert procedure will be started by the Coast Guard.

Fig. 3: A graphical display of AIS data

Fig. 4: Map of the harbour of Den Helder

To design an automated surveillance system the monitoring task, the reasoning and decision making task and communication of the human operators has to be automated. A human operator is scanning the screen with AIS data and eventually his attention will be triggered by unusual events. He is able to do this job thanks to his long year training and experience. In the automated system an agent will be attached to every vessel and the track of the vessel will be analysed by the agent. The knowledge of the operators was extracted and implemented in the agent systems.

As a proof of concept the design and implementation of a surveillance system around the military harbour of Den Helder will be presented. This was joint research of K.Scholte and L.J.M.Rothkrantz [6].

Vessel positions sensed by the AIS system will be displayed on a map of the area of the military harbour at Den Helder (see Fig. 4.). These maps are annotated with the following data:

- Traffic Separation corridors. To regulate global ship movements corridors have been defined with one way traffic movements. These corridors are marked by floating buoys.
- Free sailing routes. Outside the main traffic routes ships are free to sail. To research this ship movements an AIS antenna was installed at the entrance of the harbour with a reach of 50 km. All ship movements were logged during the time October-November 2012. The data analysis reveals secondary traffic corridors which were annotated on the maps.
- Tracks. At regular times the position of vessels are annotated on the map and a track can be computed. Variation of speed and changes of headings can be annotated along the ship tracks.
- Regions of Interest (ROI's). In general ROI's are no-go areas or areas with limited access. Examples critical infrastructure such as areas around oil platforms or windmill parks, entrance of the military harbour. But also fishing grounds that require a permit to enter, or areas with shallow water, nature reserves.
- Personal space. Every ship is surrounded by an area shaped as an ellipse. To prevent collision this ellipse is a no-entrance area.

The proposed automatic surveillance system has to detect unwanted behaviour by analysing tracks of vessels on an annotated sea map. The following classes of unwanted behaviour are considered:

Violating traffic rules:

- Change of directions, U-turns
- Deviant sailing behaviour such as continuous change of heading, change of speed or even stopping. Snake-like behaviour (high sigma of mu course) could be caused by mechanical problems (or drunk/ill/incompetent captain)
- Surpassing speed limits, neglecting traffic signs.

Sailing at unexpected/forbidden places and time

- Intent of intrusion in ROI's or personal space
- Leaving Traffic Separation Corridors (TSC)
- Switching off the AIS system at unexpected place and time
- Sailing at unusual time.

In the next section a knowledge based system will be described to detect unwanted behaviour automatically.

2.1 Rule based system or Bayesian network

Knowledge based systems have been developed to detect unwanted behaviour. These systems are modelled after a human operator [15,19, 20, 23, 29, 30, 31, 36, 39, 40, 44, 45, 47, 57, 65, 71, 73, 74, 75, 90, 101]. An operator monitoring traffic data will be triggered by unusual events. A hypothesis of what is probably going on is popping up in his mind. Next he will look for validation of the hypothesis by waiting for new data or taking data from context. If conflicting data appear the current hypothesis will be given up and possibly replaced by a new hypothesis. If the hypothesis has been verified possible actions are generated. This procedure is very similar to the OODA-loop (Observation-Orientation-Decision-Action) , a well-known human perception model in the military domain. A list of possible triggers, hypothesis, hypothesis verifications and actions has been defined by knowledge extraction from the human operators. Possible triggers are for example sudden change of headings and speed or intrusion ROI's. Possible hypothesis are for example terroristic attack, illegal fishing or illness or incompetence of the captain. Verification of the hypothesis takes place by noise cancelling and verification if the assumed behaviour is going on in the next future or next events are a logical consequence of the preceding actions. Possible actions of the Coast Guard are generating alerts, or starting an alarm procedure. More details can be found in Rothkrantz & Scholte [6, 54].

