US 2004/0093181 A1 discloses a method and apparatus for tracking moving objects or persons along a passageway, comprising a series of light sensors disposed along the passageway.

US 2003/0179127 A1 discloses a device for counting the number of people passing through a passage, the device comprising at least one distance sensor arranged to emit a radar or ultrasonic radiation across the width of the passageway, at an angle with respect to the direction of movement of the person.

The present invention arose in attempt to provide an improved method of monitoring the movement of people through a passageway and for the detection of a 'tailgater', and also to improve the avoidance of false alarms which may be caused by other objects present.

According to the present invention in a first aspect there is provided a system for monitoring the movement of people or objects through a passageway comprising two or more time of flight sensors deployed across the passageway in a direction substantially transverse to the direction of movement of a person or object through the passageway.

Time of flight ranging sensors comprise a transmitter of light typically in the infrared spectrum and a receiver able to detect this light reflected by an object illuminated by the transmitted light and measure the time the light has taken to travel to the object and to return to the sensor thereby giving an indication of the distance of the object.

Each sensor may be arranged to transmit a single beam of light and to receive a signal which is reflected from an illuminated area on a person or object intersecting the path of the transmitted beam. Such a sensor is configured to measure the time taken for the beam to travel to the person or object and for a reflected signal to return to the sensor. Thus, the time of flight of each sensed reflected signal is indicative of the distance from the sensor to a person or object passing through the passageway.

The system further comprises means to determine data regarding people or objects passing through the passageway based on the time of flight of a signal measured by the two or more sensors. Said means is configured to determine the number and direction of people or objects passing through the passageway. The present invention provides a low cost system for monitoring the movement of people through a passage way, which provides reliable discrimination between people and carried objects, such as bags, suitcases and trolleys, for example, requiring comparatively little processing power compared to existing technology. The system can be implemented for counting the number of people passing through a passageway, for example for monitoring footfall, controlling the operation of access control means within the passageway, such as doors, gates, turnstiles, among others, and for detecting the presence of unauthorised individuals, including tailgaters and sidegaters.

The system comprises means to determine the speed at which a person or object moves through the passageway.

According to the present invention, at least two time of flight sensors are provided, and these are located on opposing sides of the passageway in order to transmit signals in generally opposing directions across the passageway. Time of flight systems are not generally used in a situation where generally opposing beams are transmitted, since the beam transmitted by the transmitter of one sensor can be received by the receiver of an opposing sensor, causing false measurements. To prevent this, according to this embodiment of the invention, the opposing signals are transmitted and received using time-division multiplexing.

In a preferred embodiment, each sensor is configured to measure a series of one-dimensional distance data points over intervals of time. Each series of one-dimensional distance data points can be combined with the determined speed at which the person or object moves through the passageway to create a two-dimensional cross-sectional profile

of a person or object passing through the passageway relative to each sensor. In this way, the system can discriminate between the profile of one person only passing through the passageway and more than one person passing through in close proximity, either in single-file or side-by-side. Further, the system can discriminate between people and carried objects, such as bags, suitcases or trolleys, for example, for the avoidance of false detection of people passing through the passageway.

The system may be configured to monitor the number of people present within the passageway.

In one embodiment, the sensors located on opposing sides of the passageway are located directly opposite to each other and the direction of travel and speed are determined by other means.

In another embodiment, at least two of the sensors are displaced in the direction of travel. That is, one sensor may be further forward in the direction of travel, than another. The system may further comprise means to determine the speed at which a person or object moves through the passageway based on the data measured by the sensors displaced in the direction of travel.

In a preferred embodiment, one or more of the at least two sensors are deployed at a height suitable for monitoring the waist and lower torso region of an adult passing through the passageway. The height of the sensors is preferably greater than 30 cm above ground level. Monitoring is thus carried out above the foot and lower leg level, where items moving close to the ground, such as wheeled bags, trolleys and wheelchair wheels, may restrict the reliable detection of a person moving through the passageway. The height of the one or more of the sensors is more preferably 85 cm above ground level.

In a preferred embodiment, the transmitted beams comprise infrared light. In a further preferred embodiment, each transmitted beam is a single beam of laser light.

In one embodiment, the signals are transmitted at an angle perpendicular to the direction of movement of a person or object through the passageway. In a further embodiment, the signals are transmitted in a horizontal plane across the passageway.

