iris INC.

Automatic Passenger Counting

A guideline on how to select a sensor for your agency

Summary

Over the years, metropolitan regions have experienced an influx of people moving from rural areas into the cities. When coupled with the fact that the overall population size is increasing, one can see how public transportation is gaining more importance in people's daily lives.

Public transit operations are challenged to structure their routes and headways based on the demand of the mobility dynamics in their respective markets. As a result, the public transit industry is improving operational efficiencies and customer experiences to meet and exceed market demands.

Intelligent systems have become an integral part of transit vehicles as well as in control rooms as a tool to manage operations. In order to meet the needs of advanced technology, technology companies have entered the Intelligent Transportation Systems (ITS) market to provide solutions to transit agencies. With a variety of solutions on the market, selecting the best fit can be a difficult task.

For example, the worldwide transit industry is experiencing significant growth in demand for Automated Passenger Counting (APC) systems. Companies offer this service either as a standalone solution or fully integrated into related solutions. Some companies simply provide essential components of an APC system.

A key component of an APC solution is the actual sensor that collects counting data. In an effort to select the right sensors for transit vehicles, the following factors need to be considered:

1. **The importance of accurate raw data:**
   The APC sensor needs to provide a high accuracy of raw data in order to ensure that reports and statistics are reliable and robust.

2. **Definition of APC accuracy and its methodology:**
   A methodology must be in place to verify the accuracy of APC data according to the respective transit agency dynamics.

3. **Difference between stereoscopic, infrared sensors and time-of-flight technology:**
   There must be an understanding of the different APC technologies to best select and service the device.

4. **Characteristics of features and technology:**
   APC sensors must provide certain features and technology, as well as have the capability of being upgraded in the future.

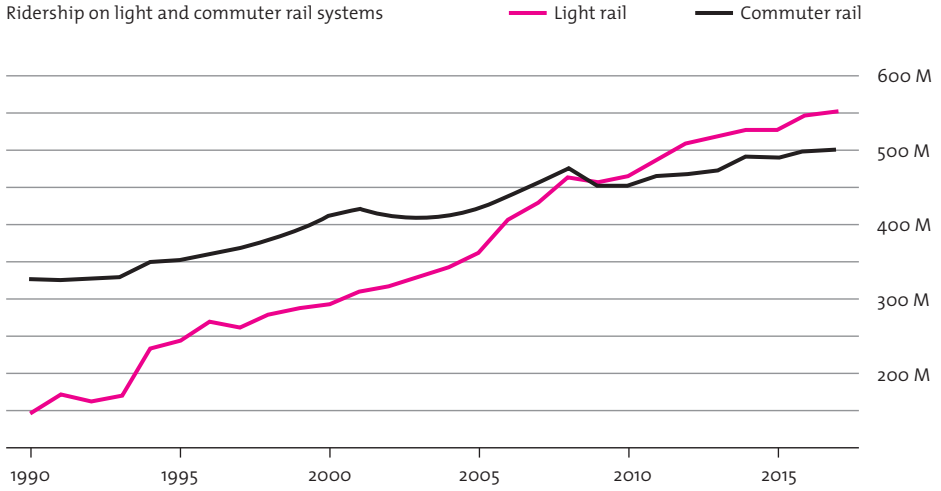
http://luminocity3d.org/WorldCity/#4/33.32/109.25

Introduction

Ridership has fluctuated over the last 20 years. While there has been a steady increase of ridership during that time frame, several regions have actually experienced ridership declines. For example, in regions like New York (USA) and Berlin (Germany) passenger volume has significantly increased on their respective urban transport systems. In addition, in 2016 alone, 37 cities throughout the world expanded their subway networks by more than 750 km (466 miles).[1] On the flip side, due to the rise of new mobility and Transportation Network Companies (TNC), public transit passengers have the option of using alternative modes of transportation. Ridership information is key to understanding the effect of this trend while also functioning as an indication of a transit agency's performance.

RIDING THE RAILS

Ridership on light and commuter rail systems



Source: American Public Transportation Association

[1] As indicated by the Institute for Transportation & Development Policy. Online at: https://www.itdp.org/category/location/south-america/brazil/rio-de-janeiro/ (last retrieval on 10/13/2017).