The relevant knowledge was extracted from operators in the control room. In a simulation study using historic logged data, operators were requested to think aloud and comment the displayed events. The knowledge of the operator is represented as if-then rules. CLIPS, a well-known expert system shell has been used to implement the knowledge rules and to design a reasoning system. Features extracted from the AIS system are fed into the expert system and the system generates possible actions

For every vessel AIS data are sampled at regular time (8 seconds). A track is computed using the changing position. The sampled data speed and acceleration, heading and ROI related position are attached as a vector to points of the track. Every two minutes the sampled value of speed and heading are averaged. If this value passed a given threshold, it is assumed that the ship is accelerating or turning and correspondent triggers are activated. Another possibility is that the position is outside TSC or inside a forbidden area. In that case again a trigger is activated. All the IF-THEN rules with these triggers in the left part are activated and possible hypothesis are generated. Next the system searches for events in the track buffer of observed AIS data of the vessel, neighbouring vessels or SOS alerts etc. to validate the hypothesis eventually and finally action are generated. A possible example of the rule based system is presented in Fig 5.We notice that the reasoning process is distributed in time. AIS data and observation data is entering the system in the course of the time. This implies that the system usually has to reason with incomplete data or is waiting for new data.

The 4 objects Trigger, Hypothesis, Validation and Action are linked together by three rules as follows:

IF <trigger> THEN Suggest <hypothesis>
<hypothesis> confirmed by <validation tests>
IF <validation tests> THEN DO <action>

To test the reasoning part of our system, many examples of forward and backward chaining were generated and validated successfully. In Fig. 5 we present an example.

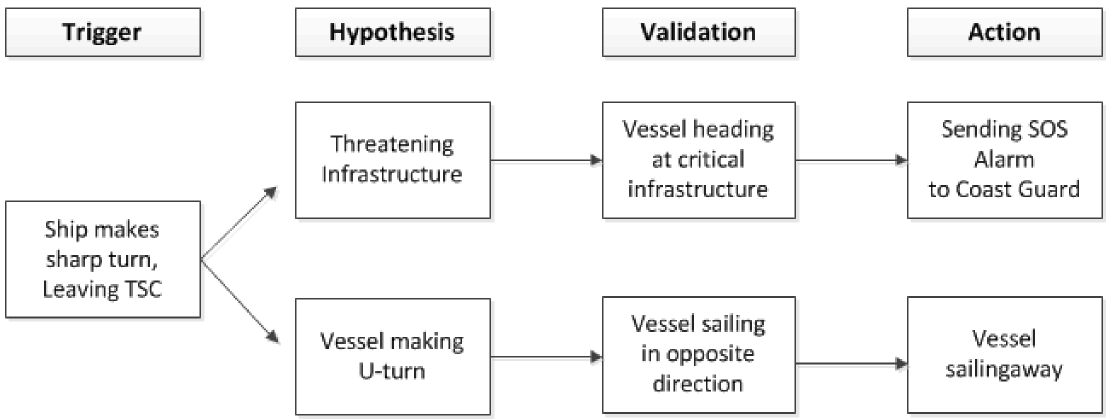

Fig. 5: Example of forward reasoning

One of the disadvantages of using a rule-based system is that IF-THEN rules are always deterministic. Either the IF-condition of the rule is fulfilled or it is not. A certain event or variable value may be an indication for more than one situation. For example, a ship changing his heading at high speed, approaching the harbour wants to embark as soon as possible or has hostile intents. We tried to solve this problem by introducing probabilities to determine the likelihood of the start and end of each, using Bayesian networks. For every possible scenario we designed a model of a Bayesian network as in Fig 6. We researched events with a very low frequency. So it is impossible to gather data by logging data for some time. Military experts have to set the values in the Conditional Probability Tables.

