Measure Name Closed-circuit television and other detection systems

Definition Closed-Circuit Television (CCTV) detection systems to differentiate a person from other objects on the right-of-way and deliver an alert on site or to local law enforcement.

Tags

Incident Type	Both trespass and suicide
Location	Both station and right-of-way
Intervention Strategy	Engineering: technological and physical deterrents
Measure Group	Detection and lighting

Description

Detection systems including closed-circuit television (CCTV) can identify the presence of a moving object in a restricted area and deliver an alert to appropriate railroad personnel or to local law enforcement. These systems may also provide an automated response to trespassers, such as an alarm or recorded warning message.

CCTV Detection Systems

The intent of this measure is to reduce trespassing and suicide within a specific area. CCTV detection systems can monitor an area for unauthorized access. Some systems may require real-time monitoring to detect a trespasser, while others use more advanced technology for detection, such as artificial intelligence (AI). Non-intelligent CCTV systems can display live footage from a camera or set of cameras from a remote location. An individual monitoring these cameras can identify persons located in a restricted area and determine a course of action for removal. This process may include activating an alert at the scene [1] or dispatching railroad personnel or local law enforcement [2]. CCTV detection systems require sufficient bandwidth to send high-quality video data to be monitored [3]. It is also essential to create a plan to respond to activation [3].

CCTV detection systems can use AI to detect people in the ROW, including those who are considering suicide. An AI system relies on a computer vision algorithm to review the video footage and detect the presence of a person in a specific restricted area. This detection could automatically activate an alert to deliver a pre-recorded warning via loudspeaker, as well as send live alerts to railroad personnel or local law enforcement. For more detailed information on these types of detection systems, their components and types of machine learning used, refer to reference four (i.e., Zhang et al., 2022) [4]. The U.S. Department of Transportation (USDOT) developed an AI software called Grade Crossing Trespass Detection (GTCD) for automatically detecting grade crossing violations and trespass activity and outputting the identified trespassers as tabular data along with annotated video files of trespass events [5].

CCTV detection is most effective in a targeted area with a high concentration of trespassers, such as a footpath across a track, bridge, or tunnel [1]. This measure may also be effective at known suicide hotspots. For an intelligent CCTV system to be effective, it should activate in every instance where an individual is trespassing while minimizing activations in other circumstances (e.g., the wind blowing

debris across the track). This is especially true for detection systems integrated with police dispatchers, as excessive false alarms could result in alarms being muted [2].

One example for a successful setup of a detection system includes three cameras, each streaming live over the Internet, with one at a grade crossing and two at railroad ROWs. This setup allows quick detection and alerts that can be sent to the railroad carrier or local law enforcement by text message or email [6]. There is also the potential for AI algorithms to detect behaviors that may indicate that someone is in distress or at imminent risk for suicide [7].

CCTV video data provides valuable information to help railroads better understand the circumstances surrounding trespass and suicide incidents occurring at a specific location on the rail system. For example, an intelligent CCTV system can automatically log information about trespass activity at a particular location. This helps assess typical pre-incident behavior and identify situational conditions around trespass and suicide incidents [8].

A 2024 study describes a railroad trespassing database that uses CCTV and artificial intelligence. This database serves as the basis for a before-and-after analysis of any implemented solutions at the chosen sites. If expanded, this system can also evaluate the effectiveness and cost-benefit ratio of measures addressing trespass incidents, and helping railroads and federal authorities enhance public safety. Although the study's scope is confined to specific locations, the system offers stakeholders an example of the data and potential analyses that can be performed. The dashboard is accessible via the Rutgers Rail and Transit Team’s Trespass Database [9].

Non-CCTV Detection Systems

Not all detection systems require video footage to identify the presence of an individual in restricted areas. Other technologies—including passive infrared sensors, radar, light detection and ranging (LiDAR), and fiber technologies—can deliver a pre-recorded warning via loudspeaker or send an activation notice to appropriate railroad personnel, a private security service, or a police dispatcher [1] [10]. Use of infrared sensors and an automated sound warning has been found to reduce trespassing between 18 percent and 44 percent at locations with known trespass issues [1].

The cost of detection systems can range from a few thousand to tens of thousands of dollars depending on the type of sensors and/or cameras, and if the system is monitored actively (e.g., private security service or police dispatcher). The cost to operate and maintain the system can be more than total cost of the system itself [3]. For a review of different detection systems and sensors used around the country, see reference nine (i.e., Warner et al., 2022) for a more in-depth evaluation [11].