Funding is necessary for not only expansions, but also to simply maintain and improve the ability to provide sustainable transit services. In the U.S., the government subsidizes such activities. The scope of those subsidies is influenced by regular reporting to the National Transit Database (NTD). Key indicators evaluated by the Federal Transit Administration (FTA) include ridership, routes, and passenger miles traveled from individual transit agencies. Transit agencies must ensure the accuracy of their data. Prior to the introduction of automated passenger counting systems, ridership data has been collected using complicated and time-consuming sampling methods.

With the advancement of ITS technology, automatic passenger counting is becoming an accepted and preferred standard. Instead of having to gain insight through the periodic collection of ridership data, APC allows constant access to ridership data.

APC ridership data may satisfy the NTD requirement. If used properly, the data can also provide additional value to transit agencies, such as instant information on travel peak times and locations, audits with fare collections, and real-time data on occupancy. These tools allow for more sophisticated analytics to improve operations and rider experiences. With the advancement of autonomous vehicles technology, accurate real-time ridership information is important on driverless vehicles to ensure passenger load and ridership is properly recorded.

Although APC systems have become a preferred solution in many ITS projects, a standard for APC accuracy has not been fully defined in North America. As a result, many low-cost solutions that meet minimum requirements as specified in RFPs (Request for Proposal) may not meet the actual needs of transit agencies.

Generally speaking, an APC system comprises two main parts: the actual APC sensor that collect the ridership data, and the backend tasked with processing the data. This white paper provides a guideline on how to select an Automated Passenger Counting sensor for your APC solution by analyzing the following indicators:

1. **Raw data**
2. **Definition and methodology of APC accuracy**
3. **Difference between stereoscopic, infrared and time-of-flight**
4. **Characteristics of features and technology**

1. The importance of the raw data

Prior to the implementation of automated passenger counting systems, transit agencies have collected data via manual counts. Manual passenger counting requires significant staffing and cost. Additionally, the counting accuracy may fall short due to human error. Finally, manual passenger counters are not deployed year-round; they are collected during certain audit campaigns, meaning that the data collected only represents a snapshot of the day-to-day ridership activities.

The above disadvantages can be avoided by using automatic counting systems. APCs are independent of time-of-day or day-of-week. APCs are also fatigue-proof and work well on crowded vehicles.

However, not every APC sensor is the same. For example, older APC sensor technologies have not improved to meet the new dynamics of increased ridership, such as the need to count more passengers that are moving simultaneously in the same or opposite direction during boarding and alighting. Other sensor technologies may have been developed for non-transit applications, such as stationary doors. These technologies may not take into account the complexity of a moving vehicle and/or environmental changes. As a result, the accuracy of the raw counting data varies from technology to technology.

Some APC solutions compensate for raw data inaccuracies by using special software programs (using algorithms) which promise to yield more accurate overall results. The quality of the conclusive results depends on two factors: raw data collected by the automated passenger counting sensor, and the level of the corrective algorithms.

With such programs, the result is always an extrapolation as opposed to an actual or provable number. If a sensor has 80% accuracy, for example, and this accuracy is increased to 95% by the application of statistical assumptions, this only minimizes the error. However, the raw data is not improved. In addition, the final data is heavily dependent on the software program, which means higher cost and a learning curve that needs to be considered.

To ensure that the data collected by the sensor shows an accurate count of passenger flow, APC users should opt for an APC sensor with a proven track record of highly accurate raw data. Not only does this save on work and time, but the error potential and dependence on data manipulation is also minimized. Data processing, including the use of an accuracy algorithm, still can be used for additional value-added use cases.

2. Definition of APC accuracy and its methodology

Most APC systems boast an accuracy rate of 95% or better. In many cases, however, no definition has been provided as to how this system derives to a practical accuracy level.

For example, a methodology that consists of a staged boarding/alighting test measuring a handful of passengers may not be sufficient for some transit agencies with a high volume of ridership. It is necessary to determine a specific method or formula for measuring the accuracy and quality of the data. This methodology can also serve to commission new or existing solutions.

Additional points should also be considered:

Accuracy testing should be done on APC raw data delivered by the sensors without any additional manipulation.

When possible, test rides should be done on revenue runs and during different shifts. Staging a test ride may not provide a real picture of sensor performance.

The APC system supplier should provide accuracy testing and evaluation tools. It is essential to provide tools to prove and evaluate the performance and accuracy of the installed APC devices if necessary.