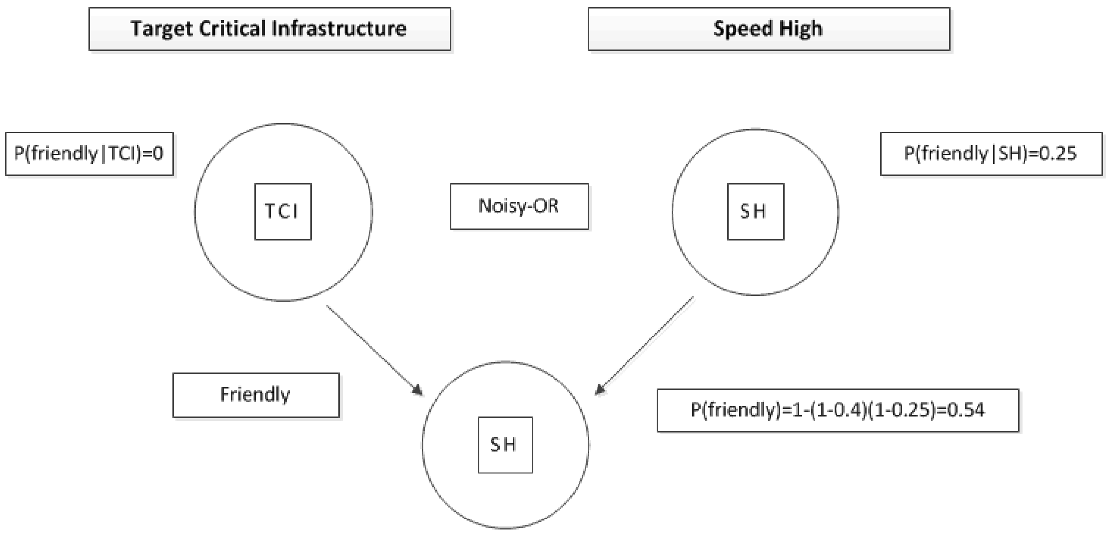

Fig. 6: Example of Bayesian inference

2.2 Automatic speed and course change detection

The “Arie Senior” (mmsi = 244060000) is a commercial fishing vessel (AIS class 30; “fishing”). It is 41 m in length and has a GT of 363.This vessel was selected because the track covers an entire fishing outing, starting and ending with the vessel moored in Den Helder, traveling to the fishing grounds and fishing. The track data spans a period from April 12th 2013 11:30:06 until April 28th 2013 04:28:04, which is (almost) the entire logged period. This entails a total track length of 1357078s or almost 16 days. This track is shown in Figure 7. The vessel travels from its port of call, Den Helder, to various destinations in the North Sea. As expected when selecting this track, the fishing behaviour of the vessel becomes particularly apparent. This pattern consists of many course and speed changes when fishing.
Similar tracks can be observed from military vessels inspecting the bottom of the sea, searching for objects as sea mines or designing maps of the bottom of the sea.
The characteristics of both tracks can be defined in terms of many parallel tracks , sharp U-turns.

