**A Research Proposal**

**For**

**A Subway Platform Safety System**

**By**

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## Paedia LLC

Paedia LLC is a product development company based in San Francisco, CA. Its principals, Douglas Clark and Brian Brown have a long history of product development in imaging, printing, and safety. More information is available on their website at www.paedia.com.

Dr. Clark is a patentee on the first commercial real-time ultrasound medical scanner sold in the U.S. This is significant in the discussion below. At Paedia, Dr. Clark and Mr. Brown invented and patented a novel work zone intrusion alarm, the SonoBlaster!™ , a FHWA Accepted NCHRP 350 Approved Category II Safety Device.[1]

## A Transportation Safety Problem in Need of a Solution— Subway and Train Platforms for Pedestrians

Subway and train platforms place waiting passengers at great risk. Passengers have fallen or been pushed from the platform and onto the tracks. Some of these passengers have been killed by the fall, electrocution by a third rail, or being hit by a train. Others have been saved through quick action of other waiting passengers who either hide them in a safe place near the tracks or lift them back onto the platform. In these instances, nothing is done to alert a train driver ahead of the station so that the train can be safely stopped or slowed in time to prevent injury to those on the tracks.

Various safety measures to keep people from falling onto train tracks have been tried and proposed, with little success. For example, in Bay Area Rapid Transit (BART) stations in the San Francisco Bay Area, yellow, textured paving strips have been placed at the platform edge to alert waiting passengers to the danger presented by approaching trains. The Metropolitan Transportation in New York City has proposed placing automatic sliding doors at a platform's edge that remain closed until a train has stopped and is ready to accept passengers. The paving strips are inexpensive and don't offer much protection. The doors offer protection but are very expensive and require substantial retrofits to subway stations. We propose an intermediate solution.

## A Selected Accident Statistic

In a selected example, a suicidal passenger climbed down into the track area of a San Francisco Bay Area BART (Bay Area Rapid Transit) station, laid down on the tracks, waited for a train to arrive and was injured.[2]

## Overview of a Train Station—Figs. 1 and 2

In the descriptions below, the term subway station also includes passenger train stations, livestock stations, and the like wherein conveyances receive and discharge passengers, including humans and livestock, above and below ground. A train comprises a railroad or subway train, a truck, a bus, and any other conveyance that transports passengers to and from a station. A subway station comprises a space where passengers congregate and wait for the arrival of a train.

**A Train Passageway.** Figs. 1 and 2 respectively show plan and cross-sectional views of a terminal in a subway or train station. A typical subway station comprises a trackway, a plurality of tracks, a plurality of ties to which the tracks are secured and which are also secured to a rigid foundation . The station also includes a crawl space or pit into which a passenger can climb in order to avoid being struck by an oncoming train. One or more tunnels or non-pedestrian areas generally determine the boundaries of a station.

One or more "third rails" are electrically insulated from their surroundings and secured to the track foundation. The third rails are connected to an electrical supply, typically 640 volts, that powers a train. The electrical return is through the train car rails. In some stations, a third rail next to the passenger platform is absent so that a passenger who falls from the platform will not be electrocuted. In this case, power is supplied through a third rail on the opposite side of the tracks. Some trains use pantographs, i.e. trolleys on the top of a train, which contact overhead wires instead of a third rail. In this case, the overhead wire is connected to an electrical supply and the electrical return passes through the train's wheels.