Sensors need to be located overhead to provide 3D process imaging and detect simultaneous passenger movement.

3. Difference between stereoscopic, infrared and time-of-flight (ToF) sensors

Most APC sensors in the market provide a 3D image processing technology to count passengers. This can only be achieved by using sensors that are installed above the door to scan the entire door area and detect passenger movement. Sensors using light barriers installed on the side of the door may not meet all requirements expected from a state-of-the-art APC sensor. This technology is considered outdated.

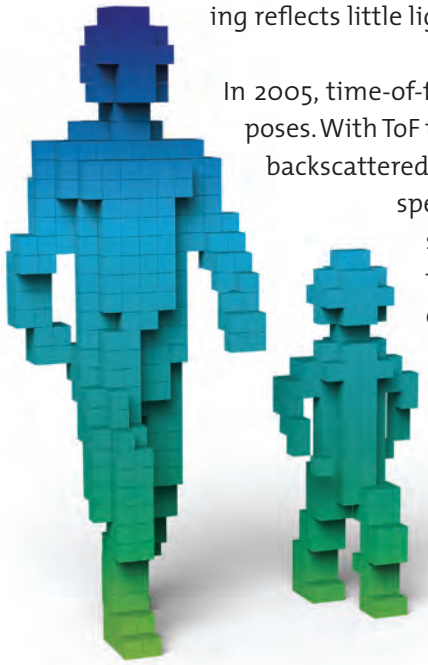
Reliable and accurate technologies include camera-based (stereoscopic) sensors, some infrared sensors and time-of-flight sensors. As a rule, camera-based systems comprise one or two recording devices located overhead (e.g. the door panel). They take high-resolution images of the passenger area, providing accurate results even when the vehicle is crowded.

Camera-based including stereoscopic sensors have evolved over the years to function more effectively in moving vehicles. If lighting and environmental conditions are optimal, passengers and objects can be identified and counted in an indisputable manner. However, these solutions rely on external lighting conditions or have to provide illumination of the scene internally for best performance. The advantage of the stereoscopic approach in comparison to mono-video cameras is the generation of 3D images of the observed area as long as the distance between the sensor and the counted person will not fall below a given limit.

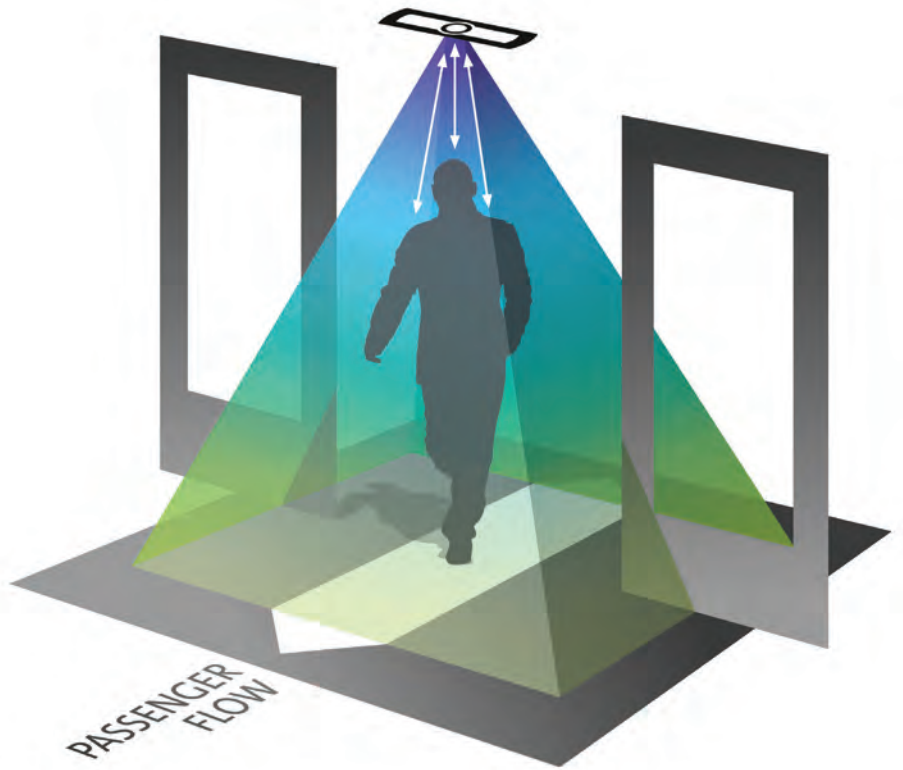
Picture quality is key to identify passengers and provide an accurate count. Stereoscopic cameras calculate 3D information from comparison of two independent 2D pictures. An algorithm extracts differences based on light and dark contrast within the scenery. That information is highly dependent on scenery, quality of the pictures, illumination, speed of objects moving underneath, shades

etc. In a moving vehicle, these factors can be inconsistent and therefore challenging.