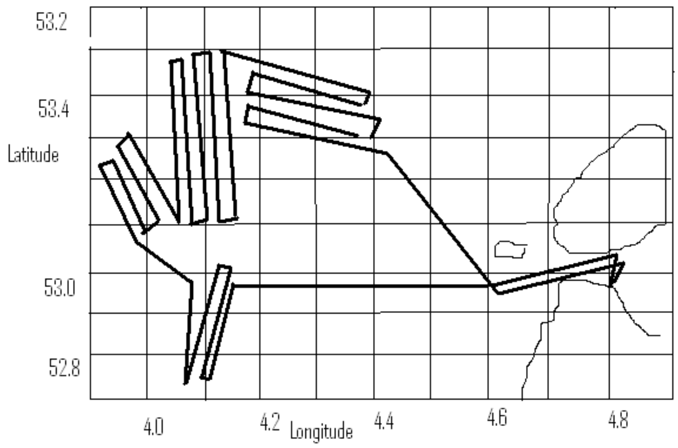

Fig. 7: Track of the vessel Arie Senior

Chapter 3
Case 2: A camera surveillance system

Fig. 8: Entrance military domain at Den Helder

At Den Helder in the North-West part of The Netherlands there is the location of the Marine harbour, the military training centre of the Royal Dutch Marine and the Faculty of Military Sciences of the Netherland Defence Academy. These areas are only accessible by people having a special ID-card or by people asking permission at the gate. The area is surrounded by gates and monitored by multiple connected cameras (Fig. 11). The cameras are monitored by surveillance employees. They have to detect intruders and unwanted behaviour. Students and lecturers are supposed to take the shortest route to the lecture rooms, the restaurant during lunch time or the dormitories at the evening. People or cars taking different routes should be monitored. Cars stopping at the armoury or arsenal, violating traffic rules or driving around without clear destination, show suspicious or unwanted behaviour. The same holds for people climbing the fence, trying to get access to military ships in a sneaky way, entering buildings via emergency doors. Fortunately the number of incidents is low. As a consequence monitoring the cameras 24/7 is a boring job which requires a lot of human and financial resources.
The goal of this chapter is to describe a (semi-) automated sensor surveillance system for the military area [13, 49, 52, 53, 63, 64, 66, 83, 84, 85, 88, 95, 103, 108, 110, 111, 114, 115, 116]. In case the system detects a suspicious event an alert will be generated. The surveillance employees analyses the events and takes appropriate actions. The backbone of the system is the existing infrastructure of surveillance cameras attached to the lampposts. Every camera will be equipped with a processor to capture and process video images. All cameras are wireless connected to its neighbours and to the central control room. The network of surveillance cameras is able to monitor the environment. The research challenge is to give a semantic interpretation of detected events with a focus on unwanted behaviour. In this way the network of human observers will be (partly) replaced by a sensor network. There is an option that even human observers communicate wireless with their smart phones with the network. In this way human observers can be considered as moving sensors.
All cameras are equipped with a processing unit and are modelled as smart agents (or surveillance angels in our terminology). A camera is able to observe its environment, to reason about the recorded data and take appropriate actions in case a suspicious event is detected. Cameras are connected to each other via a distributed blackboard system modelled as fusion agents, where the reasoning module is located. The network will be populated by agents playing different roles ranging from observer, communicator, filtering reasoning and interpretation and are located on different processing units throughout the network. In the next sections different components of the surveillance system are described in more details.

Fig. 9: Surveillance camera

3.1 Recognition of car license plates

The surveillance system should be able to monitor car traffic in the military area. A car will be identified by its license plate and in case localised in the field of view (FOV) of the distributed cameras. Based on the string of time stamped locations of a car its track can be computed. Unwanted behaviour of cars can be assessed by analysis of the car tracks presented in the next section. To enter the military area with a car the driver has to show his ID card at one of the three entrance gates blocked by barriers (see Fig. 18, 19). During the time the ID card will be checked our automatic surveillance system has the time to read the license plate of the car and to check if this car is on the list of suspicious visitors or regular visitors. Cameras on different places of the military area have to recognize car templates out of the list of cars entering the area. This guarantees a high recognition rate.

We developed a car license plate recognition system [7]. The system is capable of recognizing car license plates independent from plate location, size, dimension, colour and character style. The system is based on a well-known neural network classifier, the Neocognitron. The developed system contains an image-processor, a segment-processor and five combined Neocognitron network classifiers which act as a character recognizer. Combining Neocognitron classifiers was motivated by the fact that manually tuning a training-set for a large Neocognitron network is tedious. By connecting small Neocognitrons specifically trained for character classes that are frequently wrong classified, the performance of the recognizer was improved significantly. Our system has a character recognition accuracy of more than 98%.

