Sensors and tracking crossing borders

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1. Introduction

Securing locations with many people is becoming an ever bigger challenge. It usually is a labor intensive and hence expensive activity, while qualified personnel is difficult to find. Both security customers and security companies are therefore both looking for technological- and process-innovation to make the work more effective (more security) and efficient (reasonable costs, little interference with the usual course of business) without violating the privacy of the people involved. To this end Schiphol Airport has, for example, set up her Progress Innovation Program [1].

A second problem in large public areas is that factors like mobility, costs, privacy, comfort and security-risks lead to conflicting choices. For example, automating part of the process in order to reduce costs often raises privacy concerns, whereas improving passenger comfort may increase security-risks.

A third problem is that in most security systems people and luggage pass various checkpoints one-by-one. Security systems are thus often implemented as a chain of single detections, such as camera's, luggage scans, and metal detectors. Each control point thereby has an incomplete view of reality, since it is ignorant of the information obtained at other locations. The result is that decisions about risks and security alerts are based on incomplete information and independent of any earlier observations.

2. MUSTIC:integral risk-based security

The MUSTIC concept (Multiple Sensors Threat Intervention Corridor) aims at identifying risks of visitors and travellers on the basis of integral observation. This includes combining data from different sensors, with additional data from human observations. Integral observation hereby means that observations from different sources are judged in combination rather than in isolation.

In principle any sensor, including human observations, can contribute to the concept. For the first generation the main candidates for sensors could be face detectors, metal detectors, explosives detectors, nuclear detectors and body scanners.

Different from common practice to pass checkpoints one-by-one in a sequential manner with earlier checks having no bearing on later checks, we propose an integral evaluation of all sensor readings in one step. In this approach one still passes the sensors in a sequential way, but the sensor outcomes by themselves are no longer decisive and are only added to a person's track record. The risk profile is then the result of integral evaluation of the track record at the end of the process with, for example, pattern recognition techniques.

Recently, technology has progressed to a stage where such a new approach is feasible. More specifically, tracking people in crowded situations is on the verge of breaking through and can be used to switch from the earlier sequential approach to this novel integral and risk-based approach [2][3].

In this new approach people are automatically and anonymously tracked as they move through the public area. For each person a track record is built up with security related observations (by people or by sensors) which are linked to their track as shown in Figure 2. Only when this track record exceeds a certain risk-level the identity of the person involved might be disclosed and some privacy may be reduced. Thus, although MUSTIC might appear to decrease privacy as everyone is exposed to a large number of sensors and the data of these sensors are combined, it can actually lead to better proportional privacy for the majority of people.

This can be illustrated by using the NAIHS cognitive systems model [4] to structure the information streams in MUSTIC. At the Impact Assessment level the decision can be made whether processing or storing data at Signal, Object or Situation Assessment is proportional to the goal at hand.

Tracking can also be used to create a virtual sensor array by linking observations on people over time and space. Such an array is more robust and has better accuracy and quality than single sensor-systems. For example, rather than having one single human-controlled metal detection gate, one could combine the observations by multiple simple uncontrolled metal detection sensors in the area into a virtual sensor with the same accuracy, but without the long waiting lines.

Research related the MUSTIC concept can be found in [5], where RADAR and camera tracking are combined. In [6] chemical sensors and camera tracking are combined. Our approach can further be mapped onto the NAIHS cognitive systems model [4] at the Signal Assessment level with respect to collecting security related observations and at the Object Assessment level with respect to integrating these measurements into track records. This is further illustrated in Figure 2 where signals are collected in a person's track record (Signal Assessment). These signals are then interpreted and grouped at the Object Level (Object Assessment), using tracking over time and place.

3. Implementing MUSTIC

Introduction of the MUSTIC concept must be gradual as stakeholders first need to learn more about the behaviour and the statistics involved in the domain. Typically the implementation should progress from more constrained to less constrained demands on users and environment. A first generation implementation could act as a tool to collect information about threads and human behaviour.

MUSTIC lends itself for an introduction in cycles. This includes both the development of new sensors and the development of tracking systems. To anticipate on expected future developments MUSTIC is defined in an open, purely functional architecture. The communication between sensors and information systems is not limited to specific detection techniques.

