Passenger transport system with object detection device

The present invention relates to a passenger transport system in the form of an escalator or a moving walkway. Furthermore, the invention relates to a method for operating such a passenger transport system.

Escalators and moving walkways are used to transport passengers within structures or buildings. Escalators, which are sometimes also referred to as moving stairways, are used to transport the passengers along inclined travel paths between different levels, in particular between different floors. For this purpose, the escalator comprises a conveyor belt in the form of a stepped belt, in which a plurality of tread units in the form of tread steps are coupled together one behind the other in the direction of travel and can be moved in a revolving fashion along a strongly inclined travel path. In contrast, a moving walkway is used to transport passengers along horizontal travel paths or, at most, slightly inclined travel paths. For this purpose, the moving walkway comprises a conveyor belt in the form of a pallet belt, in which a plurality of tread units in the form of pallets are coupled together and can be moved in a revolving fashion along a travel path that is not inclined or only slightly inclined. The travel path extends between two access regions of the passenger transport system at opposite ends of the travel path. Passengers can access the conveyor belt via the access regions and then step onto one of the tread steps or pallets.

In the access regions, an immovably fixed floor plate, together with a comb plate that is also stationary and attached thereto, adjoins the moving conveyor belt. A line along which the conveyor belt adjoins the comb plate and along which the moving tread units enter or exit relative to the stationary comb plate is referred to as the comb intersection line.

Due to this typical device design, objects such as a piece of clothing, a shoe or similar items, or waste such as a discarded bottle, can, etc., can accumulate in a transition region adjoining the comb intersection line. It has been observed that potentially dangerous situations can arise in this context. In particular, the object can become wedged between the tread step or pallet and the comb plate, or remain lying in front of the comb plate and, for example, act as a trip hazard. This could potentially lead to damage to the object or, in

the worst case, even injuries to passengers. Furthermore, potentially significant damage to the escalator or moving walkway can occur.

It was therefore considered to monitor the transition region adjoining the comb intersection line of escalators or moving walkways for the presence of unwanted objects. For example, EP 3 299 330 B1 describes the detection of a state of engagement between a step and a comb plate of a passenger transport system. However, it was detected that conventional approaches to monitoring the aforementioned transition region can be costly with respect to the hardware and/or software required therefor. WO2015/090764 A1 describes various arrangements of monitoring sensors in the transportation region of an escalator in order to monitor passengers from the most ideal position possible.

There may therefore be a need, among other things, for a passenger transport system in the form of an escalator or moving walkway, in which the transition region can be monitored for the presence of unwanted objects in a simplified manner, in particular with low requirements in terms of the hardware and/or software to be provided. Furthermore, there may be a need for a method for operating such a passenger transport system by means of which the transition region can be advantageously monitored for the presence of unwanted objects, in particular with low costs and/or high reliability.

A need of this kind can be met by the subjects according to the independent claims. Advantageous embodiments are explained both in the dependent claims and in the description below and depicted in the drawings.

A first aspect describes a passenger transport system in the form of an escalator or moving walkway, wherein the passenger transport system has a transition region on which a moving conveyor belt of the passenger transport system adjoins a stationary floor plate of the passenger transport system equipped with a comb plate. The passenger transport system additionally has an object detection device for detecting objects in a monitoring volume. The monitoring volume is defined by vertical dimensions, longitudinal horizontal dimensions, and transverse horizontal dimensions. The monitoring volume is located in the transition region above a tread surface plane and at a defined vertical distance therefrom. In the tread surface plane, an upwardly directed surface of a tread surface extends from a tread unit of the conveyor belt adjoining the comb plate. The object detection device is configured and arranged on the passenger transport system so

as to monitor the monitoring volume contactlessly and three-dimensionally with respect to the position and extent of at least one object located therein and to exclude surrounding neighboring volumes outside the monitoring volume from the monitoring process. The feature “neighboring volumes outside the monitoring volume” comprises all volumes surrounding the monitoring volume that do not belong to the monitoring volume. This, in particular, also includes the neighboring volume that is created below the monitoring volume and thus between the monitoring volume and the tread surface plane or conveyor belt and/or comb plate as a result of the defined vertical distance. The feature “located” means, on the one hand, that the dimensions of the monitoring volume are spatially limited or defined, and, on the other hand, that the monitoring volume occupies a defined spatial position above the tread surface plane in the transition region, or is arranged in a defined spatial position in the transition region.

A second aspect describes a method for operating a passenger transport system according to an embodiment of the first aspect of the invention. The method comprises contactless and three-dimensional monitoring of the monitoring volume while maintaining a defined vertical distance between the monitoring volume and a tread surface plane with respect to the position and extent of at least one object located in the monitoring volume, wherein neighboring volumes outside the monitoring volume are excluded from the monitoring process.

By way of introduction, a basic idea for embodiments of the invention described herein will be briefly explained; this explanation is to be interpreted as merely a rough summary and not as limiting the invention:

As already indicated above, a transition region adjoining the comb intersection line between the stationary comb plate and the moving conveyor belt is to be monitored for the presence of unwanted objects. Traditionally, camera systems were often used for this purpose, which visually recorded the transition region. For example, EP 3 299 330 B1—mentioned at the outset—describes an approach in which the engagement between teeth of the comb plate on the one hand and grooves in the tread surface of the conveyor belt on the other hand is to be monitored in order to be able to detect, for example, broken teeth.