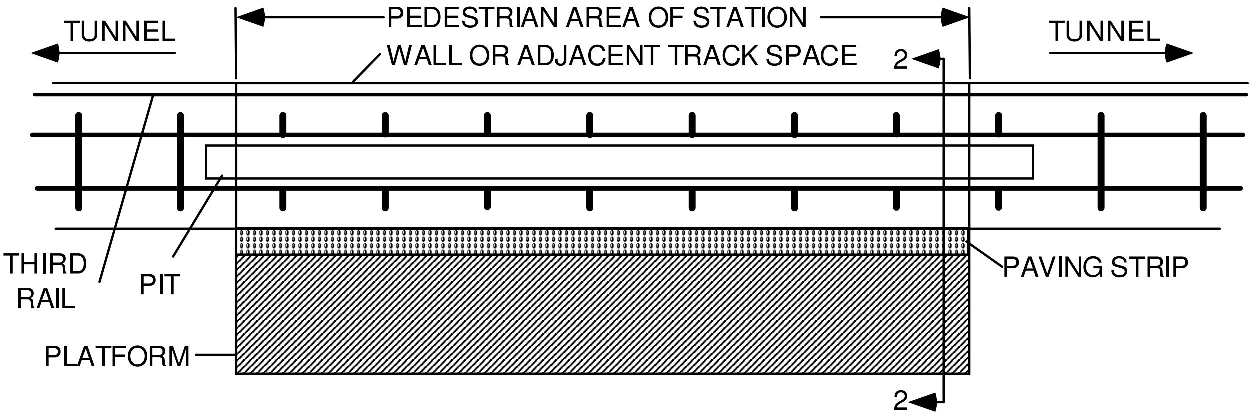


Fig. 1

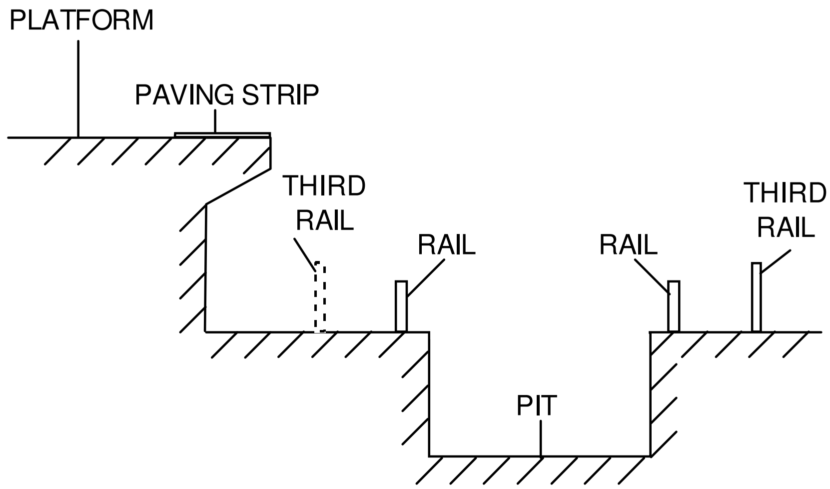


Fig. 2

**A Pedestrian Space.** Passengers embark and disembark from a train in a platform area. A brightly-colored, textured paving strip is located at the edge of the platform that is nearest the trackway. When a train is stopped at the station, the edge of a passenger car is located directly adjacent the platform, i.e., typically within 1-2 inches. At this time, the train's doors are opened by an operator so that passengers can safely enter and leave the train.

## Overview of Train Controls—Figs. 3 through 5.

Fig. 3 is a block diagram that shows a train that is operated by manual controls. A train engineer uses levers, buttons, and pedals to provide the functions of starting, controlling speed, stopping, and reversing a train. The train is commonly used for freight-hauling, track maintenance work, and general railroad yard use. It is usually powered by diesel fuel or electricity. Other controls include those that cause track switching, regulate air conditioning, deposit sand on tracks for traction, open and close doors, and the like.