Introducing MUSTIC in several generations also allows the different technologies involved (tracking, sensor concepts, pattern recognition, and information fusion) to gradually adapt to the problem at hand. In the beginning not all knowledge on risks and human behavior will be available. However, during introduction of the different generations and in order to

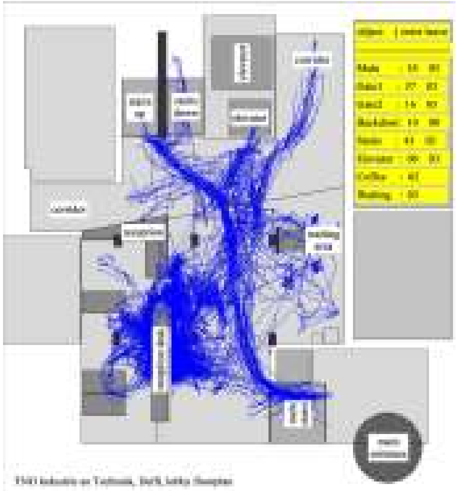

Figure 1. Traces and statistics of about 65 people who were tracked with multi-camera tracking while they entered the TNO lobby within a timeframe of 20 minutes.

make maximal use of the new information available from the first generations it is important to store (part of the) data and allow researchers to use this data to develop and improve technology.

In addition tracks can also be used to obtain information about behaviour and contacts between individuals. It is expected that more research is needed into human behaviour in order to make proper use of this kind of information. MUSTIC can make a valuable contribution to this research by making available large amounts of data.

4. Multi-camera tracking

Robust tracking of people can be used to match different sensor readings to the correct person. The coupling of sensor readings to individuals based on tracking poses high requirements on the tracking as errors in tracking lead to contamination of the data in the track records.

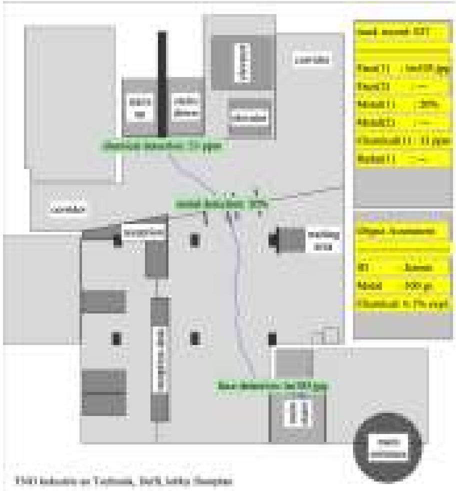

Figure 2. Track of one person going from the main entrance to the stairs to the first floor. The figure shows possible measurements which are added sequentially to the track record as the person navigates the lobby.

To perform robust tracking we have used multi-camera tracking. In particular occlusion of people by objects or other people can be solved in the multi-camera setting [3][4]. Recent developments in tracking people with multiple cameras are very promising with respect to accuracy and robustness against threads like occlusion and broken tracks. We expect that multi-camera tracking (perhaps in combination with other tracking methods) can mature to accurate tracking within a couple of years. Multi-camera tracking thereby has the additional advantage that observed people have very limited possibilities to influence the tracking system, in contrast to, for example, RFID and GSM based tracking methods which allow one to simply pass the tracking device to someone else.

To test multi-camera tracking as a backbone for the MUSTIC concept in a real

but limited world domain, we have realized a live demonstrator in the lobby of the main TNO building. This demonstrator was build with the following important guiding principles from the start on:
(1) The system is designed and implemented to perform real-time tracking,
(2) We have not made optimizations that cannot be applied in real world situations. The camera viewpoints are all set relatively low, since in most indoor applications overview cameras from high viewpoints will not be available. Also difficult lighting conditions (shadows, bright sunlight) are present at the test location as these are common practice in real world situations.

The system at the TNO lobby consists of 8 high-resolution IP cameras. These are connected to a set of processing computers through a 1GB LAN. All material used is 'commercial-off-the-shelf' (COTS). The camera positions and tracks resulting from about 65 people walking through the lobby in a timeframe of 20 minutes are shown in Figures 1 and 2.

5. Discussion

By describing MUSTIC in an open functional architecture, we think it offers a viable roadmap for the public and private sector, while facilitating all sorts of transparent and auditable information streams. As stated in chapter 3, MUSTIC elegantly offers, and simultaneously benefits, from a cyclic introduction in real world scenarios.

By building a live robust tracking system with COTS hardware, we have shown that multi-camera tracking is indeed a viable technology for the near future.

MUSTIC will benefit from ongoing investments in tracking and sensors. Future work includes building and refining a model that predicts the performance of Signal- and Object Assessment, performance parameters of individual sensors and the quality of tracking.

The MUSTIC information architecture is also exceptionally well suited to be embedded into a legal framework because Signal-, Object-, Situation and Impact Assessment are well separated.

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