However, it was determined that evaluating images recorded with conventionally used camera systems can be very time-consuming. In particular, it was found to be difficult to distinguish, on the one hand, between the moving conveyor belt and the stationary comb plate and floor plate, and on the other hand, between objects moving relative to both the conveyor belt and the comb plate, and it was found that image processing and image analysis that is often very complex is needed for this purpose. In other words, when monitoring the transition region, also capturing moving components of the passenger transport system can in particular impair the quality of the detection signals (recording quality of the images and frames), increase the amount of data, and make their evaluation more difficult.

The approach presented herein proposes the use of a special object detection device to monitor the transition region. This object detection device is specifically configured to monitor only a limited monitoring volume with respect to objects located therein and to targetedly exclude adjoining neighboring volumes from the monitoring process. The object detection device is in particular configured in such a way that the monitoring volume is located at least slightly above a tread surface plane formed by the conveyor belt. In other words, the monitoring volume is targetedly not intended to extend to or comprise the moving components of the conveyor belt, but rather be at at least a slight, defined vertical distance therefrom. Furthermore, the object detection device is configured to monitor the position and extent of objects located within the monitoring volume in a contactless and three-dimensional manner. For example, a 3D camera, a 3D LiDAR system or a 3D laser scanner can be used for this purpose.

By means of the monitoring volume monitored by the object detection device being located at a defined vertical distance above the conveyor belt, it is possible to ensure that detection data recorded by the object detection device is not disturbed by the influence of the moving conveyor belt or is not difficult to evaluate. In particular, when using an object detection device in the form of a 3D camera, a 3D LiDAR system or a 3D laser scanner for monitoring, recorded image data or, more generally, captured data can therefore only record objects within the monitoring volume, without also recording the conveyor belt located underneath or, if applicable, partial regions of the comb plate and the adjoining floor plate, which would make data evaluation more difficult. Furthermore, objects of a small height such as a handkerchief or a piece of cardboard that poses no danger to users and the passenger transport system do not extend into the monitoring

volume. Thus, such objects lying on the conveyor belt are not detected and do not lead to the output of a trigger signal to change the operating mode of the passenger transport system.

Overall, this can significantly simplify the detection of unwanted objects in the transition region near the comb plate. A defined vertical distance can be understood, on the one hand, as a distance from the tread surface plane that remains the same over time. On the other hand, it is also possible to vary the defined vertical distance during the execution of the monitoring method within the limits specified below (scanning the monitoring volume in the vertical direction).

In the following, possible designs and advantages of embodiments of the passenger transport system and the method usable for operating the passenger transport system will be described in more detail.

The object detection device of the passenger transport system proposed herein is specifically configured to be able to detect objects within a spatially limited monitoring volume. The object detection device can contactlessly detect objects. Object detection is performed depending on whether an object is located at least partially within or completely outside the monitoring volume.

For this purpose, the object detection device is, for example, able to be directed at a larger overall volume comprising the monitoring volume, but only record data that represent the presence of an object or parts of an object within the monitoring volume, whereas no data is recorded that reflects the presence of objects outside the monitoring volume, or such data are ignored. For this purpose, the object detection device is designed to three-dimensionally, i.e., spatially, record monitoring data that represent the presence of objects in its surroundings. In particular, the object detection device is configured to detect only objects that are located within or protrude into a predetermined monitoring volume as potentially critical or unwanted objects. The object detection device can detect both the position and the spatial extent of such an object on the basis of the monitoring data it has recorded.

The object detection device can be configured to record the monitoring data in various ways. For example, monitoring data can be recorded optically, acoustically,

electromagnetically, or in another contactless manner. In particular, an object detection device designed for optical monitoring, for example by means of visible light or infrared light, may be preferred.

For example, according to one embodiment, the object detection device may comprise a 3D camera, a 3D LiDAR system and/or a 3D laser scanner for monitoring the monitoring volume.

Such object detection devices can optically, i.e., visually, monitor the monitoring volume and also ascertain relative positions, in particular distances, between an object located in the monitoring volume and the object detection device. Due to information ascertained in this way, it is possible, among other things, to detect whether the object is located inside or outside the monitoring volume and, if necessary, also the current position of the object within the monitoring volume and/or its dimensions. Furthermore, it is possible to detect in which direction and/or at what speed the object is currently moving.

A 3D camera can detect three-dimensional images of the monitored surroundings. Various techniques can be used for this purpose. For example, cameras can be used that can measure distances by means of a Time-of-Flight method (so-called ToF (Time-of-Flight) camera). For example, the surroundings can be illuminated using light pulses, and the camera can then ascertain for each captured image point or pixel how long the emitted light pulse needs to return to a detector provided in the camera after being reflected at an object. Thus, the distance to the recorded object is ascertained for each image point.

Similarly, a 3D LiDAR system can be used to determine distances by targeting an object or surface with a laser and measuring the time needed for the reflected light to return to the receiver. LiDAR (an acronym for “light detection and ranging”) can operate in a fixed direction (e.g., vertically) or scan in multiple directions; in this case, it is also referred to as LiDAR scanning or 3D laser scanning, a special combination of 3D scanning and laser scanning.

Due to its ability to ascertain positions of objects in a monitored region three-dimensionally, the object detection device can be specifically configured to monitor only the spatially limited monitoring volume with respect to the presence of an object located therein, without also monitoring neighboring volumes located outside the monitoring

volume. The monitoring volume is defined by vertical dimensions, longitudinal horizontal dimensions and transverse horizontal dimensions, which are assumed in three orthogonal directions. The vertical dimensions relate to a vertical direction, the longitudinal horizontal dimensions refer to a longitudinal direction parallel to a longitudinal direction of extension and direction of movement of the conveyor belt within the transition region of the passenger transport system, and the transverse horizontal dimensions refer to a transverse direction orthogonal to both the longitudinal direction and the vertical direction.

