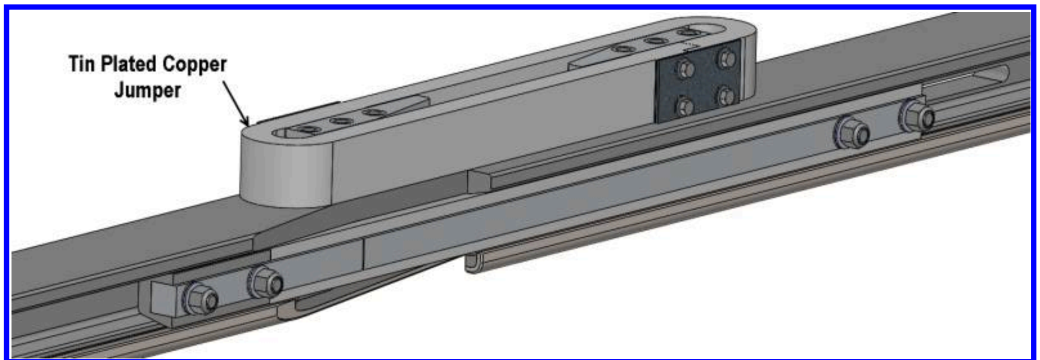

Figure 19:Air Gap expansion shown with jumper cover removed

4th Rail Side Contact Airport APM

An airport APM system uses an overlapping finger gap expansion joint with jumper cables. The extensive cabling for each expansion joint was a concern to designers from both an installation and maintenance cost stand point. See figure 20. The overlapping finger gap expansion joint was redesigned to incorporate a shorter stroke and a laminated jumper. See figure 21. This new design will increase the number of expansion joints needed on the system but eliminate the need for the cables at each expansion joint with an overall net savings and a simplified installation.

Figure 20: Overlapping finger gap expansion joint using jumper cables

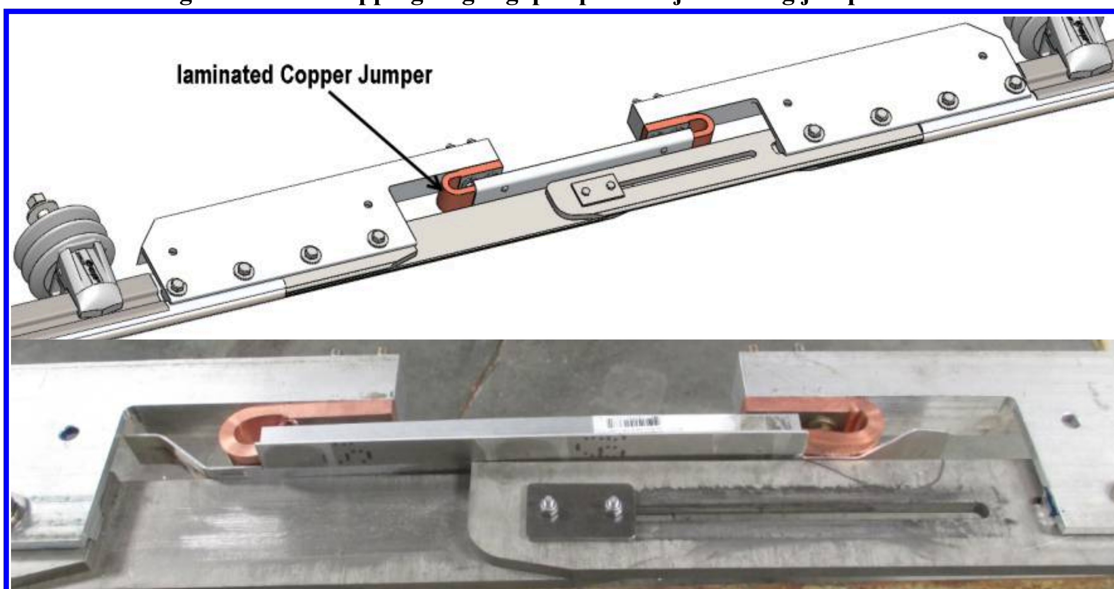

Figure 21: Overlapping finger gap expansion using laminated jumper

CONCLUSION

There are a myriad of solutions for expansion management in AL/SS power rail systems and this white paper only gives a general over view of the possibilities. Each system will have its own conditions and unique requirements which will dictate the optimal expansion joint design.