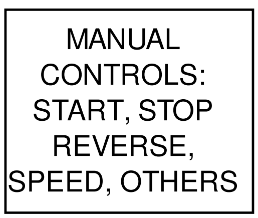


Fig. 3

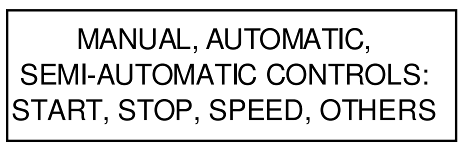


Fig. 4

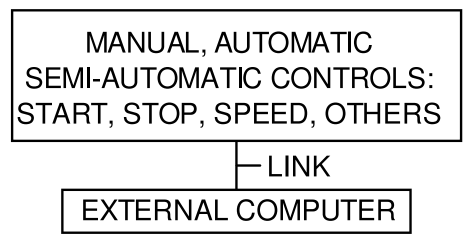


Fig. 5

Fig. 4 shows a train that is operated by both manual and automatic controls. The train includes automatic or semi-automatic controls in addition to manual ones. For example, a train engineer uses levers, buttons, and pedals to start a train in motion and a computationally-capable system maintains the train's speed at a predetermined value. The train is commonly used for freight and passenger hauling and is powered by diesel fuel or electricity.

Fig. 5 shows a train that is operated by manual and automatic controls and in addition receives operating instructions from an external computer. The computer can be located within the train or remotely at another physical location. This train is used in modern subways and passenger trains. In some cases, the external computer communicates with the train's automatic controls via a link to start, stop, and set the speed of the train. For example, a subway train operates automatically under the control of an external computer and its own internal computational capabilities. When a train is stopped at a station, doors open and then close. When the doors close after passengers board, the train's engineer presses a button that signals a computer and the computer then issues instructions via a link to the train's internal controls that in turn cause train to accelerate. The external computer monitors the position of the train and issues instructions for the train to stop at the next station, all in well-known fashion.

## A Solution[3]

We have discovered and devised a method and apparatus to improve safety at train platforms. Our system offers more protection than paving strips, yet is less costly than automatic sliding doors. Our system applies equally well to the above-described train types.

In our system, an array of ultrasonic sensors constantly monitors a volume of space around train tracks. Ultrasonic sensors, similar to those used on automobiles, are used because they are rugged and not adversely affected by the dirt and grime found on and near tracks in subway and train stations, as would be the case with optical cameras.

An imaging and detection system associated with the ultrasonic sensors constantly surveils a volume defined by a space between a platform and a region on the far side of the tracks in the horizontal direction, and the bed that supports the tracks, and at least the height of a platform in the vertical direction. This volume of space is called a track space. Our system detects the presence of an object, including a human, which is larger than a minimum size within a track space. An object of minimum size might be a rat or bird, for example. Both animals are commonly found in subway and train stations.

Our system constantly records and analyzes a digital image of the track space. In the event that an object such as a person or animal enters the space, a computing system with software algorithms analyzes the image, looking for size and movement of the object. If the object meets predetermined criteria, then the system issues an alarm. The alarm can be in the form of warning lights and sounds within an oncoming train or at a point near the train tracks that is located at or before the oncoming end of a platform. It can also be a digital alarm that is conveyed to a train's control system, such as a local (within the train) or remote (train substation or headquarters), or to an operator of a train. A train operator or a computer system that controls operation of a train can slow or stop the train before an intruding object is struck. A third rail can be deactivated to eliminate the possibility of electrocution. While our system cannot prevent injury or death to a person who is pushed or falls off a platform just as a train reaches the spot where they're standing, our system is designed to prevent injury or death when there are longer stopping times. Response time of our system is measured in fractions of a second so that action can be taken very quickly.

For documentation purposes, a record can be maintained that includes the latest 5 minutes (or another interval) of surveillance. This record can be used to determine a sequence of events in the event of an intrusion onto train tracks, for example. For more information, an alarm opens a closed container and activates a video camera that is stored inside. The video camera stores information from the time an alarm is issued until it is manually stopped or runs out of memory.

**Ultrasonic Sensors—An Overview—Figs. 6 and 7**

Figs. 6 and 7 show a typical ultrasound sensor in use. An ultrasound sensor is connected to driver and receiver electronics that are controlled by a computer. In Fig. 6, the driver electronics cause a sensor to emit a beam of ultrasound that is made up of a short pulse of waves. The waves leave the sensor and strike an object. In Fig. 7, the waves strike the object and are reflected back at the sensor and recorded by receiver electronics. There are many other kinds of ultrasound sensors. Sound in air travels at about 1120 feet/second so a sensor will detect an object 20 feet away in about 18 milliseconds x 2 = 36 milliseconds.