The monitoring volume can be cuboid in shape, i.e., it can have a constant thickness as its vertical dimension, a constant length as its longitudinal horizontal dimension, and a constant width as its transverse horizontal dimension. Alternatively, however, the monitoring volume can also have other shapes or contours, for example with rounded edges and/or corners, concave or convex surfaces, or the like.

According to one embodiment, the monitoring volume is located horizontally between lateral boundary planes and at a transverse horizontal distance therefrom, in which planes opposite surfaces of lateral boundary elements of the passenger transport system extend on opposite sides of the transition region.

In other words, the monitoring volume is preferably not only intended to be at a distance from the conveyor belt vertically downward, but also horizontally at a distance from lateral boundary elements in a direction parallel to the transverse horizontal dimension of the monitoring volume. The corresponding distance is referred to herein as the transverse horizontal distance and should be chosen to be sufficiently large—similarly to the defined vertical distance mentioned above—so that the object detection device is not disturbed by the lateral boundary elements when monitoring the monitoring volume, since these are located outside of and at a distance from the monitoring volume.

Lateral boundary elements can laterally adjoin the conveyor belt, the comb plate and the floor plate, and extend, for example, in parallel with the conveyor belt. In this context, balustrade bases of balustrades extending on both sides of the escalator or moving walkway can be considered as lateral boundary elements.

According to one embodiment, an upwardly directed surface of a tread surface of a floor plate adjoining the comb plate extends in a floor plate plane. The defined vertical distance between the tread surface plane and the monitoring volume is greater than the distance between the tread surface plane and the floor plate plane.

In other words, the monitoring volume should preferably be configured and located in such a way that it is not only at a distance from the upwardly directed surface of the tread surface of a tread unit of the moving conveyor belt, but also from the upwardly directed surface of the tread surface of the floor plate adjoining the conveyor belt and the comb plate. In other words, the defined vertical distance between the monitoring volume and the surface of the tread surface on the conveyor belt is to be chosen such that the monitoring volume is also at a distance from the surface of the tread surface of the floor plate, which typically projects vertically above the surface of the conveyor belt or runs higher than it.

Accordingly, the monitoring volume is chosen so that neither parts of the moving conveyor belt nor parts of the stationary floor plate protrude into the monitoring volume. This ensures that neither reflections on the conveyor belt nor reflections on the floor plate interfere with monitoring the transition region.

According to one embodiment, the defined vertical distance is between 1 mm and 100 mm, preferably between 3 mm and 50 mm. On the one hand, it was discovered that such a defined vertical distance ensures that reflections on the surface of the conveyor belt are sufficiently reliably prevented from interfering with the monitoring process, or that negligibly small objects located on the conveyor belt are prevented from being detected as unwanted objects in the monitoring volume. On the other hand, it was discovered that such a defined vertical distance can ensure that objects located on the conveyor belt whose height exceeds a minimum height protrude into the monitoring volume in which they are thus detected by the object detection device.

Alternatively or additionally, according to one embodiment, the transverse horizontal distance can be between 1 mm and 100 mm, preferably between 3 mm and 50 mm. Choosing such a transverse horizontal distance can ensure that reflections from lateral boundary elements next to the conveyor belt do not interfere with the process of monitoring the transition region.

According to one embodiment, the monitoring volume extends vertically above a comb intersection line on which the conveyor belt adjoins the comb plate, and/or extends, in a region, vertically above a partial region of the conveyor belt adjoining the comb intersection line in the longitudinal horizontal direction.

In other words, the monitoring volume is preferably intended to be located above the region referred to as the comb intersection line, on which the conveyor belt enters the comb plate and on which objects can preferably accumulate due to the relative movement between these two components. This makes it possible to monitor, at least in a volume above the comb intersection line, whether one or more objects accumulate here, which were transported along with the conveyor belt, for example, and then get stuck on the stationary comb plate.

Alternatively or additionally, the monitoring volume should also monitor a region above the conveyor belt, with this region extending longitudinally adjoining the comb intersection line. This means that objects located on the conveyor belt at a slight distance from the comb intersection line in the longitudinal direction can also be detected within the monitoring volume.

In particular, the height of the monitoring volume in the direction of the vertical dimensions can be less than or equal to 200 mm. In other words, the thickness of the monitoring volume can be limited to said dimensions. Due to such a limited height or thickness of the monitoring volume, the evaluation of data and signals provided by the object detection device while monitoring the monitoring volume can be limited, or the amount of data can be reduced. Conversely, it is possible to ensure that objects located further above the conveyor belt, for example, do not interfere with monitoring the transition region or are not detected as critical or unwanted objects.

Furthermore, the length of the monitoring volume in the direction of the longitudinal horizontal dimensions can be less than or equal to 400 mm. In other words, the length of the monitoring volume can be limited to said dimensions. Limiting the length of the monitoring volume in this way can also simplify the evaluation of data and signals or reduce the amount of data.

According to one embodiment, the object detection device can be arranged on and/or in one of the lateral boundary elements of the passenger transport system.