By understanding the environmental, physical, and electrical conditions of the entire system and considering the necessary design inputs at the beginning of the design phase, the AL/SS power rail system can be designed with proper expansion management for consistent reliability and optimal performance.

REFERENCES

Adle, J.M., (1957). “Kaiser Aluminum Bus Conductors Technical Manual”, Kaiser Aluminum & Chemical sales, Inc., Illinois

ASCE 21.3 (2008), “Automated People Mover Standards, Part 3” ASCE, Virginia

Figures [1- 21] Conductix-Wampfler, Inc.

Forman, K. (2015, August 25). Global Director of Transit, Conductix Inc. Personal interview

Kirkpatrick L. (1989). “Aluminum Association Handbook”, the Aluminum Association, D.C.

Lim, M. (2015, October 30). Engineering Manager, PS&D Transportation Division, SNC-Lavalin Inc. Personal interview

NFPA 70 (2014), “National Electric Code”, National Fire Protection Association, Massachusetts

An Innovative System to Detect Obstacles on Rail Tracks

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Abstract

Since urbanization continues at a rapid pace, more and more people live in cities. Hence, urban transports systems face an ever increasing ridership demand. As a consequence, many transport operators consider turning conventional (driver-based) systems into automatic operation to increase performance and provide more reliable train service. If converting an existing subway line into fully-automatic operation, the safety of passenger on platforms becomes a vital aspect. An intrusion detection system based on stationary video cameras and intelligent image processing has therefore been developed with dedicated focus on railway safety requirements. Once, the system detects suspicious behavior or a person on the track, central control can be informed and a braking signal can be sent directly to the train via ATP. Since not only the station track is a hazardous zone but passengers standing too close to the platform edge can be at danger as well, a complementary safety function is provided. A 50 cm wide strip at the platform edge is supervised and an audio announcement can be triggered to request people to step back so as to even prevent people from getting too close to the track. This system has been implemented and tested in various installations, e.g., with the Berlin subway operator (BVG) and the subways of Nuremberg and Munich. The system architecture, related safety aspects as well as the operational experiences are presented in this paper.

1 Introduction

Protecting the guideway from intrusions or detecting intrusions and provide an alert to central control is explicitely considered by two standards at the moment. First, there is the ASCE 21 standard which applies to Automated People Mover systems (ASCE, 2013) and there is a more specific standard which describes safety requirements for automatic subways in Germany (VDV, 2000). While the first one is dedicated to APMs in general the latter one was explicitly created for the first automated subway line in Germany in Nuremberg. Both standards allow two technical solutions, which is either a complete physical separation of the guideway from the platform, e.g., platform screen doors, or a detection system to supervise the guideway for intrusions.

Although the installation of platform screen doors (PSD) is appropriate for most green field applications, many existing subways face serious problems when retrofitting PSDs. This includes but is not limited to:

- Different generations of trains with different door locations require very wide screen doors or even prohibit the installation of doors because the PSDs cannot be matched with all possible combinations of doors from different train models.

- Narrow platforms and emergency exits may become less easily accessible. Adequate amount of space for people waiting for trains is not available anymore. Fast and sufficiently spaced emergency exits / walkways are not available anymore upon installation of platform doors.
- Structural deficiencies of existing platforms require extensive civil work to reinforce them. Usually, existing platform are not able to bear the substantial load of additional doors installed close to the edge. Therefore, the platforms need to be re-enforced which can cost nearly as much as the doors themselves.
- Further aspects, e.g., architectural considerations, may play a role when retro-fitting PSDs.

A more flexible and cost-efficient solution to protect passengers from accidents with trains is required in such cases. Intrusion detection systems may then provide a serious alternativ (Parris, 2015). Once a person or a large object infringes the train clearance an alarm is generated and then transmitted to central control and/or the Automatic Train Protection system to stop the train in front of the person or obstacle.