Additional search terms: *artificial intelligence*, AI, *camera, recordings, surveillance, videos,*

Advantages

- AI algorithms have been shown to detect trespassing events and achieve near perfect accuracy in some settings [6].
- GTCD can be applied at nearly any rail grade crossing/ROW where video can be collected without requiring additional training of the computer vision models [5].

- CCTV and other detection systems integrated with a police dispatcher system can support rapid law enforcement response and oversight over the ROW [2][3].
- Two short-term studies found reductions in trespassers from 18 percent to 60 percent [1][3].

Drawbacks

- Specialized knowledge is needed to setup and maintain an AI system.
- GCTD's accuracy is lower when dealing with skewed camera angles or in conditions of poor visibility [5].
- Strong processing power is needed to support video in real time.
- Access to a high-speed network is required for the most advanced CCTV systems to work reliably [6].
- Much of railroad ROW lacks easy access to commercial power. Battery powered systems need to be considered and maintained regularly [1].
- Example trespassing events are required to train the AI system to work properly [6].
- In some locations, existing cellular infrastructure is insufficient to provide uninterrupted high-definition video from multiple cameras [2].
- False positives and false negatives caused by false activation detections or activation failures can occur when using AI-based technology [9].
- Law enforcement officials may have a low tolerance for false alarms and mute the alarms if they became too frequent [2].
- Yearly operation and maintenance cost of a system can exceed the initial cost of implementing the system [1][2]. The use of cameras or drones as surveillance in or around train tracks near residential communities should be clearly indicated to address any privacy questions/concerns that may arise with individuals [11].
- It is impossible to watch every location along a railroad right-of-way [12]. Research is essential in determining hotspots to monitor.

Notable Practices

- For intelligent systems, the AI must be able to accurately detect trespassers under a wide variety of conditions (video artifacts, shadows, headlight glare, and other distortions), and environmental variables (e.g., rain, snow, day, night, and fog) [6].
- For intelligent systems, the AI must be able to process frames with sufficient speed to maintain a fast response time to trespassing events [6].

- Intelligent systems may be an effective way to assess before and after impacts of certain events or countermeasure implementations [9].
- Installing "backup or redundant components, such as an extra sensor, could be used temporarily in case the primary sensory component failed" [3].
- Install a mechanism to disable the warning notice during maintenance of track by authorized personnel [3].
- Ensure that the broadband connection enables constant live surveillance and instantaneous alarm notification. A lag in video feed relative to when the sensors detect an intruder could lead to a trespass event being categorized as false alarm [3].
- Detection systems should be reliable under the range of lighting and weather conditions, as well as cyber-attack intended to disrupt image capture, transmission, processing, and storage [4].
- Develop a trespass incident detection procedure to ensure that the response to a trespass event is appropriate and consistent [3].
- Develop an operation and maintenance plan for addressing a range of situations, including positive detection of intruders or obstacles in the ROW, or failure of the warning system [3].
- Detection systems with sound warnings are best suited at locations where trespassers are concentrated in a small area, such as a footpath across railroad tracks, bridge, or tunnel [1].
- For systems using video motion detection, consider cutting back vegetation or redrawing detection zones for systems using video motion detection as the seasons change [2].
- Data integrity and equity considerations should be considered and be free from gender and racial bias [4].
- Place warning and prohibitive signs near the detection system to help convey that an area is restricted.

References

[1] Kallberg, V.P, & Silla, A. (2017). Prevention of railway trespassing by automatic sound warning—A pilot study. *Traffic Injury Prevention*, 18:3, 330-335.

Abstract

Objective: The objective of this study was to investigate the effects of a sound warning system on the frequency of trespassing at 2 pilot test sites in Finland.

Methods: The effect of automatic prerecorded sound warning on the prevention of railway trespassing was evaluated based on observations at 2 test sites in Finland. At both sites an illegal footpath crossed the railway, and the average daily number of trespassers before implementation of the measures was about 18 at both sites.

Results: The results showed that trespassing was reduced at these sites by 18 and 44%, respectively. Because of the lack of proper control sites, it is possible that the real effects of the measure are somewhat smaller.

Conclusions: The current study concludes that automatic sound warning may be efficient and cost effective at locations where fencing is not a viable option. However, it is not likely to be a cost-effective panacea for all kinds of sites where trespassing occurs, especially in countries like Finland where trespassing is scattered along the railway network rather than concentrated to a limited number of sites.

[2] Barron, W. and daSilva, M. (2020). *Trespasser Detection Systems on Railroad Rights-of-Way*. Technical Report No. DOT/FRA/ORD-20/34. Washington, DC: U.S. Department of Transportation, Federal Railroad Administration.