In other words, the object detection device can, for example, be integrated into or mounted on a balustrade extending alongside the conveyor belt or in the balustrade base thereof. Alternatively, the object detection device can be integrated into or mounted on, for example, the head of a base brush or a handrail guide profile. The object detection device should be arranged close to the comb intersection line in the longitudinal direction, for example with a longitudinal distance of less than 50 cm, preferably less than 30 cm. In this case, the object detection device is located in the immediate vicinity of the transition region to be monitored. For example, a minimum distance between the object detection device and the monitoring volume can be less than 100 cm, preferably less than 50 cm or less than 20 cm or even less than 10 cm.

This ensures, among other things, that when monitoring the monitoring volume, no objects located, for example, between the monitoring volume and the object detection device can cause shadowing and thus inadequate monitoring of the transition region.

According to one embodiment, the passenger transport system may further comprise an evaluation device which is configured to ascertain the speed of movement at which an object observed within the monitored monitoring volume moves relative to the comb plate on the basis of detection signals from the object detection device.

In other words, the evaluation device can use data and signals it receives from the object detection device, which represent the position and extent of an object located in the monitoring volume, to infer the speed at which the detected object is moving relative to the stationary comb plate.

From the knowledge of this speed, it is possible, as explained in more detail below, to deduce, among other things, whether the object is an unwanted object that is shifting relative to the moving conveyor belt or an object moving along with the conveyor belt that is unlikely to be a critical object.

The evaluation device can be integrated into the object detection device or arranged spatially separate therefrom. The evaluation device can communicate with the object

detection device, i.e., exchange data. The evaluation device may comprise a computing unit, a data storage medium, an input interface and/or an output interface. In particular, the evaluation device can be programmable and operated using evaluation software.

According to one embodiment, the evaluation device can be configured to execute or control a method according to embodiments of the second aspect of the invention, as described herein in particular in the following passages.

In this preferably computer-implemented method, the monitoring volume is monitored contactlessly and three-dimensionally with respect to the position and extent of at least one object located therein, wherein neighboring volumes outside the monitoring volume are excluded from the monitoring process. Monitoring in this context can be understood to mean the continuous or cyclical, for example at periodic intervals, observation of the monitoring volume in order to detect objects located therein.

According to one embodiment, the method can comprise ascertaining the speed of movement of an object observed within the monitored monitoring volume on the basis of detection signals from the object detection device.

In other words, the detection signals supplied by the object detection device can be evaluated not only to detect an object located within the monitoring volume and, if necessary, to detect the dimensions or contour thereof, but also to detect a current speed at which the object is moving relative to the object detection device. As explained in more detail below, the information about the object speed can provide an indication of whether the object is an unwanted object.

According to a further specific embodiment, when carrying out the method, the observed object can be detected in first detection signals from the object detection device due to signal data which correlate with the size and/or contour of the object, and can be re-detected in second detection signals from the object detection device that are recorded after a time interval due to signal data which correlate with the size and/or contour of the object. In order to ascertain the speed of movement on the basis of the first and second detection signals, a spatial displacement of the detected and re-detected object can be determined and a relationship between said displacement and the time interval is established.

In other words, the object detection device and the method carried out by the evaluation device can be configured in such a way that the system also works if an observed object is briefly obscured, for example by a person, and therefore cannot be captured. The "disappearance" of the object, i.e., the fact that the object is briefly not captured by the object detection device, and the "reappearance" of the object, i.e., the fact that the object is captured by the object detection device again after a short pause, are to be processed so as to detect that this is the same object. The object can initially be detected in the captured detection signals due to its size and/or contour, or be re-detected after a brief "disappearance." By measuring the time between the "disappearance" and the "reappearance" of the observed object, it is possible to conclude the speed at which the object was moving during its "disappearance."

Overall, the described approach makes it possible to observe objects that move relative to the object detection device even when they are briefly obscured, i.e., become "invisible" to the object detection device. In this process, an object can be uniquely identified by comparing it with a previously detected visual feature, such as, in particular, its size and contour, and re-detected after a brief "disappearance." In particular, the speed of the observed objects can also be ascertained in such cases.

According to one embodiment, the method can comprise outputting a trigger signal if the ascertained speed of movement of the observed object is lower than the current speed of the conveyor belt.

In other words, if it is detected that an object observed within the monitoring volume is moving slower than the conveyor belt, it is possible to conclude that the object is an unwanted object or even an object that endangers the operation of the passenger transport system. Upon detection of such a potentially critical object, a trigger signal can then be output, for example in the form of an electrical or optical signal. This trigger signal can trigger various responses.

In contrast, it can be assumed that objects moving along with the conveyor belt and thus having the same speed as the conveyor belt, or objects moving even faster than the conveyor belt, can typically be considered non-critical, so that no trigger signal needs to be output.

In this context, information about the current speed of the conveyor belt can, for example, be requested from a controller of the passenger transport system.

A decision on whether or not the trigger signal is to be output can take into account a predefined speed tolerance. For example, a trigger signal can only be output if the current speed of movement of the observed object is at least 2%, at least 5%, at least 10% or even at least 20% less than the current speed of the conveyor belt. In particular, a trigger signal can be output if the observed object is detected to not be moving, i.e., is stationary relative to the moving conveyor belt, or if the observed object is moving periodically back and forth.

Passenger transport systems of the aforementioned type have two transition regions, and therefore an object detection device is preferably arranged in both. Only the transition region in which the conveyor belt moves toward the comb plate poses a danger. Since older users often wait briefly on the comb plate when entering the conveyor belt, the object detection device could misinterpret this as a lying object. To avoid such “false signals,” the trigger signal is preferably output depending on the direction of travel.