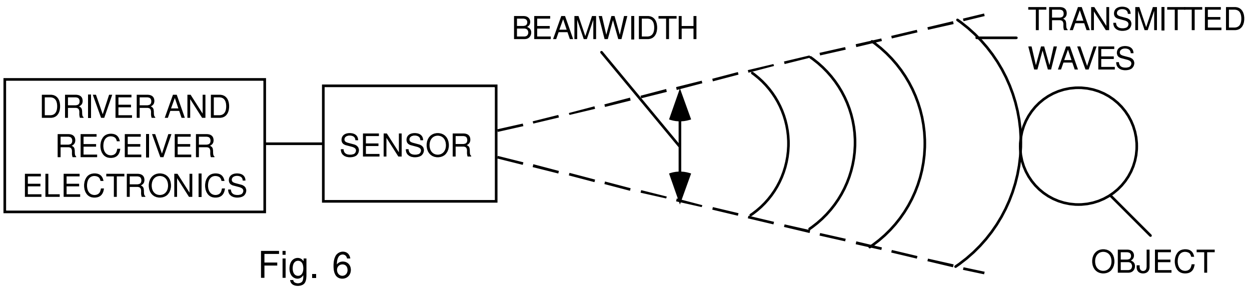


Fig. 6

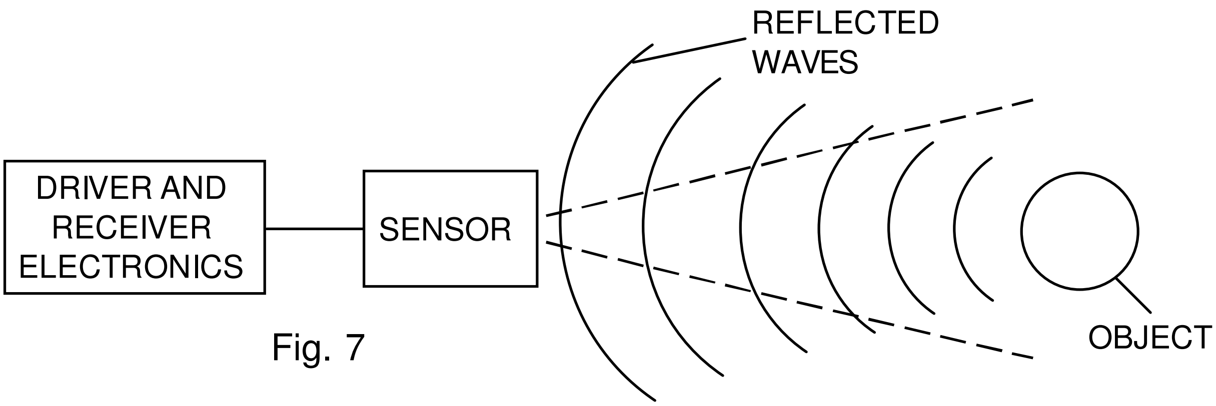


Fig. 7

**Locations of Sensors in a Subway Station—An Example—Figs. 8 and 9**

Fig. 8 is a cross-sectional view of a train station showing various placements of ultrasonic sensors. A line of sensors (Fig. 9) is located in a crawl space underneath a platform. In this location the sensors are well protected from mechanical and other kinds of damage. Other locations are on a wall opposite the platform or on a ceiling above a train. The horizontal and vertical beamwidths are chosen to include the entire track space, as defined above.

Fig. 9 is a view of a train station as seen from the tracks, as indicated by the arrows in Fig. 8. This example shows 13 sensors. The number of sensors used depends on the beamwidth of the individual sensors. Beamwidths range from about 1 to 120 degrees. For sensors with a beamwidth of 30 degrees, the spacing between sensors in this example is about 3 feet. Sensors L1, L2, R1, and R2 detect the arrival and departure of a train. Sensors A through I detect objects in the track space.