Abstract: The U.S. Department of Transportation's Volpe Center, under the direction of DOT's Federal Railroad Administration Office of Research, Development, and Technology, conducted a research study to evaluate the effectiveness of trespass detection technology on rail property linked to and controlled by a local police department. The system was operated for several years, while different communications and sensor technologies were tested for their abilities to overcome shortcomings. Researchers found that wireless broadband service in this area was insufficient in providing uninterrupted high-resolution video from multiple cameras, and while TV white space transceivers had adequate bandwidth, their short transmission range limited their usefulness. Providing live video directly to the local police department resulted in quick response to trespassing events; however, dispatchers were particularly unhappy with false alarms.

[3] DaSilva, M., Barron, W. and Carroll, A. (2012). *Railroad Infrastructure Trespassing Detection Systems Research in Pittsford, New York*. Technical Report No. DOT/FRA/ORD-06/03-1. Washington, DC: U.S. Department of Transportation, Federal Railroad Administration.

Abstract: The U.S. Department of Transportation's Volpe National Transportation Systems Center, under the direction of the Federal Railroad Administration, conducted a 3-year demonstration of an automated prototype railroad infrastructure security system on a railroad bridge. Specifically, this commercial-off-the-shelf technology system was installed at a bridge in Pittsford, New York, where trespassing is commonplace and fatalities have occurred. This video-based trespass monitoring and deterrent system had the capability of detecting trespass events when an intrusion on the railroad right-of-way occurred. The interactive system comprised video cameras, motion detectors, infrared illuminators, speakers, and central processing units. Once a trespass event occurred, the in-situ system sent audible and visual signals to the monitoring workstation at the local security company where an attendant validated the alarm by viewing the live images from the scene. The attendant then issued a real-time warning to the trespasser(s) via pole-mounted speakers near the bridge, called the local police, and then the railroad police, if necessary. All alarm images were stored on a wayside computer for evaluation. The system was installed in August 2001 and evaluated over a 3- year period ending in August 2004. This paper describes the results of this research endeavor. Topics addressed include the project location, system technology and operation, system costs, results, potential benefits, and lessons learned. The results indicate this interactive system can serve as a model for railroad infrastructure security system for other railroad ROW or bridges deemed prone to intrusion.

[4] Zhang, T., Aftab, W., Mihaylova, L., Langran-Wheeler, C., Rigby, S., Fletcher, D., ... & Bosworth, G. (2022). *Recent Advances in Video Analytics for Rail Network Surveillance for Security, Trespass and Suicide Prevention—A Survey*. Sensors, 22(12), 4324.

Railway networks systems are by design open and accessible to people, but this presents challenges in the prevention of events such as terrorism, trespass, and suicide fatalities. With the rapid advancement of machine learning, numerous computer vision methods have been developed in closed-circuit television (CCTV) surveillance systems for the purposes of managing public spaces. These methods are built based on multiple types of sensors and are designed to automatically detect static objects and unexpected events, monitor people, and prevent potential dangers. This survey focuses on recently developed CCTV surveillance methods for rail networks, discusses the challenges they face, their advantages and disadvantages and a vision for future railway surveillance systems. State-of-the-art methods for object

detection and behaviour recognition applied to rail network surveillance systems are introduced, and the ethics of handling personal data and the use of automated systems are also considered.

[5] Bedini Jacobini, F., & Ngamdung, T. (2022). RAILROAD TRESPASS DETECTION USING DEEP LEARNING-BASED COMPUTER VISION. *FRA Office of Research, Development & Technology*.

The U.S. Department of Transportation (US DOT) John A. Volpe National Transportation Systems Center (Volpe), under the direction of the Federal Railroad Administration (FRA) Office of Research, Development, and Technology (RD&T), developed an Artificial Intelligence (AI) software application for automating the detection of grade crossing violations and trespass activities from static camera video feeds. Volpe researchers conducted the work from 2020 to 2021. The Grade Crossing Trespass Detection (GTCD) software application outputs predicted grade crossing violations and right-of-way (ROW) trespassing as tabular data in MS Excel format along with annotated video files of trespass events. An example of video processing output showing pedestrian and vehicles traversing a grade crossing in Ramsey, NJ, during an activation is shown in Figure 1.
Accurately detecting when a trespass event occurs using standard video input reduces the time needed to collect safety data. Currently, railroads and many state DOTs have a wealth of video data on their systems, but that data is generally only analyzed if there is a documented incident. Automated identification and processing of trespass events from the existing video data may yield significant safety data currently not being analyzed. This software application is available for download at https://public.huddle.com/b/jPDLGE/index.html.