In particular, according to one embodiment, an operating mode of the passenger transport system can be changed in response to the trigger signal.

The term “operating mode” can be interpreted broadly here. In particular, an acoustically or optically perceptible alarm can be issued in response to the trigger signal that is output, for example. The alarm can be output directly in the region of the passenger transport system in order to be perceived by any passengers there, for example. Alternatively or additionally, the alarm can also be output at a remotely arranged monitoring center. Alternatively or additionally, the travel mode of the escalator or moving walkway can be changed. For example, its speed can be reduced to a crawl or the conveyor belt can even be brought to a complete stop.

The following example is to serve to illustrate the essential functions of the object detection device. With the aforementioned object detection device, the monitoring volume can be limited by filter settings in the software of the recording device so that its width almost corresponds to the distance between the two base plates of the passenger

transport system. The length of the monitoring volume can be limited to 50 mm and extend from the comb intersection line across the conveyor belt. A defined vertical distance of 10 mm can be set between the tread surface plane and the monitoring volume, and the height of the monitoring volume can be limited to 50 mm, so that an upper horizontal surface of the monitoring volume extends 60 mm above the tread surface plane. Objects such as a bottle, a suitcase, or a child's arm that are located within the monitoring volume are detected by the object detection device. Small, flat objects such as chewing gum, a ballpoint pen or a scrap of paper are not detected due to the defined vertical distance of 10 mm. Furthermore, only detected objects whose speed is slower than the speed of the conveyor belt are taken into account. A sufficiently large object that has accumulated in the comb intersection line has the speed of 0 m/s and is therefore taken into account. If the presence of an object is continuously detected for a period of 0.5 to 2 seconds, the object detection device triggers a first trigger signal, which activates an acoustic warning signal. If the presence of an object is detected continuously for a period of more than 2 seconds, the object detection device triggers a second trigger signal to interrupt the power supply to the motor and brake of the drive machine of the passenger transport system. The warning signal continues and the start switch of the passenger transport system must not be actuated until the object detected by the object detection device has been removed.

According to another embodiment, the monitoring volume is monitored using an evaluation device which is configured for machine learning and which was previously trained using training data, wherein the training data represent detection signals from the object detection device with respect to possible operating situations when monitoring the monitoring volume.

In other words, the evaluation device can comprise artificial intelligence capable of machine learning, which has been pre-trained to detect objects in the detection signals supplied by the object detection device that are located within the monitoring volume and which are to be classified as potentially critical.

The artificial intelligence may have been pre-trained using training data that correspond to the detection signals supplied by the object detection device. Such training data can, for example, be real measurement data and may have been recorded using a real passenger transport system, for example, capturing as many different operating situations

as possible for training purposes. Specifically, a plurality of objects such as cans, bottles, bricks, different sizes of bags, body parts of mannequins and the like can be placed individually or collectively in different positions on the moving conveyor belt. Each time an object is detected (i.e., when a detection signal or signal pattern corresponding to the detected object differs from the signal pattern without a detected object, and defined criteria relating to, for example, the speed of the object relative to the travel speed of the passenger transport system are met), it is possible to confirm, for example by means of a manual input, that this object must be recognized by the artificial intelligence as an unwanted object. Alternatively or additionally, artificially generated training data can be used, for example by generating signal patterns to be detected through simulation or modeling on a 3D CAD system, which can also be used to simulate movements. Overall, the training data can represent a wide variety of scenarios that occur or are conceivable during operation of the passenger transport system. The training data can be detected and labeled as such. Accordingly, artificial intelligence is capable of monitored machine learning. Alternatively, the system can also be configured for unsupervised learning, in which objects detected during daily operation, for example with their significant outlines or position and extent, are continuously saved as training data.

The use of an evaluation device that is capable of machine learning and that has been appropriately trained beforehand can enable particularly reliable detection of unwanted objects in the transition region of the passenger transport system.

Embodiments of the invention will be described below with reference to the accompanying drawings, wherein neither the drawings nor the description are intended to be interpreted as limiting the invention.

Fig. 1 is a perspective view of a passenger transport system according to one embodiment of the present invention.

Fig. 2 is a longitudinal sectional view of the passenger transport system from Fig. 1.

Fig. 3 is a plan view of the passenger transport system from Fig. 1.

The drawings are merely schematic and are not to scale. Like reference signs refer in different drawings to like or analogous features.

Fig. 1 shows a perspective view of a passenger transport system 1 in the form of an escalator 3. Fig. 2 and 3 show a longitudinal sectional view and a plan view, respectively, of a transition region 5 of the passenger transport system 1.

The passenger transport system 1 comprises a moving conveyor belt 7. The conveyor belt 7 is composed of a plurality of tread units 8 in the form of steps arranged one behind the other and coupled together. The conveyor belt 7 can be moved in a revolving fashion along a travel path, for example by a drive wheel 51 (see Fig. 2). At the transition region 5, the moving conveyor belt 7 adjoins a comb plate 9 arranged in a stationary manner and a floor plate 11 that is also stationary and adjoins it in the longitudinal direction. A boundary line on which the conveyor belt 7 adjoins the comb plate 9 is referred to as the comb intersection line 41.