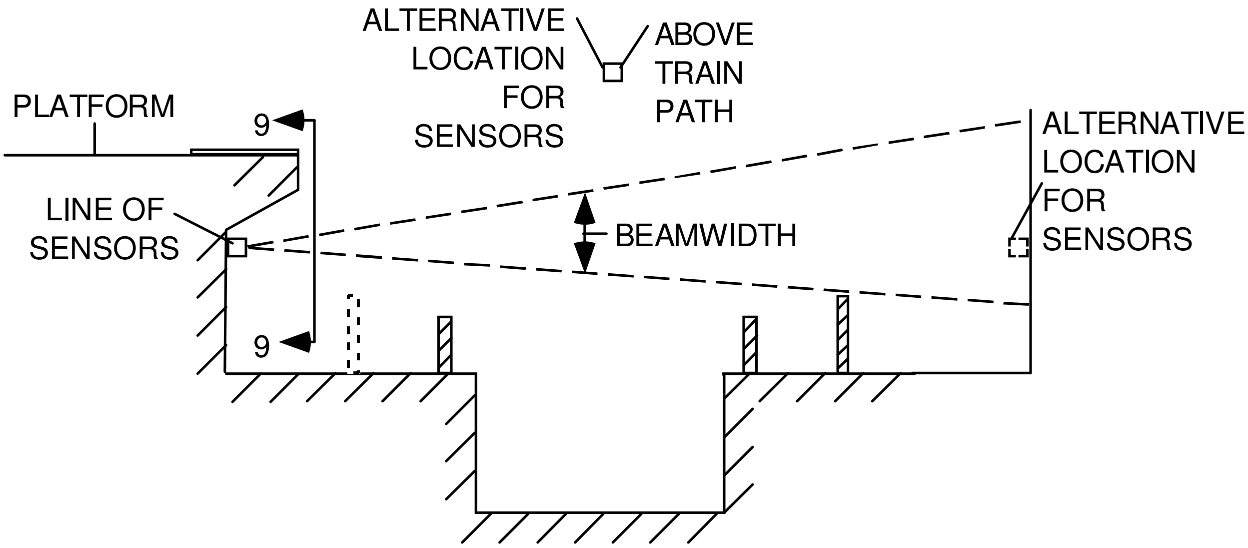


Fig. 8

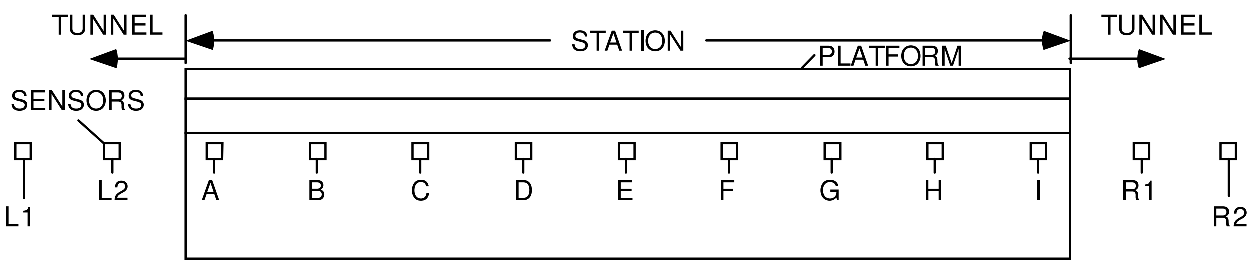


Fig. 9

**Alarm System—An Example—Fig. 10.**

Fig. 10 is a schematic block diagram showing an exemplary operating system. A computing device such as a computer or microprocessor has at least some standard features such as a display, keyboard, mouse, memory, input/output capability and alarm capability. When the computing device is energized, one or more algorithms control aspects of its operation.