[6] Zaman, A., Ren, B. and Liu, X. (2019). Artificial Intelligence-Aided Automated Detection of Railroad Trespassing. *Transportation Research Record: Journal of the Transportation Research Board, 2673*(7), 25-37.

Abstract: Trespassing is the leading cause of rail-related deaths and has been on the rise for the past 10 years. Detection of unsafe trespassing of railroad tracks is critical for understanding and preventing fatalities. Witnessing these events has become possible with the widespread deployment of large volumes of surveillance video data in the railroad industry. This potential source of information requires immense labor to monitor in real time. To address this challenge this paper describes an artificial intelligence (AI) framework for the automatic detection of trespassing events in real time. This framework was implemented on three railroad video live streams, a grade crossing and two right-of-ways, in the United States. The AI algorithm automatically detects trespassing events, differentiates between the type of violator (car, motorcycle, truck, pedestrian, etc.) and sends an alert text message to a designated destination with important information including a video clip of the trespassing event. In this study, the AI has analyzed hours of live footage with no false positives or missed detections yet. This paper and its subsequent studies aim to provide the railroad industry with state-of-the-art AI tools to harness the untapped potential of an existing closed-circuit television infrastructure through the real-time analysis of their data feeds. The data generated from these studies will potentially help researchers understand human factors in railroad safety research and give them a real-time edge on tackling the critical challenges of trespassing in the railroad industry.

[7] Bernert, R. A., Hilberg, A. M., Melia, R., Kim, J. P., Shah, N. H., & Abnousi, F. (2020). *Artificial Intelligence and Suicide Prevention: A Systematic Review of Machine Learning Investigations*. *International Journal of Environmental Research and Public Health, 17*(16).

Abstract: Suicide is a leading cause of death that defies prediction and challenges prevention efforts worldwide. Artificial intelligence (AI) and machine learning (ML) have emerged as a means of investigating large datasets to enhance risk detection. A systematic review of ML investigations evaluating suicidal behaviors was conducted using PubMed/MEDLINE, PsychInfo, Web-of-Science, and EMBASE, employing search strings and MeSH terms relevant to suicide and AI. Databases were supplemented by hand-search techniques and Google Scholar. Inclusion criteria: (1) journal article, available in English, (2) original

investigation, (3) employment of AI/ML, (4) evaluation of a suicide risk outcome. N = 594 records were identified based on abstract search, and 25 hand-searched reports. N = 461 reports remained after duplicates were removed, n = 316 were excluded after abstract screening. Of n = 149 full-text articles assessed for eligibility, n = 87 were included for quantitative synthesis, grouped according to suicide behavior outcome. Reports varied widely in methodology and outcomes. Results suggest high levels of risk classification accuracy (>90%) and Area Under the Curve (AUC) in the prediction of suicidal behaviors. We report key findings and central limitations in the use of AI/ML frameworks to guide additional research, which hold the potential to impact suicide on broad scale.

[8] Ceccato, V., Wiebe, D. J., Vrotsou, K., Nyberg, U., & Grundberg, A. (2021). The situational conditions of suicide in transit environments: An analysis using CCTV footage. *Journal of Transport & Health, 20*, 100976.

Abstract: Introduction: We explore the use of CCTV footage to map suicidal self-injurious behavior on a subway platform to better understand the settings and the situational conditions of individuals just before they attempt suicide.
Methods: We use footage from CCTV cameras for gaining new insight into the situational conditions that relate to suicidal self-directed violence in the transit system in Stockholm, Sweden. We adopt a space-time budget template to record, step-by-step, what happens over time as individuals on the platform wait for an incoming train. The analysis applies visualization tools (VISUAL-TimePAcTS) and uses a cross-over design to identify risk factors associated with suicide.
Results: Findings show that suicide risk varies both temporally and spatially. Among all types of possible behaviors and places, being close to the edge of the platform of the opposite direction of the train and crossing the security line – this behavior and place combined – are associated with increased risk of suicide.
Conclusions: We confirm that using CCTV footage as data source provides valuable insight into relevant situational conditions in which suicides take place, which can be useful to inform prevention strategies, particularly information about behavior and place combined. The article concludes by reflecting upon the importance of these results for future research.

[9] Zaman, A., Huang, Z., Li, W., Qin, H., Kang, D., Liu, X. (2024). Development of Railroad Trespassing Using Artificial Intelligence. Technical Report No. DOT/FRA/ORD-24/09. Washington, DC: U.S. Department of Transportation, Federal Railroad Administration.