In the transition region 5, as can be seen in particular in Fig. 2, the tread units 8 of the conveyor belt 7 move in such a way that a surface 21 of a tread surface 23 of a tread unit 8 adjoining the comb plate 9 extends in a plane which is referred to herein as the tread surface plane 19. The comb plate 9 and the floor plate 11 extend at least partially above this tread surface plane 19 such that a plane referred to herein as the floor plate plane 37 runs along a surface 39 of the tread surface of the floor plate 11 above the tread surface plane 19 and at a distance D_{BT} therefrom, measured in the vertical direction, of from a few millimeters to a few centimeters, for example between 1 mm and 2 cm.

As can further be seen in Fig. 1 and 3, a balustrade 47 extends on either side of the conveyor belt 7, which supports a handrail 49. A balustrade base 33 runs at the base of the balustrade 47 and directly laterally adjoins the conveyor belt 7 or is at most slightly at a distance therefrom, and is referred to herein as a lateral boundary element 31. A surface 36 of the lateral boundary element 31, directed toward the conveyor belt, runs in a lateral boundary plane 35.

During operation of the passenger transport system 1, situations may arise in which unwanted objects 15 are located within the transition region 5. For example, waste dropped by a passenger when traveling on the escalator 3 can be transported along with the conveyor belt 7 and then accumulated on the comb plate 9. The drawings show a bottle as an example of such an unwanted object 15. Since the comb plate 9 projects or

protrudes upward above the tread surface plane 19 of the conveyor belt 7, such unwanted objects 15 cannot be transported out of the passenger transport system 1 by the conveyor belt 7, but instead accumulate in the transition region 5 and in particular adjoining the comb intersection line 41. In an alternative situation, for example, a piece of clothing or a shoe may become trapped in the transition region 5 between the stationary comb plate 9 and the moving conveyor belt 7. In both cases, unwanted or even dangerous situations for passengers of the escalator 3 and/or damage to the escalator 3 may occur.

In order to reliably detect unwanted objects in the transition region 5 with as little technical effort as possible, the passenger transport system 1 has an object detection device 13. In the example shown, the object detection device 13 has a 3D camera 29, for example in the form of a ToF camera or a stereo camera. Such a 3D camera 29 is able to record three-dimensional images of its surroundings and, in addition to two-dimensional lateral image resolution, also provide information about distances of surfaces or objects recorded in this image. In other words, it is possible, among other things, to set up this camera 29 in such a way that it only records images within a predetermined volume.

For the passenger transport system 1 described herein, the object detection device 13 is specifically configured such that it exclusively monitors a spatially limited monitoring volume 17 adjoining the comb plate 9 in the transition region 5 for unwanted objects 15, but does not monitor adjoining neighboring volumes 27 outside the monitoring volume 17, i.e., ignores them or does not even record them in the first place. The monitoring volume 17 can, in principle, have any shape and contour and have vertical dimensions H, longitudinal horizontal dimensions L in a direction that is parallel to a direction of movement of the conveyor belt 7 and transverse horizontal dimensions B in a direction that is transverse to the direction of movement of the conveyor belt 7 and transverse to the vertical. Preferably, the monitoring volume 17 can be cuboid, i.e., having a uniform height as the vertical dimensions H, a uniform length as the longitudinal horizontal dimensions L, and a uniform width as the transverse horizontal dimensions B.

For example, the camera 29 used as the object detection device 13 can continuously record three-dimensional images or video sequences within a field of view. Detection signals recorded can represent a kind of point cloud. The point cloud can be filtered within a capturing time in such a way that only detection signals which only represent objects 15 and feet of passengers within the monitoring volume 13 remain.

The object detection device 13 is specifically configured to contactlessly and three-dimensionally detect objects 15 located in the monitoring volume 17 with respect to the position and extent thereof. In other words, for example, the camera 29 of the object detection device 13 can provide three-dimensional image data, which can be used to analyze whether and where an object 15 is located within the monitoring volume 17 and what dimensions this object 15 has. Preferably, the object detection device 13 can also be used to determine the exact shape and/or contour of the detected object 15.

To simplify the analysis of detection signals provided by the object detection device 13, the object detection device 13 is configured and arranged such that the monitoring volume 17 observed thereby is located at least slightly above the tread surface plane 19. There is a defined vertical distance D_H between the tread surface plane 19 and a lower boundary surface of the monitoring volume 17 directed vertically toward it. The defined vertical distance D_H should be, for example, between 1 mm and 100 mm, preferably between 3 mm and 50 mm.

In particular, it may be preferable to select the defined vertical distance D_H to be sufficiently large that it is larger than the distance D_{BT} between the floor plate plane 37 and the tread surface plane 19 such that the monitoring volume 17 is also vertically at a distance from the floor plate plane 37.

Selecting or arranging the monitoring volume 17 in this way can ensure that the object detection device 13 does not also record the moving conveyor belt 7 and, if applicable, the comb plate 9 and the floor plate 11, which would otherwise make it more difficult to analyze the recorded detection signals. In other words, it is targetedly avoided that the object detection device 13 generates detection signals which represent information with respect to the moving conveyor belt 7 and/or the comb plate 9 and the floor plate 11, since it was detected that such information is not helpful for the desired monitoring of the transition region 5 for unwanted objects 15, and makes the evaluation of the detection signals more difficult. Instead, the object detection device 13 is limited to recording only detection signals relating to the monitoring volume 17 located above the conveyor belt 7 and preferably also above the comb plate 9 and the floor plate 11.