The computing device is connected to a multiplexer via a digital link. The multiplexer contains a set of switches that connect one or more of sensors L1-R2 to the computing device under control of the above-mentioned algorithms. Such multiplexers are well-known. For example, an algorithm running in the computing device connects the device to sensor L1 by issuing instructions to the multiplexer. A switch within the multiplexer the computing device to sensor L1. When sensor L1 is triggered, its return signal from an echo is delivered to the computing device. Operation is similar for the remaining sensors.

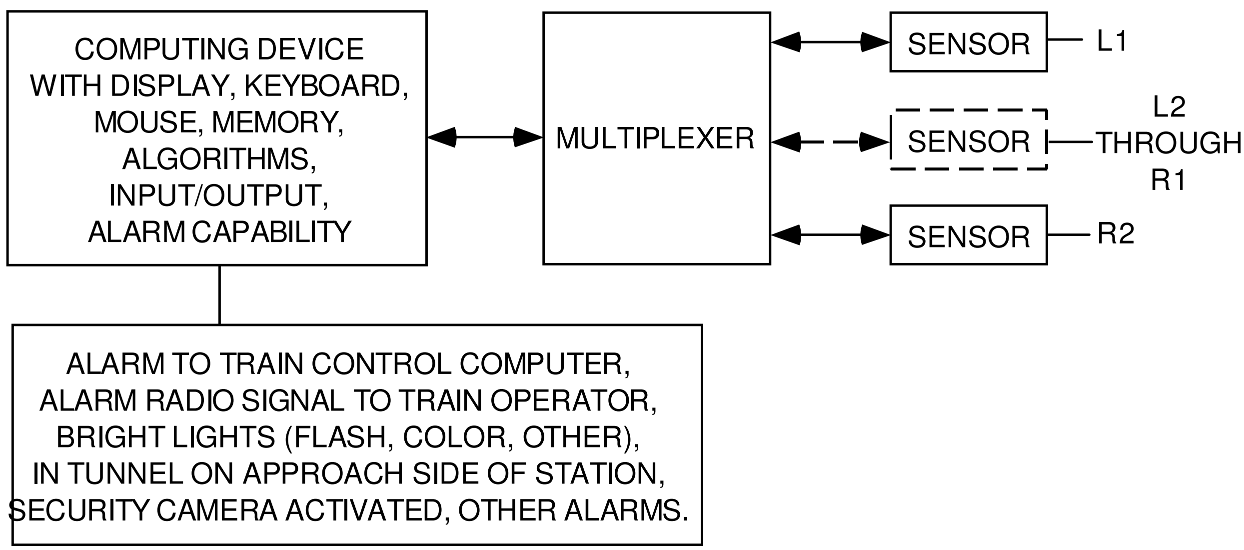


Fig. 10

When an alarm is to be issued, the computing device communicates information to one or more alarms. The alarm can be a signal to a train control computer identifying the station and train, a radio signal to a train operator approaching a station, bright lights near the approaching station, and other alarms. The purpose of all alarms is to stop or slow a train before it enters a station where an alarm has occurred.

**Alarm System Operation—An Example of a Protocol—Fig11.**

Numerous protocols exist for obtaining image data using linear arrays of ultrasonic sensors. These are well-known and are used in medical and non-destructive test scanning. The present system is capable of obtaining detailed image information about the volume of space over train tracks by using these techniques. However, in the present embodiment, only the approximate size and location of an intruding object within a track space are required. The following protocol accomplishes this. In the explanation of this protocol, it is assumed the train is approaching from the left side of the station in Fig. 9.

Fig. 11 is a flowchart showing one aspect of operation of the complete alarm system. In all cases below, sensors L1, L2, R1, and R2 are always activated and their outputs sensed by the computing device in Fig. 10. Other cases can be envisioned.

**Case 1.** *No object has been detected in the track space. Train is arriving at station.* Train is first detected by sensors L1 and L2. The object detected is a train and sensors A-I are not scanned by the computing device since the only object in the track space will be a train. Two sensors are used redundantly in case one senses debris outside the station.

*Train is leaving station.* As the last car of a train passes sensors R1 and R2, the computing device recognizes that the train is gone from the station and sensors A-I are activated and scanned continuously by the computing device.