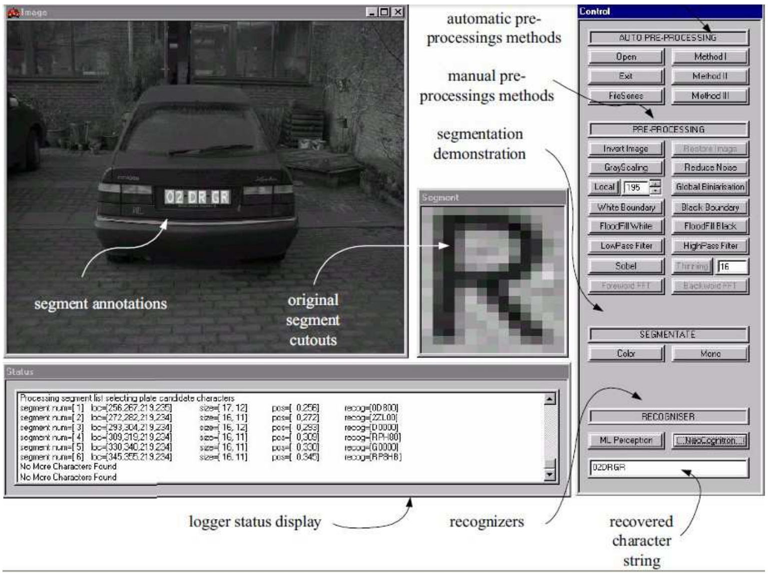

Fig. 10: License plate recognition

3.2 Analysis of car tracks

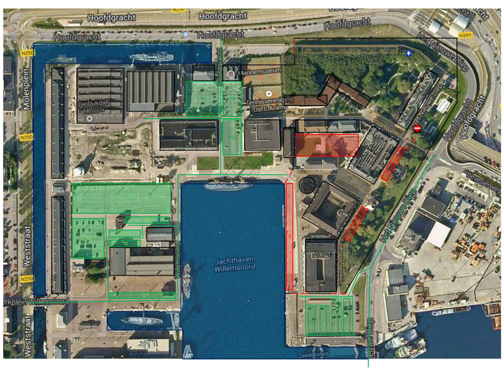

Fig. 11: Simulated military area split up in areas covered by a camera and a network of waypoints where cars can change directions

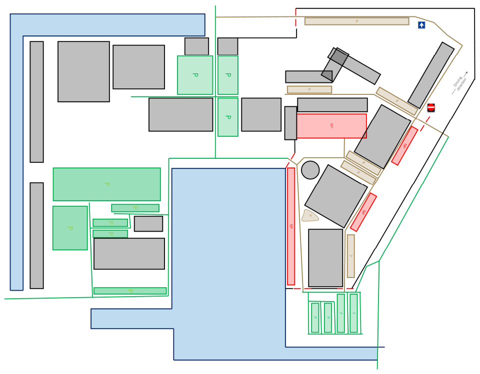

Fig. 12: Schematic visualization of the military area

The developed surveillance system is able to identify, localize and track cars [18, 48, 50, 51, 67, 68, 96, 109]. Cameras are attached to lamppost and every street is covered by a camera (see Fig 9). The cameras are equipped with software to detect moving cars using a simple background subtraction algorithm. The goal is to detect unwanted behaviour. Examples are:

- Violation of traffic rules (entering one way streets, neglecting speed limits, parking at forbidden places
- Showing unwanted driving behaviour (switching lanes, curved trajectory, streetcar races
- Entering Region of Interest (ROIs) around critical infrastructure (ships, military vehicles)
- Driving at wrong time and wrong place (driving in the middle of the night)
- Driving without clear goal or destination (wandering about, sleeping in the car).

Detection of unwanted behaviour is realized by context sensitive track analysis. The military area will be spit up in different section and for every section there is a list of unwanted behaviour given time and place in that sector.

Annotated maps
In Fig 11,12, the military area has been displayed (Google maps). It is necessary to highlight the streets with traffic signs, the parking places, the houses of commander and officers, the guesthouse, the sleeping houses, entrances of buildings, weapon room, ships, military vehicles, quays, squares, green fields, gates, entrances etc. Next we have to place the cameras and their vision field and the waypoints on the crossing points. As mentioned before moving objects as cars are localised and identified in the FOV of a camera. A trajectory is a sequence of waypoints or more precise as mentioned before a sequence of areas, with time of entrance and time of exit. As long as a car is moving it can be tracked. If it stops the car becomes invisible. More advanced object recognition software could be installed at the cameras but given the quality of the existing camera system and limited budget this was not an option.

Processing data
As mentioned before the information captured by an individual camera is displayed on a blackboard or a shared blackboard of neighbouring cameras. Basically we have to analyse trajectories of cars to detect unwanted behaviour. The system is very similar to the surveillance system of vessels as described before. The reasoning modules are implemented using rule based systems and Bayesian networks. More details can be found in [15, 19, 20, 23, 29, 3, 31, 36, 39, 40, 44, 45, 47, 57, 65, 71, 73, 74, 75, 90, 101]. Next we present some examples of the reasoning process:

- If a car is not visible on a trajectory, then either he turns around a corner and will be detected by a neighbouring camera on a crossing street in some time range or he stops , parked or is covered by other objects on the trajectory and is not detected by neighbouring cameras on crossing streets in some time interval
- If a car makes a U-turn and drives back, it will be detected by cameras at crossings streets at the beginning and not and the end of the trajectory
- If a car intrudes ROI of critical infrastructure t, stops for a while, this is suspicious behaviour
- If the time of entrance at a gate and time of arrival at a parking place passes some predefined threshold, then the car was driving too fast and an alert will be generated
- If a car enters the gate in the middle of the night and leaving after a while is

suspicious behaviour

- If a car has to be tracked or stopped by the safety guard, the position of the suspicious car can be computed by our distributed camera system.

