People Flow Monitoring

Jussi Kuutti
Aalto University, Finland

Matti Linnavuo
Aalto University, Finland

Raimo E. Sepponen
Aalto University, Finland

INTRODUCTION

People flow measurement has applications in various fields including evacuation studies (Helbing, Farkas, & Vicsek, 2000), transportation engineering (Daamen & Hoogendoorn, 2003), shopping center management (Hui, Fader, & Bradlow, 2009), security (Meyn et al., 2009) and demand-based control of environmental conditions (Benezeth, Laurent, Emile, & Rosenberger, 2011). People flow monitoring has also been widely utilized in nature parks and conservation areas around the world (Arnberger & Hinterberger, 2003; Cessford, Cockburn, & Douglas, 2002).

This article sums up the concepts, issues, challenges, opportunities and most promising innovations of people flow monitoring systems. At the end, some related terms and definitions are listed.

BACKGROUND

General about People Flow Monitoring

People flow rate represents the number of people passing through a certain passage per unit time. People flow sensor—also called a pedestrian or visitor counter—is a device capable of measuring people flow rate and often also the direction of passing people. The sensor is triggered by physical signals caused by the pedestrians like visual appearance, heat emission, reflections of the body surface, or pressure against the path (Bauer, Brandle, Seer, Ray, & Kitazawa, 2009).

Knowledge of the people flow sensor performance is important as the more reliable data a sensor provides, the better are the results of applications utilizing it (Cessford et al., 2002). Manual counting by human observers is tedious, expensive, and typically used only for a short period of time, making the results quite unreliable in general (Heikkilä & Silvén, 2004). Thus it is usually used only to check the accuracy of sensor-based counting. Sensor technologies have been widely tested for pedestrian and bicycle traffic counting and safety related presence detection (Bu, Greene-Roesel, Diogenes, & Ragland, 2007; Chan & Bu, 2005; Dharmaraju, Noyce, & Lehman, 2001; Diogenes, Greene-Roesel, Arnold, & Ragland, 2007; SRF Consulting Group, 2003). For presence detection purposes, the detection reliability of people in a certain area is often more important than counting every individual in the possible group or crowd. Previous people flow sensor comparisons have been mostly accomplished in the context of outdoor applications.

People Flow Sensor Technologies

The selection of commercially available people flow sensors is diverse. The price spread of the sensors is wide and as, a rule of thumb, sensors with good performance and high capacity are usually expensive (Mathews, Poigné, & Rinner, 2009).

Active optical light beam sensors can be based on infrared (IR) or visible light. When the light beam of a side-mounted sensor is interrupted, a counting pulse can be registered with a data logger. Nowadays the sensor's transmitter and receiver are usually placed in the same casing, and a separate reflector might be needed. Two beam sensors can be used to provide the direc-

DOI: 10.4018/978-1-4666-5888-2.ch681

tion information but either they cannot count several pedestrians passing side by side (Bu et al., 2007). The sensor can be equipped with an adjustable detection delay to prevent overcounting caused, e.g., by swinging arms and legs (Cessford et al., 2002). Active overhead IR sensor arrays illuminate the detection area with low power IR energy. They detect the intensity of the light reflected from the target and, with a proper algorithm, they are capable of classifying pedestrians and cyclists (Dharmaraju et al., 2001).

Passive infrared (PIR) sensors detect the IR radiation of a passing object and they consume less power than active sensors. Their detection range is dependent on the IR characteristics of the object and its backgrounds. Additionally, sudden lighting changes can trigger false counts (Cessford et al., 2002). The sensors are usually based on pyroelectric technology and might have an adjustable temperature threshold. Double sensors are capable of direction sensing (Bu et al., 2007). PIR sensors can be installed on ceiling or walls, but they cannot detect multiple passers-by simultaneously.

Thermal overhead IR camera sensors are often classified under PIR sensors as they do not emit any IR light but absorb heat emitted by objects. Still, they differ fundamentally from PIR sensors, as they involve active image processing and can be used to detect multiple pedestrians simultaneously. IR camera sensors can better handle challenging lighting conditions than visual cameras and can operate even in complete darkness. On the other hand, possible air flows caused e.g. by temperature gradients can cause errors in their detection. Some IR cameras can be utilized in people tracking in their detection area (Chan & Bu, 2005).

Video camera sensors use an image processing technique to subtract the static background, track the remaining objects to determine whether they are pedestrians, and to count them. Variations in lighting conditions, pedestrian clothing, occlusions, and shadows can set challenges to them. The sensors can detect multiple pedestrians simultaneously, and a video capture can be acquired for manual control counting (Bu et al., 2007). Best counting accuracy is usually reached with overhead installation. Motion-based detection can efficiently reduce the number of false positive detections, but it is worse in detecting stationary persons than the shape-based method (Chan & Bu, 2005). Even imaging-based sensors tend to undercount pedestrians during very high flow rates (Cessford & Muhar, 2003).

Pulse ultrasound sensors send pulsed waves and measure the propagation time of the reflected echo. Continuous ultrasound sensors send the waves continuously and use the Doppler principle for object detection. The Doppler principle can be used to determine the object's speed and direction, but not to detect stationary objects. For ultrasound sensors, a preferred assembly is facing directly downwards or horizontally sideways to the monitored area. As the speed of sound varies according to the temperature and medium, the pedestrian's clothing and, when operating outdoors, weather conditions affect the detection (Chan & Bu, 2005).

Microwave radar sensors send radio waves and detect changes in the waves reflected from the moving objects (Cessford et al., 2002). Different microwave sensor technologies can be integrated for more versatile operation, they demand simpler signal processing than computer vision and can operate in variable environmental conditions. Microwave sensors can also be hidden behind materials that are permeable to radio frequency signals and can be used to classify detected objects based on power spectrum of the reflected signal (Chan & Bu, 2005).

Laser scanners emit IR laser pulses and detect reflections from the objects using the time-of-flight method. Some scanners can cover the entire 360-degree viewing angle. Applying a procedure similar to image processing, a high resolution image of the surroundings can be obtained (Chan & Bu, 2005). Depending on the device the scanning can be performed horizontally or vertically. The distance detection accuracy of the scanners is in the order of a centimeter and the azimuth angel accuracy is between 0.25–1 degrees (Bu et al., 2007). Laser scanners are relatively expensive and they are a reasonable option for corridor widths from about 5 m. Conditions affecting the visibility—like fog and snow—limit the operation range of a laser scanner (Chan & Bu, 2005).

Mechanical counters, like hinged boardwalks, turnstiles and gates, can be installed to existing structures but their moving parts are subject to environmental burdens, abrasion, and vandalism. Pressure sensors include pneumatic tubes, sensor cables, pressure pads, strain gauges and piezoelectric sensor mats. The pressure sensors can be installed under covering material, they may have adjustable sensitivity and logging delay to exclude false counts and they are low in power use (Cessford et al., 2002). Seismic and vibration counters register oscillations originating from a buried sensor.