**Case 2.** *An object (person, animal, container, other) has been detected in the track space. Train is approaching station at a speed and distance to permit significant slowing or stopping before it reaches the station.* An alarm is raised by the computing device and one or more track and train alarms are raised. The alarm is recognized and the train slows or stops prior to reaching the station so that the object can be removed. When the object is removed and normal operation can continue, all data collected just before, after, and during the alarm condition are recorded for later use, the algorithm within the computing device is reset, cancelling the alarm and normal train operation continues.

Fig. 11 is a flow chart showing operation of the system during cases 1 and 2. At the start (block 1), trains operate normally. When an object is detected in the track space (block 2), an alarm is immediately raised (block 7) and control passes to block 8 which causes operation of the alarm

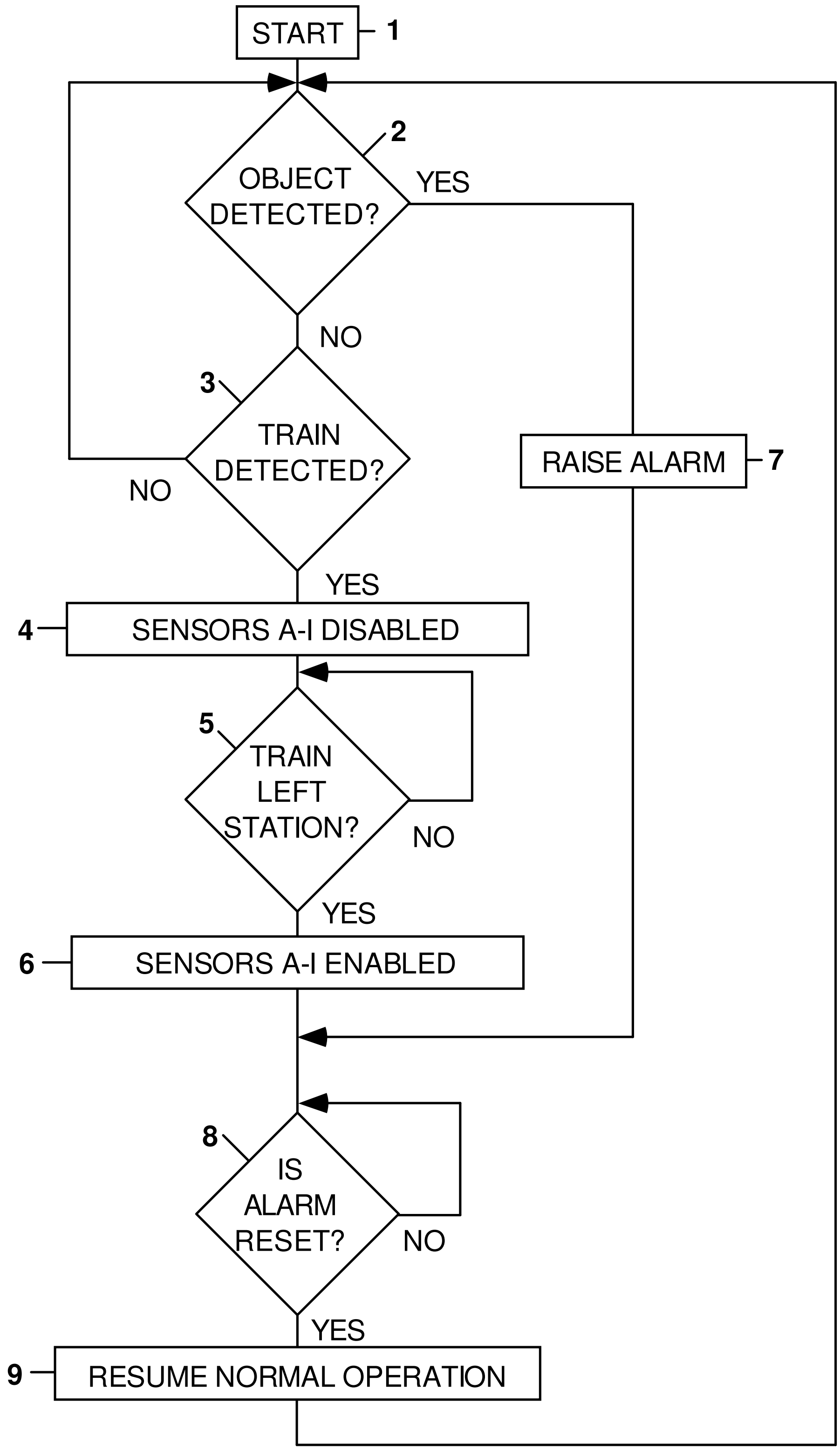
START
1
2
OBJECT DETECTED?
YES
NO
3
TRAIN DETECTED?
NO
RAISE ALARM
7
YES
4
SENSORS A-I DISABLED
5
TRAIN LEFT STATION?
NO
YES
6
SENSORS A-I ENABLED
8
IS ALARM RESET?
NO
YES
9
RESUME NORMAL OPERATION