3.3 Trajectory analysis of people

On the military area, people move from the entrance gate to one of the buildings or from one building to the other. People can be identified as moving objects and their tracks can be computed and analysed [8, 9, 33]. To detect unwanted or suspicious behaviour it is important to analyse where people are walking but also the way people are walking. For example a person walking straightforward from the entrance to the restaurant is probably a regular visitor. On the other hand a person wandering around and returning several time to the same location is either a disoriented person, or somebody unfamiliar with the environment or somebody with suspicious goals in his mind. To find a context sensitive semantic interpretation of tracks the environment has to be split up in Region Of Interest (ROI). For every ROI wanted or unwanted behaviour can be defined. Possible ROI's are the area around the entrance gates, area in front of the buildings, walking tracks between the buildings but also areas around the fences and grass fields. If somebody is detected in the area around the fences this is suspicious behaviour. But also hanging around the entrance of the building outside the smoking area is suspicious.
To localize and track people Mean shift algorithm was used together with the more recent Predator algorithms were both considered. The first algorithm uses colour histograms and the Bhattacharyya distance, while the second one is built on the Lucas-Kanade tracker, and provides long tracking by employing a P-N learning algorithm [8]. Both methods require an initialization phase in which the properties of the object to be tracked are computed. We reduce the manual intervention of the user, by incorporating context properties, which imply that every customer enters the area or leaving a building in a specific ROI. When a person is detected in the entering ROI, the tracker algorithm is started.
A first interpretation of the behaviour was extracted from the a person's walking patterns, which are relevant for deciding if the subject is familiar with the environment and the objects places or on the contrary is confused, looking for support or to execute criminal actions. Human walking patterns were described by their trajectories.
Special trajectory features were extracted (e.g. speed, acceleration, Euclidean distance, and curvature) and a spatial-temporal classification method was used (Hidden Markov Model), which enabled to discriminate between a 'goal oriented', a 'disoriented' or a 'looking around' or a running/fleeing type of visitor. Furthermore, trajectories are useful for extracting features of the relevant regions of interest in the environment (ROIs), facilitating the semantic interpretation of the behaviour.

3.4 Analysis of facial expressions and nonverbal behaviour at the entrance

Fig. 13: Entrance barrier at KIM-area

A visitor entering the KIM area has to show his ID-card. A visitor without ID card or in case of malfunctioning of the system he has to push the button and starts a dialogue with the guard. During the interaction the visitor shows his face to the camera build in the Intercom. This enables the system to check the identity of the visitor and if the visitor is on the list of suspicious persons or regular visitors. We developed face recognition system in Matlab using PCA eigenfaces as