The system may further comprise means to control the operation of components of the passageway in response to the number and/or direction of people detected passing through the passageway. For example, in one embodiment the system may comprise means to control the access of people through the passageway in response to the number and direction of people detected passing through the passageway. The means to control access of people through the passageway may be, for example, doors, gates or turnstiles, or any other such means that would restrict the passage of people through the passageway. The system may be arranged to allow access of only one person at a time through the passageway. In such a case, the system is arranged to prevent the access of people through the passageway in the event that more than one person is detected passing through the passageway. In another embodiment, the system comprises means to generate an alarm in response to the number and direction of people detected passing through the passageway. The alarm may be an audio or visual signal. The alarm may be generated, for example, in the event that more than one person is detected passing through the passageway or a person is detected moving through the passageway in an unauthorised direction.

According to a further aspect of the present invention, there is provided a method for monitoring the movement of people or objects through a passageway, comprising:

- positioning two or more time of flight sensors to transmit a signal across the passageway in a direction substantially transverse to the direction of movement of a person or object through the passageway, wherein at least two of the sensors are located on opposing sides of the passageway;
- measuring the transverse distance of a person or object intersecting the path of the signal relative to each of the sensors over a series of time intervals;

- determining the speed at which the person or object moves through the passageway;
- combining the series of one-dimensional distance data points obtained from each of the sensors with the determined speed at which the person or object moves through the passageway to create a two-dimensional cross-sectional profile of the person or object moving through the passageway relative to each of the sensors;
- determining the number and direction of people moving through the passageway based on the two-dimensional cross-sectional profiles created from the data obtained from each of the sensors.

The method may further comprise a step of controlling the access of people through the passageway in response to the number and direction of people detected passing through the passageway. In another embodiment, the method further comprises a step of generating an alarm in response to the number and direction of people or objects detected passing through the passageway.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying schematic drawings in which:

Figure 1a shows a plan view of a system for monitoring movement of people through a passageway according to an embodiment of the present invention;

Figure 1b shows a perspective view of a system for monitoring movement of people through a passageway according to an embodiment of the present invention;

Figure 1c shows a perspective view of a system for monitoring movement of people through a narrow doorway according to an embodiment of the present invention;

Figure 2 shows a person passing through a passageway monitored by a system according to an embodiment of the present invention;

Figure 3 shows two people in close proximity passing through a passageway monitored by a system according to an embodiment of the present invention;

Figure 4 shows a person carrying a bag passing through a passageway monitored by a system according to an embodiment of the present invention; and

Figure 5 shows a system for monitoring movement of people through a passageway according to an embodiment of the present invention, comprising an alarm and means to control access of people through the passageway.

Figure 1a shows, in plan view, a schematic representation of a passageway 1 with two lateral boundaries 2a, 2b fitted with a system for monitoring the movement of people through the passageway according to an embodiment of the present invention. The system comprises two time of flight sensors 3a, 3b arranged to transmit signal beams 4a, 4b across the passageway in a direction substantially transverse to the direction of movement of a person or object through the passageway T. In the embodiment shown in Figure 1a, the two sensors 3a, 3b are located on opposing lateral boundaries 2a, 2b of the passageway 1 and are arranged such that the signal beams 4a, 4b are transmitted in opposing directions across the passageway 1. A typical time of flight sensor is a VL53L0X Time of Flight Ranging sensor made by STMicroelectronics (RTM), which generates a single beam of laser light.

Where sensors are deployed in opposing directions across the passageway, it is likely that a signal transmitted by one sensor will be received by the other sensor, thus interfering with the time of flight measurements made by each sensor. In order to avoid this, each of the sensors of the system are preferably configured to transmit and receive beams using time division multiplexing. Thereby, the sensors are configured to transmit beams intermittently and in sequence such that the two or more sensors do not transmit signals simultaneously, thus avoiding interference of opposing signal beams.

Figure 1b shows a schematic representation of passageway 1 in a perspective view. In the embodiment of Figure 1b, sensors 3a, 3b are deployed on opposing lateral boundaries 2a, 2b at equal heights above ground level and are displaced in the direction of travel T. In some embodiments, the sensors may be vertically displaced such that the heights of the two sensors above ground level are not equal. In a further embodiment,

the sensors 3a, 3b are located directly opposite to each other. The sensors may also be displaced both vertically and horizontally.