Similarly, the object detection device 13 is further configured and arranged such that the monitoring volume 17 observed thereby is located at an at least slight lateral distance from the lateral boundary planes 35 in which the surfaces 36 of the lateral boundary elements 31 directed toward the conveyor belt 7 extend. There is a transverse horizontal distance D_B between each of the lateral boundary planes 35 and a lateral boundary surface of the monitoring volume 17 directed laterally theretoward. The transverse horizontal distance D_B can be between 1 mm and 100 mm, preferably between 3 mm and 50 mm. This lateral spacing toward the lateral boundary elements 31 also makes it possible to evaluate or analyze the detection signals supplied by the object detection device 13 more easily, since they are not disturbed by the—usually unnecessary—recording of data representing the lateral boundary elements 31.

The object detection device 13 is further configured and arranged such that the monitoring volume 17 extends vertically above the comb intersection line 41 and preferably in a region 43 vertically above a partial region of the conveyor belt adjoining the comb intersection line 41 in the longitudinal horizontal direction.

The monitoring volume 17 can have a limited height H of less than or equal to 200 mm, but preferably greater than 5 mm. This makes it possible, among other things, to ensure that the monitoring volume 17 is as small as possible and only covers height ranges in which typically unwanted objects such as waste carried on conveyor belt 7 are expected. The length L of the monitoring volume 17 can be less than or equal to 400 mm, but is preferably greater than 50 mm. This also allows the monitoring volume 17 to be limited to a region sufficient for detecting unwanted objects 15, thus minimizing the amount of data of the data signals provided by the object detection device 13.

The object detection device 13 can be arranged on or in one of the lateral boundary elements 31. For example, the object detection device 13 can be mounted on or in the balustrade base 33.

The passenger transport system 1 additionally has an evaluation device 45. The evaluation device 45 can, for example, be integrated into the object detection device 13, but can also be located at a distance therefrom. The evaluation device 45 serves to analyze the detection signals supplied by the object detection device 13 in such a way that the speed of movement at which an object 15 detected within the monitoring volume 17

moves relative to the comb plate 9 can be concluded therefrom. In other words, the detection signals supplied by the object detection device 13 are not only to be used to actually detect an object 15 within the monitoring volume 13, but preferably also to determine how fast this object 15 is moving relative to stationary components of the passenger transport system 1.

The information about the speed of movement of the object 15 can then be used to decide whether object 15 is a potentially critical and therefore unwanted object 15, such as waste, or whether currently only an object is detected in the monitoring volume 13 which is regularly transported through the monitoring volume 13 during operation of the escalator 3, such as a passenger's foot.

In particular, the detection signals from the object detection device 13 can be evaluated by the evaluation device 45 in such a way that only if the ascertained speed of movement of the observed object 15 is less than the current speed of the conveyor belt 7 is it possible to conclude that this is potentially an unwanted object 15. In this case, a trigger signal can then be output.

In response to the trigger signal, an operating mode of the passenger transport system 1 can then be changed. For example, the trigger signal can be forwarded from the evaluation device 45 to a controller of the passenger transport system, which, upon receiving the trigger signal, causes a drive of the passenger transport system, for example, to only continue moving the conveyor belt 7 at a slower speed, i.e., in a creeping motion, or even to stop the movement of the conveyor belt 7 completely. In addition or alternatively, the trigger signal can be used to trigger the output of a warning signal. The warning signal can be output optically, acoustically, or in another way. The warning signal can be used to provide a warning to passengers of the passenger transport system. Additionally or alternatively, a remotely located monitoring center can be alerted using the warning signal.

Since the approach described herein for monitoring the transition region 5 of the passenger transport system 1 is also intended to function when objects carried by the conveyor belt 7 are briefly obscured, for example by passengers, and therefore temporarily cannot be captured by the object detection device 13, it may be advantageous to design the object detection device 13 or the evaluation of its detection signals carried

out by the evaluation device 45 in such a way that an object 15 can briefly “disappear” and be re-detected after it reappears.

For this purpose, the observed object 15 can initially be detected in first detection signals of the object detection device due to signals that correlate with the size and/or contour of the object 15. If the object reappears after a short time interval following its brief disappearance, it can be re-detected due to signal data which in turn correlate with its size and/or contour. To detect or re-detect the size and/or contour of the object, corresponding image data can, for example, be subjected to image analysis. The intrinsic speed of the object 15 detected and re-detected in this way can then be determined by relating the spatial displacement of the object during its “disappearance” to the time interval within which it had “disappeared.”

The detection of unwanted objects 15 within the monitoring volume 13 can be further improved, among other things, by using a machine capable of machine learning as the evaluation device 45 and by pre-training this evaluation device 45 capable of learning with training data prior to commissioning the passenger transport system 1, which data correspond to the detection signals from the object detection device 13 to be evaluated later on during operation.

The training data can be recorded, for example, during a trial phase in which the passenger transport system 1 is targetedly operated in such a way that unwanted objects 15 are located in the monitoring volume 17. Alternatively or additionally, training data can also be artificially generated, for example through computer simulations.

The training data can be configured in such a way and/or the evaluation device capable of learning can learn using the training data in such a way that later on during the actual operation of the passenger transport system 1, for example, an analysis of the movement and/or of geometric properties of observed objects 15 can be carried out in such a way that makes it highly likely to be able to distinguish between unwanted objects 15 and non-critical objects.

Furthermore, by training the evaluation device 45, situations can be learned, for example, in which observed objects are temporarily obscured and thus seem to disappear for the object detection device 13, only to reappear after a time interval.