Most infrared sensors use passive and/or active detection technology. The passive sensor version is a kind of "intelligent motion detector" which counts passengers based on the temperature difference relative to the environment. However, if there are only slight differences in temperature between body temperature and the temperature inside the vehicle, the sensors may not recognize passengers. On the other hand, if there is a significant difference between external temperature and the temperature inside the vehicle, the sensor may miscount passengers when the doors open and warm/cold air enters the vehicle. Active infrared sensors do not present any of the above disadvantages. They "scan" the environment with infrared rays and gain information from the reflected light. This type of measurement does not rely on temperature or lighting conditions. Nevertheless, there are inaccuracies, e.g. when dark clothing reflects little light and is hard to detect.



In 2005, time-of-flight (ToF) sensors were introduced for APC purposes. With ToF technology, infrared light is sent out by the sensor, backscattered by the passengers and detected by the sensor. The speed of the light, which is the transit time from sensor to object and back to sensor, is used to measure the distance between the sensor and the detected object. The distance results from the runtime between time of emission and time of reception, hence time of flight. By measuring the distance at different detection points, the sensor analyzes height, shape and direction of movement of passengers and objects passing the detection area. The result is a three-dimensional image of the detection area and the detected objects.



The key advantage of ToF technology is that the sensor actually measures a passenger/object contour in the door area and yields a 3D silhouette of the passengers and objects passing the sensor zone.

The image of a ToF scan provides a measured distance value for each pixel, the 3D information is not derived from image processing and calculations, but a direct result of the physical measurement of the travel time of light.

Therefore, ToF provides constant, robust measurement. It is not affected by temperature, brightness, moisture, ambient light, sun/shade contrast or condition of the background (reflecting or non-reflecting surfaces). Consequently, sensors based on ToF are immune to influences and/or changes of the environment.

4. Characteristics of features and technology

An APC sensor should be able to provide high-quality raw data, a proven commissioning methodology and a robust technology designed for moving vehicles. It is also important to consider the evolution of APC technology. Generally speaking, a bus has a life span of 10-12 years before decommissioning, for trains this life span may last for more than 30 years. Thus, it is expected that devices on vehicles can last as long as the vehicles or at least until the next refurnishment. Factors like longevity, installation, maintenance and design also play an increasingly important role.

In terms of longevity, there are three things to consider: 1) the actual design lifetime 2) the mean time to failure (MTTF) or mean time between failures (MTBF), which should be available for each sensor generation, and 3) being able to stay up-to-date with evolving technology.

Technology is in constant development. In the early 1990s, the first generation of sensor technologies became available in the market. These were continuously improved in order to fulfill increasing demands. During a vehicle life span, several new generations of sensors may have entered the market. It must be determined on a strategic basis whether upgrading is worthwhile.

Technology companies have been challenged with how to design hardware devices that can still meet future needs in an innovation-driven era. A good APC sensor is a device that needs to be installed only once but is also capable of being upgraded with new features in the future.

For example, APC sensor manufacturers are currently developing features such as bicycle and wheelchair/stroller counting. These may not be fully available at the time of commissioning. However, with a simple firmware update, these features could later be integrated on the already-installed device.

Another example could be that due to budgetary constraints, a transit agency would add certain features at a later point in time. A simple firmware update would not only save cost and labor time, but also allow new features to be added more quickly and software bugs to be resolved. Accordingly, the agencies can take advantage of more customized solutions.

Customizable solutions may also imply that agencies can pick from a variety of devices and technologies available in the market. While there are only a few companies manufacturing high-quality APC sensors, the sensors should be

agnostic to allow integration in a variety of solutions. An agency can then request a sensor of its choice. In the event that an agency switches its vendor, an agnostic sensor would not need to be replaced; it would simply need to be connected to the new vendor'sinfrastructure.