Several technical solutions based on different technologies have been developed in the past some of which have been abandoned (e.g. infrared light barriers) while others are considered serious options for future use.

A general overview of existing technologies is given in Table 1.

Table 1. Characteristics of platform protection systems

		Platform Screen Doors	Contact Sensors	Active Electronics (IR-Light, RADAR, LASER)	Video Image Processing	Thermal Imaging
selectivity between persons and objects		not necessary, (physical barrier)	not possible	not possible	possible; recognize and differentiate objects, persons, trains	detection of "cold" objects? detection of warm people in hot environments?
availability and maintainability		high, proven equipment difficult to retrofit	availability limited by high number of components and false alarms (vandalism), requires extensive maintenance (requires service interruption)	limited (many electro-magnetically active components in dirty environment); vandalism, maintenance requires service interruption	high availability, proven (few) standard cameras with high MTBF Central Control "sees" obstacles repair/maintenance requires only short or no track access	medium availability , still special technology low maintenance; regular (!) re calibration?
cost structures	**invest**	high	medium	medium	low	medium
	ownership	medium	high	high	low	medium
extendibility		no extended functions	no extended function additional cameras required for alarm investigation and acknowledgement	no extended function additional cameras required for alarm investigation and acknowledgement	additional functions for security alarm image also used for investigation and alarm verification purposes	additional functions for security difficult to use for CCTV operators, additional camera necessary for alarm investigation

Nowadays, there is a very strong tendency to move from single sensor solutions (implemented and tested in the past) to a combination of several sensors. This strategy shall help combine advantages and disregard disadvantages from two or more technologies (Fernández, 2013). The solution described in this paper is based on a dual-sensor approach comprising video cameras with image processing and laser scanner technology.

2 System Architecture and Functionality

2.1 System Structure

The system uses stationary video cameras as sensors which are situtated along the platform edge depending on the platform infrastructure (length, bend, tunnel height). The exact number of cameras is determined by the geometry of the station and must be designed taking into account the site-specific characteristics. They supervise the problematic areas of the platform (platform edge strip, platform intrusion area) and station tracks in all scenarios (no train in station, incoming train, train at regular stop during passenger exchange, outgoing train, passing skip stop trains).