Furthermore, the evaluation device 45 can learn through training at which speeds of movement of observed objects 15 there is a high probability that they are unwanted objects.

Finally, it should be noted that terms such as “having,” “comprising,” etc., do not exclude other elements or steps, and terms such as “a” or “an” do not exclude a plurality. Furthermore, it should be noted that features or steps which have been described with reference to one of the above embodiments may also be used in combination with other features or steps of other embodiments described above, provided these combinations are included in the scope of protection of the accompanying claims.

Claims

1. A passenger transport system (1) in the form of an escalator (3) or a moving walkway,
the passenger transport system having a transition region (5) in which a moving conveyor belt (7) of the passenger transport system (1) adjoins a stationary floor plate (11) of the passenger transport system (1) that is provided with a comb plate (9), and the passenger transport system (1) having an object detection device (13) for detecting objects (15) in a monitoring volume (17), which monitoring volume (17) is defined by vertical dimensions (H), longitudinal horizontal dimensions (L) and transverse horizontal dimensions (B), characterized in that the monitoring volume (17) is located above a tread surface plane (19) at a defined vertical distance (D_H) therefrom in the transition region (5), and in which tread surface plane (19) an upwardly directed surface (21) of a tread surface (23) of a tread unit (25) of the conveyor belt (7) adjoining the comb plate (9) extends,
the object detection device (13) being configured and arranged on the passenger transport system (1) so as to monitor the monitoring volume (17) contactlessly and three-dimensionally with respect to the position and extent of at least one object (15) located therein and to exclude surrounding neighboring volumes (27) outside the monitoring volume (17) from the monitoring process.

2. The passenger transport system according to claim 1,
wherein the object detection device (13) comprises a 3D camera (29), a 3D LiDAR system and/or a 3D laser scanner for monitoring the monitoring volume (17).

3. The passenger transport system according to any of the preceding claims,
wherein the monitoring volume (17) is located horizontally between lateral boundary planes (35) and in each case with a transverse horizontal distance (D_B) therefrom, in which planes opposite surfaces (36) of lateral boundary elements (31) of the passenger transport system (1) extend on opposite sides of the transition region (5).

4. The passenger transport system according to any of the preceding claims,
wherein an upwardly directed surface (39) of a tread surface of the floor plate (11), which adjoins the comb plate (9), extends in a floor plate plane (37), and

wherein the defined vertical distance (DH) is greater than a distance (DBT) between the floor plate plane (37) and the tread surface plane (19).

5. The passenger transport system according to either claim 3 or claim 4, wherein the defined vertical distance (DH) is between 1 mm and 100 mm, or between 3 mm and 50 mm.

6. The passenger transport system according to any of claims 3 to 5, wherein the transverse horizontal distance (D_B) is between 1 mm and 100 mm, or between 3 mm and 50 mm.

7. The passenger transport system according to any of the preceding claims, wherein the monitoring volume (17) extends vertically above a comb intersection line (41) on which the conveyor belt (7) adjoins the comb plate (9), and/or extends, in a region (43), vertically above a partial region of the conveyor belt (7) adjoining the comb intersection line (41) in the longitudinal horizontal direction,
and wherein the following further applies:
a height (H) of the monitoring volume (17) in the direction of the vertical dimensions is less than or equal to 200 mm, and/or
a length (L) of the monitoring volume (17) in the direction of the longitudinal horizontal dimensions is less than or equal to 400 mm.

8. The passenger transport system according to any of the preceding claims, wherein the object detection device (13) is arranged on and/or in a lateral boundary element (31) of the passenger transport system (1).

9. The passenger transport system according to any of the preceding claims, further comprising an evaluation device (45) which is configured to ascertain the speed of movement at which an object (15) observed within the monitored monitoring volume (17) moves relative to the comb plate (9) on the basis of detection signals from the object detection device (13).

10. A method for operating a passenger transport system (1) according to any of claims 1 to 8,
wherein the method comprises:

contactlessly and three-dimensionally monitoring while maintaining a defined vertical distance (D_H) between the monitoring volume (17) and a tread surface plane (19) with respect to the position and extent of at least one object (15) located in the monitoring volume (17), wherein neighboring volumes (27) outside the monitoring volume (17) are excluded from the monitoring process.

11. The method according to claim 10,
further comprising:
ascertaining the speed of movement of an object (15) observed within the monitored monitoring volume (17) on the basis of detection signals from the object detection device (13).

12. The method according to claim 11,
wherein the observed object (15) is detected in first detection signals from the object detection device (13) due to signal data which correlate with the size and/or contour of the object (15) and is re-detected in second detection signals from the object detection device (13) that are recorded after a time interval due to signal data which correlate with the size and/or contour of the object (15), and
wherein, in order to ascertain the speed of movement on the basis of the first and second detection signals, a spatial displacement of the detected and re-detected object (15) is determined and a relationship between said displacement and the time interval is established.

13. The method according to claims 11 and 12,
further comprising:
outputting a trigger signal when the ascertained speed of movement of the observed object (15) is lower than the current speed of the conveyor belt (7).

14. The method according to claim 13,
further comprising:
changing an operating mode of the passenger transport system (1) in response to the trigger signal.

15. The method according to any of claims 10 to 14,

wherein the monitoring volume (17) is monitored using an evaluation device (45) which is configured for machine learning and which has been previously trained using training data,

wherein the training data represent detection signals from the object detection device (13) with respect to possible operating situations when monitoring the monitoring volume (17).