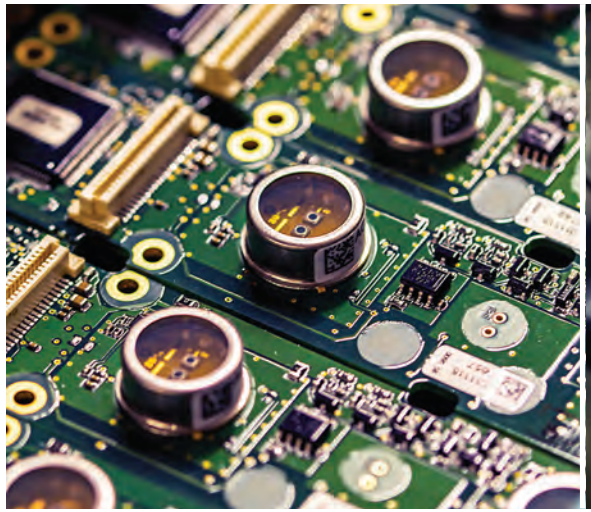
Finally, sensors have to be designed for simple installation and maintenance. Once a sensor is installed correctly, maintenance requirements should be minimal. Furthermore, direct support from the sensor manufacturer is of great value and should be taken into consideration. The sensor manufacturer is the Subject Matter Expert (SME). Thus, its involvement may reduce cost and downtime of the vehicle. That is why sensor manufacturers should also be considered for project support in proposals. A manufacturer with a strong focus on service can perform training on maintenance and new technological developments for the vendors and transit agency staff.

Intelligent sensors: 25-plus years of iris-GmbH

For more than 25 years, iris-GmbH has been the worldwide leader of Automated Passenger Counting sensors. The company entered the market in the early 1990s with an infrared overhead APC sensor. The company solely focuses on the development, design and manufacturing of APC sensors for transit agencies.

iris-GmbH's objective is to provide the most accurate APC sensor for the industry. In addition, the company has highly skilled project managers who are assisting agencies and their ITS providers on various projects. IRMA sensors, the company's product line of APC sensors, count passengers at more than 400 transit agencies around the world. The sensors have been connected to over 100 different ITS providers' on-board units.

In 2014, iris-GmbH opened a subsidiary in Atlanta/Georgia, the iris Inc. North America. The company's objective is to provide local technical and commercial support for its APC users. Other additional sales offices exist in France, Poland and Russia.



IRMA MATRIX: state of the art APC sensor

The IRMA MATRIX is the 5th generation state of the art APC sensor of iris-GmbH. The IRMA MATRIX uses time-of-flight (ToF) technology to generate a 3D image for count processing. With a resolution of 500 (25x20) pixels, one pixel can measure 4,096 different height values. Generally speaking, one sensor is sufficient for a standard door in North America. The data collected can be transmitted to an on-board intelligent device via Ethernet and CAN, or alternatively with a gateway via J1708, RS232 and RS485. Based on bus type (i.e. low-floor or high-floor buses), a specific firmware per type is available. The IRMA MARIX sensor has an accuracy rate of 98% based on raw data collected from revenue runs.

Thanks to its long lifespan and a mean time between failures (MTBF) of more than 1.2 million hours, as well as its sturdy aluminum housing and IP65/IP67 protection, IRMA MATRIX ensures a long service life and investment security. Installation is simple and no calibration or adjustments are required. The sensor is installed "overhead" so that it covers the full door area and detects even complex situations. The reduction of the number of system components further reduces error and failure risk while also simplifying maintenance. The sensor has a modern design with a closed, smooth surface that can be integrated unobtrusively into any vehicle or door. It is available in two versions: 1) the surface-mount sensor is a sensor intended for retrofitting, 2) the flush-mount sensor is designed for new factory-provided installation.

The image generated by the sensor allows reliable identification of passengers and movement pattern, such as direction and speed of movement. It also can measure the height of individuals. The sensor is also capable of recognizing bicycles and strollers/wheelchairs. Pilot projects for this kind of object counting are presently running in Europe and the United States. IRMA MATRIX ensures high counting accuracy independent of color, temperature and moisture, as well as in darkness, strong sunlight and reflections.

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IRMA 6

Accuracy made easy

iris will launch the 6th generation of IRMA sensors at the InnoTrans 2018 show in Berlin, Germany. For more information, please contact the iris office.

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