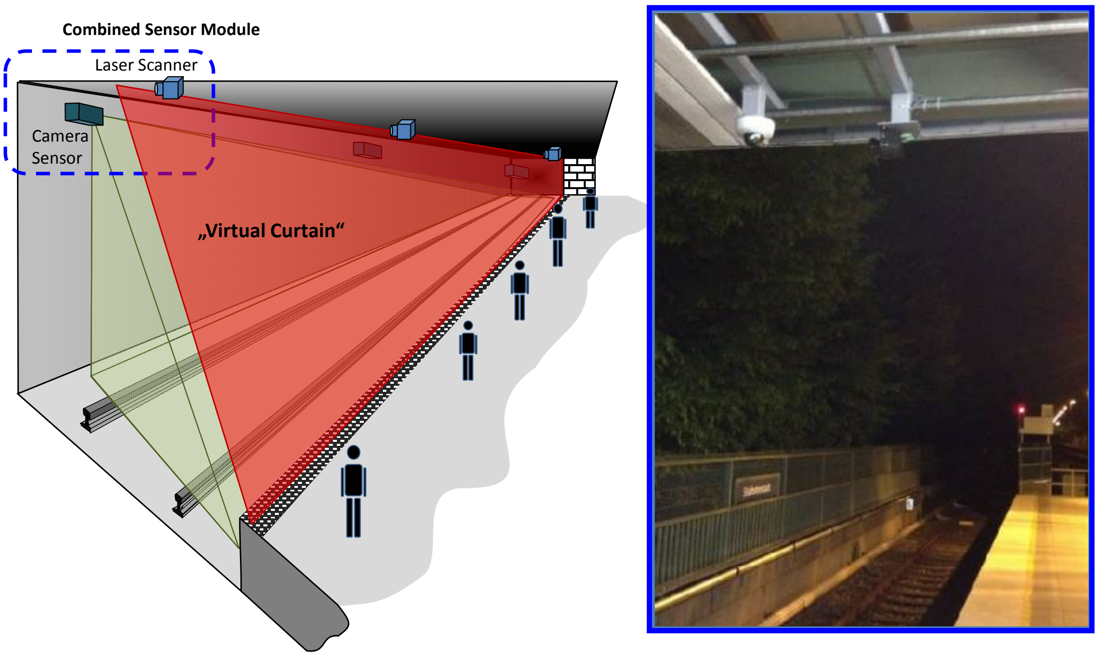

Figure 1. Generic sensor architecture and field installation of sensor module (camera + laser attached to ceiling)

Image sequences captured by the cameras are transmitted to evaluation computers that use robust and safe image processing techniques to detect persons and obstacles, specifically designed according railway safety standards and paradigms. The object detection itself includes only a restricted and validated set of methods, such as motion detection, comparison with reference images, detection of texture discontinuity, as well as usage of specific object features. The system reaction in a situation of danger is determined by the size of the detected object. The system can recorgnize different train types based on a generic train model. Maintenance and trackwork vehicles are also recognized like passenger trains.

The requirements for the size of critical objects of current guideway intrusion detection standards result in approximately one camera per 35m track section. This guarantees images with objects of proper resolution. The camera installation point itself is flexible, the only requirement is a position from which each of the cameras have “visibility” of the full track section ahead and the platform edge itself, preferably also a warning strip along the platform.

Camera sensors are complemented with laser scanner modules to form a „Virtual Curtain“ along the platform (see Figure 1). Preferably, the laser scanners are mounted vertically over the edge of the platform. This virtual curtain then serves as an additional discriminating sensor level to reduce the number of unjustified alarms significantly. Both standards, the ASCE 21 as well as the VDV 399 (ASCE 2013, DVD 2000), require to detect people and objects that move from the platform to the track. This virtual curtain perfectly fits this requirement and helps suppress false alarms caused by something else, e.g. trash on the track. Furthermore, the laser sensors alongs the platform edge can also be used for additional supervision tasks, such as to support the departure signal of trains (nobody stands to close to train, all train doors are closed, no obstructions due to trapped objects) if required.

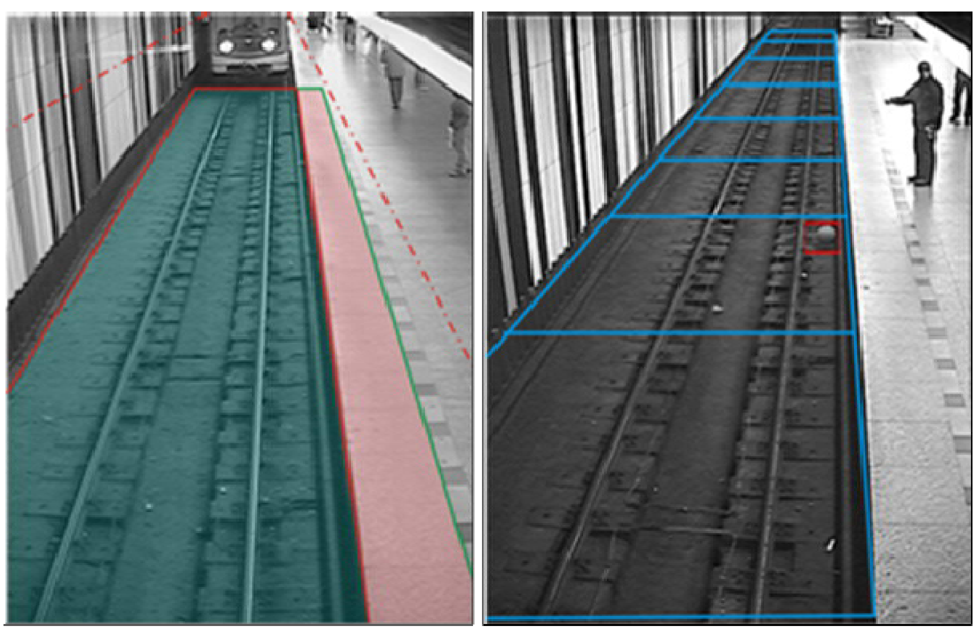

Figure 2. Camera supervision sectors at the track (green) and warning strip along the platform edge (red)

2.2 System Functions and Interfaces

The overall track surface area and train clearance profile as well as the platform edge are continuously supervised for people and objects that approach the platform edge or move from the platform onto the track (see Figure 2).