A person or object intersecting one or more of the signal beams 4a, 4b will cause a signal to be reflected back to the sensor from which it was transmitted. Each sensor is configured to measure the time taken for the signal to travel to the person or object and to return to the sensor. Thus, the time of flight of each sensed reflected signal is indicative of the distance from the sensor to a person or object passing through the passageway. The system thereby provides quasi-realtime distance measurement across the width of the passageway. The system further comprises a processing means 9 connected to each of the sensors and configured to receive one dimensional distance data points measured by each of the sensors and to analyse the data to determine information regarding people or objects passing through the passageway. In a preferred embodiment, the processing means are configured to determine the number and direction of people passing through the passageway in quasi-realtime.

Preferably, the sensors 3a, 3b are positioned at a height suitable for monitoring the waist and lower torso region of an adult passing through the passageway. In a preferred embodiment, the sensors are deployed at a height greater than 30 cm above ground level. More preferably, the sensors are deployed at a height greater than or equal to 60 cm and less than or equal to 120 cm above ground level. Most preferably, the sensors are deployed at a height of 85 cm above ground level, which might be considered to be a typical waist height. However, it will be appreciated by any person skilled in the art that the sensors can be arranged at any height suitable for monitoring a person passing through the passageway. In some embodiments, it may be desirable for a plurality of sensors to be arranged at a plurality of different heights across the passageway to further improve detection and discrimination.

In passageways such as those to be monitored by the present invention, the footprint of the passageway can be defined as the dimension of the passageway in the direction of travel of a person moving through the passageway.

In some embodiments, it may be desirable that the sensors are displaced in the direction of travel by a distance less than the typical thickness of a person, such that two or more beams will at some point be intersected at the same time by a person passing through the passageway. This embodiment is of particular importance in small footprint passageway, such as doorways. Figure 1c shows a schematic diagram in perspective view of a doorway across which two sensors 3a, 3b are deployed in generally opposing directions. As a person moves through the passageway, beam 4b is intersected before beam 4a ceases to be intersected. In other words, both beams 4a and 4b will be simultaneously intersected at some point by a person moving through the passageway. As such, it is not possible for a person to be positioned in between beams without intersecting at least one of the beams. In other embodiments, where the passageway has a large footprint, it may be desirable that the sensors are displaced by a larger distance, such that a person moving through the passageway will fully pass through the beam transmitted by one sensor, before intersecting the beam of the adjacent sensor.

The system comprises means to determine the speed at which a person or object passes through the passageway. In embodiments of the present invention in which two or more sensors are displaced in the direction of travel T, the speed at which a person or object passes through the passageway can be determined by correlation of data from the two or more sensors. However, it will be appreciated by any person skilled in the art that any alternative means for determining the speed at which a person or object passes through the passageway can be used.

Figures 2 to 4 show how the system may be used to monitor the movement of people through a passageway. Figures 2a and 2b show the system monitoring the movement of one person 10 through the passageway. Figure 2a shows a person 10

moving through passageway 1, as described in relation to Figures 1a and 1b. Figure 2b shows a graphical representation of data measured by sensors 3a and 3b over intervals of time to create two-dimensional cross-sectional profiles 5a and 5b relative to sensors 3a and 3b, respectively. As person 10 moves through passageway 1 in direction of travel T, person 10 first intersects beam 4a and reflects the signal back to sensor 3a, which measures the distance from the sensor at which the beam has been intersected. As person 10 continues to move through passageway 1, further distance measurements are made by sensor 3a over intervals of time. The distance measured will be dependent on the illuminated area across the cross-sectional profile of person 10 at which the beam is intersected and a signal is reflected. The processing means can combine the distance data points measured by sensor 3a over intervals of time with the determined speed at which a person or object passes through the passageway in order to create a two-dimensional cross sectional profile 5a of person 10, which is depicted graphically in Figure 2b. Thus, the cross-sectional geometry of a person or object passing through the passageway is determined in quasi-realtime.

As person 10 continues to move through passageway 1, beam 4b is intersected and the one-dimensional distance data points are analysed by the processing means to create two-dimensional cross sectional profile 5b, as depicted graphically in Figure 2b. In the embodiment shown in Figures 2a and 2b, sensors 3a and 3b are located on opposing lateral boundaries of the passageway, and thus profiles 5a and 5b correspond to opposite sides of person 10. In some embodiments, two or more of the sensors may be located on the same lateral boundary of the passageway, in which case the profiles created will correspond to the same side of person 10.

Figure 3a shows a scenario in which both person 10 and person 11 move passageway 1 in direction of travel T in close proximity to each other. Figure 3b shows a graphical representation of data measured by sensors 3a and 3b over intervals of time and analysed by the processing means to create two-dimensional cross-sectional profiles 15a and 15b relative to sensors 3a and 3b, respectively. As shown in Figure 3b, profiles 15a