described by A. Pentland [12, 27, 87, 93, 102]. Our system is trained using the FERET database. The recognition rate of our system in laboratory condition is 85%. Given the fact that the database of regular visitors is limited to about 250, the recognition rate limited to such a small database is more than 95 %.
In case the interaction visitor–guard is non optimal or if a visitor is not recognized by the system, this can result in a stressful situation. The emotional state of the visitor can be recognized by his facial expressions or by nonverbal behaviour such as gestures. We developed a system to recognize the emotional state of a visitor automatically.
The automatic recognition of facial expressions is based on the Active Appearance Model (AAM). The AAM model has proven to be a powerful tool for modelling deformable visual objects. Although they are linear in both shape and appearance, AAMs are nonlinear parametric models in terms of the relation between the pixel intensities and the parameters of the model. Fitting an AAM to an image consists of minimizing the error between the input image and the closest model instance; i.e. solving a nonlinear optimization problem. We used a fitting procedure for a 3D AAM, based on Kernel methods for regression. The statistics computed on data generated with our 3D AAM implementation show that the kernel methods give better results compared to the linear regression models [37, 42, 43, 54, 69, 76, 79, 89, 91, 99].
Following the use of active appearance models, we built descriptive face models based on geometric features. First, we selected a set of face landmark points on the face area from the set of key points handled by AAM. The landmark points are also called facial characteristic points – (FCPs), (see Fig. 14). The feature parameters are then computed as values of specific angles and/or Euclidean distances between FCPs. These features relate to the position of various facial features. The geometric features are assumed to reflect the onset of facial expression categories. Figure 15 shows how the variation of geometrical features correlates with the onset of each prototypic emotion.
Based on the nonverbal behaviour of people (facial expressions, way of speaking, posture, body language) we were able to assess emotions [7, 11, 17, 25, 26, 32, 34, 35, 38, 41, 46, 55, 59, 60, 61, 70, 72, 77, 78, 80, 86, 92, 94, 98, 100, 104, 105, 106, 107, 112, 113, 120, 121]

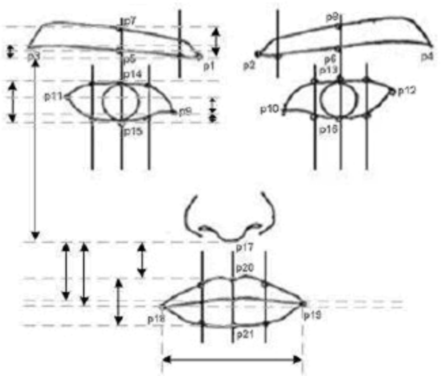

Fig. 14: Facial Characteristic Point model.

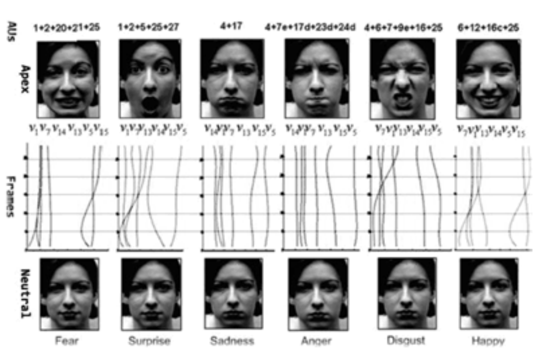

Fig. 15: The variation of FCP-based parameters for each facial expression.

3.5 Automatic gesture recognition

Stressful situations are likely to occur at human operated service desks, or at the entrance of military areas as well as at human-computer interfaces used in public domain. In those situation we can observe stressful nonverbal behaviour as facial expressions and gestures (See Fig.16). Automatic surveillance can help notifying when situations are getting out of hand and extra assistance is needed. Our goal was to investigate how multimodal communication, and more specifically speech and gestures, are used for conveying stress, and how they can be used for automatically assessing stress. As a first step, we proposed a model for how humans convey and perceive stress based on speech and gestures. We defined four variables that encode the extent to which stress is perceived by speech and gestures using the content of the semantic message, as well as the way in which the semantic message was delivered (e.g. intonation for speech, speed and rhythm for gestures). We annotated these variables in multimodal recordings, and based on the annotations we analysed the dominant cues for stress perception by humans and what is the relation between them. As a second step, we focused on the automatic assessment of stress. An open problem in automatic behaviour analysis is the semantic gap between the low