In case of a detection of movements of persons and objects from the platform into the track area, the system outputs the discrete signal “Track Obstacle Alarm” in all other cases the system outputs the discrete signal “No Track Obstacle Alarm”. The system continuously supervises its health status, e.g. valid image, no frozen image, sufficient image brightness. Should some of these checks fail, the system will trigger a System Health Status, indicating the technical failure status. A warning signal is output in case a passengers stands inside a defined warning zone near the platform edge, e.g. a 50 cm wide strip for a certain time. This function is deactivated while trains are in the station in order not to be disturbed by normal passenger exchange. In order to help investigate the situation (remotely) when an alarm is transmitted to Central Control, the video signal with view on the track and on the platform edge is supplied, too.

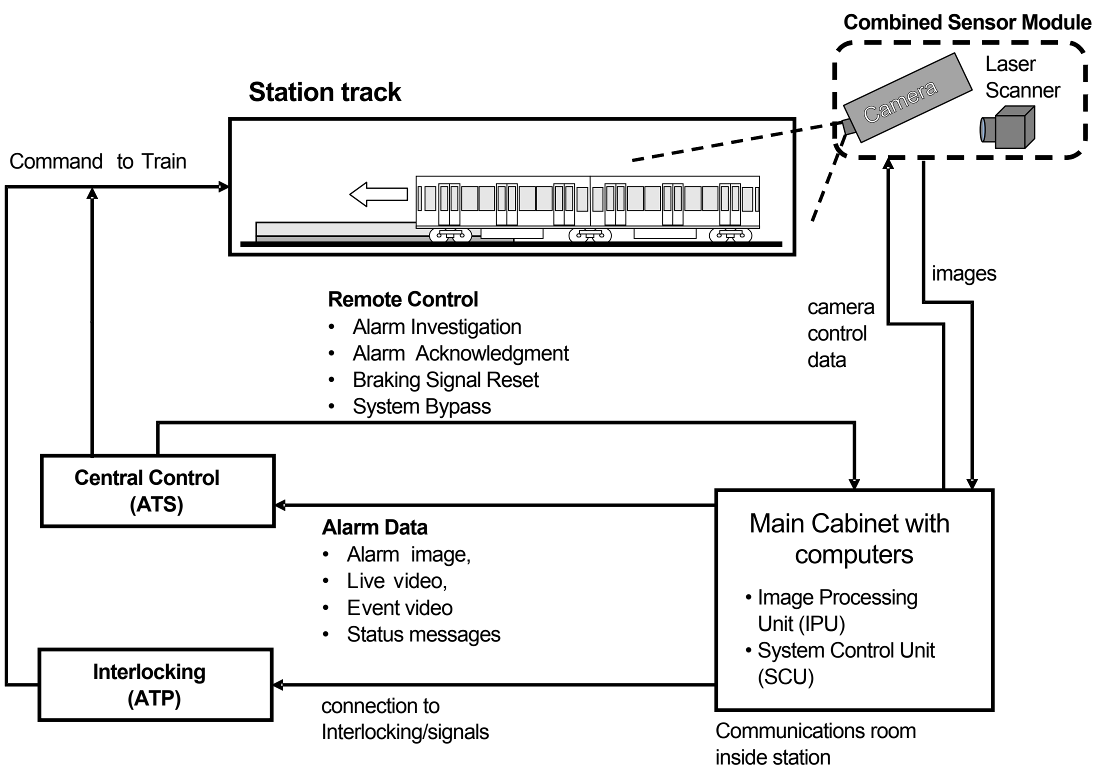

Figure 3. System main elements and interfaces

2.3 Event Data Storage and Archiving

The Guideway Intrusion Detection System (GIDS) Safety-Kernel software logs every Track Obstacle Alarm together with date, time, camera id and camera image (with red indication frame, see Figure 5).