Abstract: The Federal Railroad Administration (FRA) sponsored a research team from Rutgers University to develop a proof-of-concept Trespassing Database using Artificial Intelligence (AI) technology to automatically process large volumes of live or recorded video data. The team used the Rutgers AI algorithm to analyze over 27,000 hours of live video data and 1,176 hours of recorded video data from rights-of-way and grade crossings at 11 locations in 6 states. The AI algorithm collected trespassing-related data, including traffic, rail signal activations, train events, and trespass events. Trespass event data were automatically collected for each trespasser, including date, time, type (e.g., person, car, truck, bus, motorcycle), weather, trespasser's path, and a video clip. The team manually validated all trespass event detection results to ensure that accurate data was included in the database. Over 29,000 trespass events were detected by the AI algorithm across all studied locations in this research. This report also presents two year-long, in-depth case studies of one grade crossing in New Jersey (21,202 trespass events) and one right-of-way (ROW) location in North Carolina (476 trespass events). This report provides temporal and spatial analyses of trespass events and discusses AI-informed mitigation strategies.

[10] Catalano, A., Bruno, F. A., Pisco, M., Cutolo, A., & Cusano, A. (2014). An Intrusion Detection System for the Protection of Railway Assets Using Fiber Bragg Grating Sensors. *Sensors*, *14*(10), 18268–18285.

Abstract: We demonstrate the ability of Fiber Bragg Gratings (FBGs) sensors to protect large areas from unauthorized activities in railway scenarios such as stations or tunnels. We report on the technological strategy adopted to protect a specific depot, representative of a common scenario for security applications in the railway environment. One of the concerns in the protection of a railway area centers on the presence of rail-tracks, which cannot be obstructed with physical barriers. We propose an integrated optical fiber system composed of FBG strain sensors that can detect human intrusion for protection of the perimeter combined with FBG accelerometer sensors for protection of rail-track access. Several trials were carried out in indoor and outdoor environments. The results demonstrate that FBG strain sensors bonded under a ribbed rubber mat enable the detection of intruder break-in via the pressure induced on the mat, whereas the FBG accelerometers installed under the rails enable the detection of intruders walking close to the railroad tracks via the acoustic surface waves generated by footsteps. Based on a single enabling technology, this integrated system represents a valuable intrusion detection system for railway security and could be integrated with other sensing functionalities in the railway field using fiber optic technology.

[11] Warner, J. E., Lee, D., Trueblood, A. B., Cline, J. C., Johnson, N. A., & Christjoy, A. (2022). Strategies for deterring trespassing on rail transit and commuter rail rights-of-way, volume 1: Guidebook. *Washington, D.C: The National Academies Press.*

Objective: This guidebook is intended to provide information on strategies to deter trespassing on rail transit and commuter rail exclusive and semi-exclusive rights-of-way, including within station areas outside designated pedestrian crossings. In general, trespassing is accessing rail transit and commuter rail restricted areas without permission or proper authorization, intentionally or unintentionally. The guidebook documents the extent of trespassing in the United States; existing decision-making guidance that agencies can utilize; causes, consequences, and risks associated with trespassing; mitigation countermeasures to reduce trespassing risks; and tools that agencies can utilize to identify possible mitigation strategies for a particular trespassing problem or concern.

[12] Sueki, H. (2021). Railway suicides are less likely to occur on rainy days: Evidence from Japan.

Background: Patrols at stations and along railway lines can reduce the number of railway suicides; however, it is not sufficiently clear when railway suicides are most likely to occur. Aim: We examined the relationship between daily rainfall and the occurrence of railway suicides. Methods: We received the locations and daily data on the occurrence of railway suicides from a major railroad company in Japan. We also collected rainfall data from the Japan Meteorological Agency database for a roughly central locations of the railroad company. The study covered a period of five years, from April 2016 to March 2021. Results: Suicides occurred on 23 rainy days (3.9%) and 92 nonrainy days (7.4%). The incidence of suicides on rainy days was significantly lower than that on non-rainy days. Limitations: We were not able to obtain daily data on the number of rail passengers; therefore, could not rule out the possibility that the suicide incidence rate is lower on rainy days because the number of railroad users is lower on such days. Conclusion: Information about the weather could be used to improve the efficiency of patrols to prevent railway suicides.

Related Measures

- Identify access points for potential trespassers

- Identify and monitor hotspots
- Identify funding opportunities
- Improved data collection after an incident
- Incident cost estimation
- Lighting at hotspots
- Platform fencing
- Improving the safety of individuals experiencing unsheltered homelessness
- Removal of obstructions to increase visibility
- Risk assessment using forward facing CCTV
- Unmanned Aircraft System (UAS) for detection