sensor features and the high level context sensitive interpretation of behaviours. To tackle this problem, we considered several speech and gesture related intermediate variables inspired from our model of human stress perception. We investigated what is their unique value for predicting stress and how to best fuse them. We compared this approach to a baseline stress predictor from audio and video low level features. We also investigated what is the added value of gestures over speech for our case study. We found that speech prosody is the dominant variable in conveying stress and also the best performing intermediate level variable for automatic stress prediction. The use of intermediate variables significantly improved stress assessment over the baseline of low sensor features. Using gestures increases the performance and is mostly beneficial when speech is lacking.
To analyse domain related human actions automatically the following approach was used. Several types of features were extracted and then using a classification approach for efficiently discriminating between the considered classes. We computed Optical Flow normalized Histograms (HOF) around the person to qua of the image patch into different number of blocks (HOF3x1, HOF1x3, HOF3x3, HOF4x4, HOF5x5, HOF6x6) for better capturing the motion associated with different body parts. Furthermore, we extended the HOF feature vector by proposing directional features which encapsulate up, down, inwards, and outwards type of motion. Next, we compared our approach to a state-of- the-art method consisting of computing space-time interest points (STIPs) composed of 5-bin histograms of optical flow (HOF) and 4-bin histograms of oriented gradients (HOG).For finding the best suited classification method for action recognition, we compared a set of different classifiers both spatial (e.g. Fisher, k-NN, SVM, Adaboost, LDC, QDC) and spatial-temporal ones (HMMs).
More details about the action recognition step can be found in [16, 58, 62,97].
Similar work is also reported in [10, 14, 21, 22, 24, 28, 56, 81, 82, 117, 118, 119].

Conclusion

In this paper we report about automated sensor surveillance systems. These systems were modelled after human observers. It proves that the systems were able to observer events in the environment, to reason about it and to take appropriate actions. Such systems are similar to agents based systems, in our terminology angel based systems. One of the research challenges was to give a semantic interpretation of observed data automatically. This was realised using knowledge based systems and probabilistic reasoning systems.
Prototype of sensor based surveillance systems have been developed and tested for a military area and the open sea. It proved that those systems were able to emulate the behaviour of human observers. This will solve the problem of current surveillance network. Surveillance cameras can be observed on many public places but there are not enough human operators available in the control room for real time monitoring the recorded video images.
Next future the developed prototypes will be developed to full systems. The systems will be used in surveillance systems of public spaces, shopping malls, surveillance of critical infrastructure, surveillance of traffic and surveillance of people in care centres and hospitals.

Fig. 16: Examples of gesturs at helpdesk.

The discussed research in this chapter is published in the papers [1, 5, 6, 7, 22, 24, 28, 31, 33, 34, 35, 40, 41, 43, 46, 48, 49, 50, 51, 54, 55, 57, 58, 61, 63, 66, 68, 69, 70, 71, 73, 75, 77, 81, 82, 84, 85, 87,88, 90, 92, 93, 96, 99, 101, 104, 111].

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Curriculum Vitae

Léon Rothkrantz is born at Kerkrade in 1946. After graduation at the HBS-B at Kerkrade in 1965 he joined the Dutch army in 1966. From 1967-1971 he studied Mathematics at the University of Utrecht. Next he started his PhD study from 1971-1975 at the University of Amsterdam under supervision of Prof. dr. H. Freudenthal and Prof. dr. W. van Est. He finished his PhD study on the subject: *Transformation Semigroups on non-compact Hermitean Symmetric Spaces.*
From 1975-1980 he worked as a teacher Mathematics at “De Nieuwe Lerarenlopleiding” at Delft. From 1980 he started his work at Delft University of Technology first as a as a student counselor. From that time he started his second study psychology at the University of Leiden and finished this study in 1990 on the subject *A-B typology*, under supervision of Prof. dr. L. van der Kamp.

In 1992 he started his job as an Assistant Professor and later as an Associate Professor Artificial Intelligence at Delft University of Technology (DUT) in the group Knowledge Based Systems headed by Prof. dr. H. Koppelaar.
Since 1998 he worked as a Professor Sensor Systems at The Netherlands Defence Academy (NLDA). In the meantime he was a visiting lecturer at the Technical University of Prague.
In 2011 he retired from DUT and in 2013 also from the NLDA.

Léon Rothkrantz supervised more than 150 MSc. students and 15 PhD students. He published more than 200 scientific papers in Journals and Conference Proceedings. He was involved in many National and European Research and Educational Projects. He is honored with golden medals from the Technical University of Prague and the Military Academy from Brno.

Since 1967 Léon Rothkrantz has been married with Fien Engels. They have three sons Ivo Remco and Cyril, three daughters in law Liset, Sabrina and Claire and at this moment 5 grandchildren Alyssa, Elin, Lana, Leonard and Willemijn.