Complementary, a video sequence is stored as well that captures a certain period of time before and after the incident. The exact time can be configured during installation. Typically, some 1 or 2 minutes are recommended. All protocols and logging data are stored on a separate archive PC which can be accessed via any standard FTP client application.

3 Software Architecture

3.1 Algorithmic Steps and Principles

The image processing software is the critical part of the system. Typical image processing methods and software libraries have been investigated from a safety point of view whether they are suitable for use in railway environment or not. However, they were found inappropriate to meet the high requirements on safety, including necessary safety proof, verification and validation. Common object detection or tracking algorithms combined with object classification methods such as Artifical Neural Networks or Support Vector Machines depend on a representative sample of incident data. However, this can never represent all kinds of people or dangerous objects. Hence, a generalization of such classification algorithms to properly categorize between endangered small people (such as children) and larger objects (such as a two playing birds) will never be complete. Such approaches had therefore been discarded.

Instead, the developed detection software is solely based on robust and simple image features, e.g. grey value distributions, variance distribution, which can be statistically proven with significance analyses. Thus, a quantitative analysis of the potential wrong side failure rate is possible to demonstrate a sufficient level of safety.

The specific image processing software consists of three basic methods which are combined:

- Difference Image Evaluation and Motion Detection
- Gray Value Pattern and Significance Analysis
- Logical Combinations and Context Implication

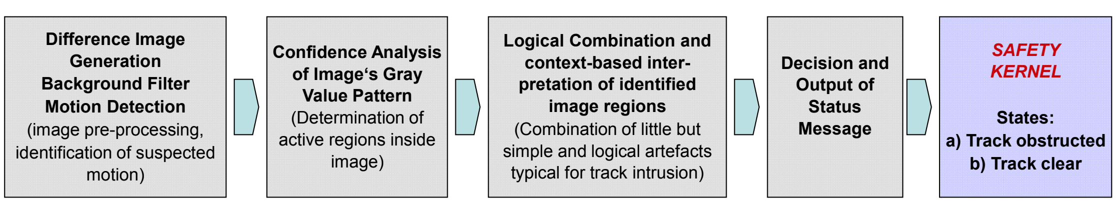

Figure 4. Processing Steps of Track Intrusion Safety Kernel software

The calibration data of the cameras and the infrastructure data (track area, edge area, intrusion area) are determined during the system engineering phase and will then be accessed as fixed parameter sets by the image processing software.

The Difference Image Analysis and Motion Detection is an important part of the pre-processing since it helps to discriminate static or (very) slowly changing image artefacts or features (e.g. setting sun illumination levels, fading lamps etc.) from the critical and interesting elements such as trains or persons. On the other hand, it has been made sure by calculation, analysis and long year's field statistics that "real" persons and objects cannot move so slowly from the platform edge into the track area that they could escape the analysis.

For the GIDS Safety-Kernel, the grey value distribution of the difference image pixels is utilized to reach an extraordinarily high significance for the detection of parts of the images that are associated with obstacles. In addition, absolute grey value distribution analysis is utilized to check undisturbed reference settings.

The activated pixels and groups of pixels, which are marked as significantly different from the normal background are used to estimate the size of the object. This estimated size value is then compared with a predefined table of threshold values which correspond to the Critical Threshold Value of e.g. 30-40 cm as a diameter value.

The Logical Combination and Context Implication investigates only basic circumstances such as "The dangerous/endangered obstacle moves somehow from the platform area into the track area", "Obstacles are physically heavy objects, if they float in the air over the track they will fall down until they hit the track ground" or "If a train is standing at a station for passenger exchange, the train occupies a dominantly large fraction of the track area". The few basic circumstances are evaluated for checks such as counting regular train entrances or failure detection of the equipments.