Fig. 11

system to continue until an alarm is reset (block 8). If an alarm is reset, normal operation of a train and the alarm system resume (block 9).

If no object is detected (block 2), block 3 tests to see if a train is detected by sensors L1 and L2 (block 3). If a train is detected, sensors A-I are disabled (block 4). Block 5 continuously checks to see if a train has left the station. If so, sensors A-I are enabled. There has been no alarm and the alarm is in a reset condition (block 8) so control passes to block 9 and normal operation of the train and alarm system resumes.

## Conclusion

We have designed a train station safety system that protects passengers who fall from a platform onto the rails. In one version, our system can temporarily deactivate the third rail, eliminating the possibility of electrocution. Our system pinpoints the location of incursion, works with all types of trains and track maintenance vehicles, can activate warning lights, warning horns, message signs, and can activate an inflatable rescue ladder to assist a victim's return to safety on a platform. Our system is far less expensive to construct and maintain than physical barriers, such as double doors, that open only after a train has stopped in a station. Our system is easily installed in a station and requires little maintenance. In one aspect, our system is not subject to vandalism because it is invisible to pedestrians in a train station and is only noticed when it raises an alarm. Instead of ultrasound, another sensor means can be used, including infrared, cameras, and LIDAR. Instead of subway stations, our system can be used in bus stations and any train station, including stations for automatically operated trains.

## Next Steps

We propose the following steps to build and test a prototype of our alarm system.

### Breadboard Phase.

1. Identify suitable hardware components

2. Begin software development
3. Build a simple test rig
4. Test single transducer performance
5. Test multi-transducer performance

**Prototype Phase.**

1. Build testbed for testing with automobile
2. Select best hardware components
3. Continue software development
4. Demonstrate testbed performance with automobile
5. Build and test a testbed in train station
6. Demonstrate testbed performance in train station with train
7. Collect design documentation and test results

**Release Phase.**

1. Solicit bids from vendors for:
    Software continued development and maintenance
    Hardware installation and maintenance
2. Transfer technology to vendors

**Footnotes**

**1.** The SonoBlaster is attached to orange traffic cones to provide a very loud alarm using a boat horn. The alarm is sounded when a cone is either tipped or struck. See: https://www.transpo.com/roads-highways/safety-products/wz-intrusion-alarm for more information.

**2.** See: http://www.berkeleyside.com/2014/11/08/breaking-north-berkeley-bart-station-closed-due-to-report-of-person-under-train. Title: "Update: Man taken to hospital with moderate injuries after incident at North Berkeley BART; station has re-opened", Publication: Berkeleyside,

Berkeleyside Inc., c/o WeWork, 2120 University Avenue, Berkeley CA 94704, Date November 08, 2014, Author: Emilie Raguso.

**3.** Patent protection is pending on certain aspects of the Transportation Platform Safety System and Apparatus described herein.



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