In essence, the GIDS Safety-Kernel employs (only) techniques that can be validated in the sense of railway signalling safety analyses to demonstrate SIL 1 equivalence. Elements of this are a restricted use of software instructions, avoidance of parameter adjustments, no dynamic configurations of whatsoever, avoidance of branchings in the code, no intermediate or nested decision statements, no complicated transformation of features/image parts etc., failure modes and effects evaluation without acceptance of residual failure states (full coverage), proof readings, etc.

3.2 Measurement of Critical Object Size

If an object or a person in the train clearance envelope is larger than a certain size, the Guideway Intrusion Detection System will trigger an alarm to approaching trains.

Some intrusion detection solutions consist of only discrete channels of information, e.g. light beams, laser scanner beams or radar beams, which scan the area above the track. Any object entering the area will accordingly be sensed through its cross section in the scanned projection layer. Since a standing person in the track (e.g. a child) presents only a smaller footprint to the scanning systems, a small value of 30 cm needs to be selected to ensure sensitivity to smaller persons. Smaller values were found unnecessary and can affect availability since objects like bottles or smaller birds would increase the number of unjustified alarms.

On the other hand, human persons of an age above six years are characterized by other values than only a one dimensional projection. Taking for example the full cross section area of a smaller person would always result in real person "cross section areas" (see Figure 5).

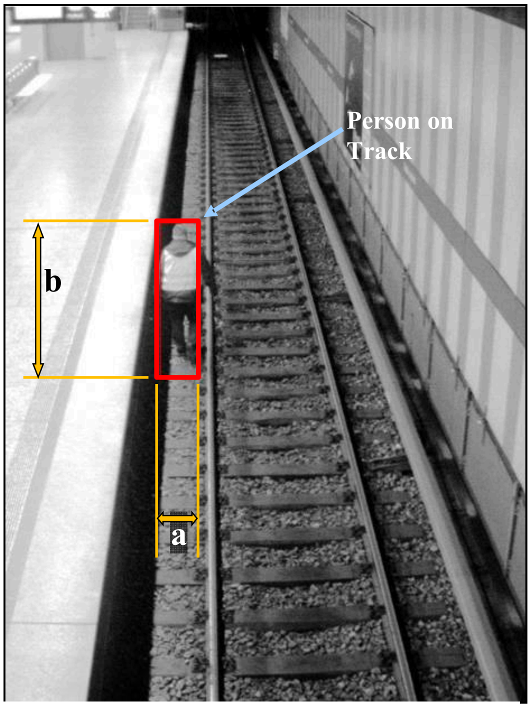

Figure 5: Detection of Person on Track and 2-Dimensional Measurement of Size

The TelSys Video GIDS has the advantage of measuring actually real cross section areas of objects (a surface of *a* times *b*) instead of "only" one dimension (length). The standard setting of the system is, however, such, that a 30cm diameter ball (test body by most operators) is safely detected.

The image analysis algorithm has the capacity of detecting even intruding sizes of well below this value and has in addition the advantage of detecting always the full cross section area of intruding elements instead of a more or less one dimensional cross section diameter. This feature can also be used to optimize safety and operational availability.

Since the Video GIDS supervises in addition not only one two-dimensional plane but the full three-dimensional train clearance profile, also smaller objects like arms or legs of persons infringing the train clearance (e.g. persons sitting on platform edge) can be detected, if required.

4 System Operation

If the supervision system has detected a person or an object of critical size, then the images of the track area can be automatically transferred to the central control room. Complementary, the alarm images are stored on the wayside image processing computers and kept for future investigation purposes.

The Central Control operator application is set up as a straightforward and easily operable Graphical User Interface (GUI) running on a laptop-style computer. Its main purpose is to

- Alert Central Control staff in case of an intrusion alarm detected by an audible alarm message,
- Pop up a graphical video image of the detected alarm scene including a red frame indication around the object that has triggered the alarm,
- Provide video camera streams of the track and in particular of the camera triggering the alarm
- Provide a log file in terms of a message list

The application's GUI is partitioned into three major parts (see Figure 6)

- An Alarm List of incoming alarms (on the left side of the screen)