Flow Line Analysis Technology for "Visualizing" Human Behavior and Utilization Examples

HARADA Noriaki, AOKI Masaru, MIKAMI Akiko, MINESHITA Satoshi, SAITO Shigetsu

Abstract

NEC has developed a flow line analysis system that analyzes the positions and conditions of persons based on camera images, combined with attribute information obtained from sensor tags. This system "visualizes" the positions and conditions of persons from images provided by several monitoring cameras and can be used as a tool for gaining an understanding of the behaivor taken by employees inside plants and distribution warehouses, as well as customers inside stores. This paper introduces related technologies for realizing this and relevant application examples.

Keywords

person detection and tracking, multiple cameras, person action analysis visualization, person attributes

1. Introduction

Cameras are installed in a variety of facilities for the purpose of monitoring and recording a diverse range of events that occur in the real world. The number of cameras and the amount of data recorded are becoming immense. In the future it will be important for the cameras to be used as visualization tools for improving work operational processes and services through a conversion of the collected camera images into valuable information.

NEC's flow line analysis system can not only visually monitor images, but also adapt a flow line analysis system for various applications, through the development of image analysis technologies. This paper introduces the features of elemental technologies for achieving "visualization" in the field by keeping track of and understanding the human actions and behavior captured by camera images, as well as application examples.

2. Flow Line Analysis Technology

NEC is developing a flow line analysis system that makes it possible to gain an understanding regarding the positions and conditions of persons through surveillance cameras installed in a variety of facilities, such as plants, distribution warehouses and stores (**Fig. 1**). Persons are detected in the images

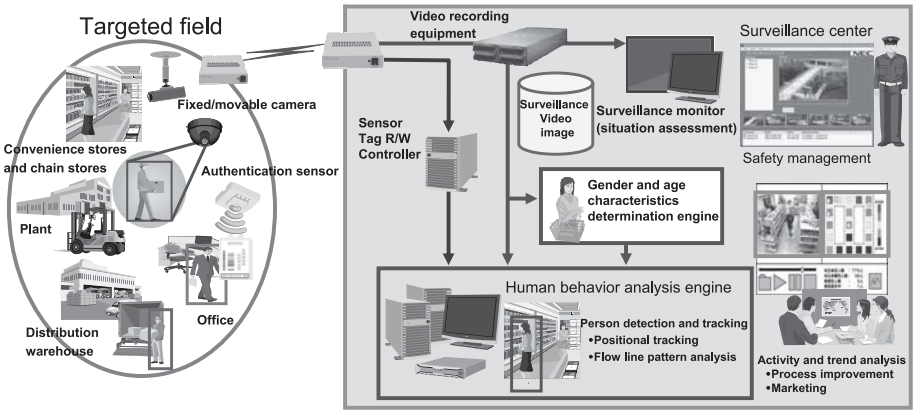


Fig. 1 Image diagram of flow line analysis system.

Flow Line Analysis Technology for "Visualizing" Human Behavior and Utilization Examples

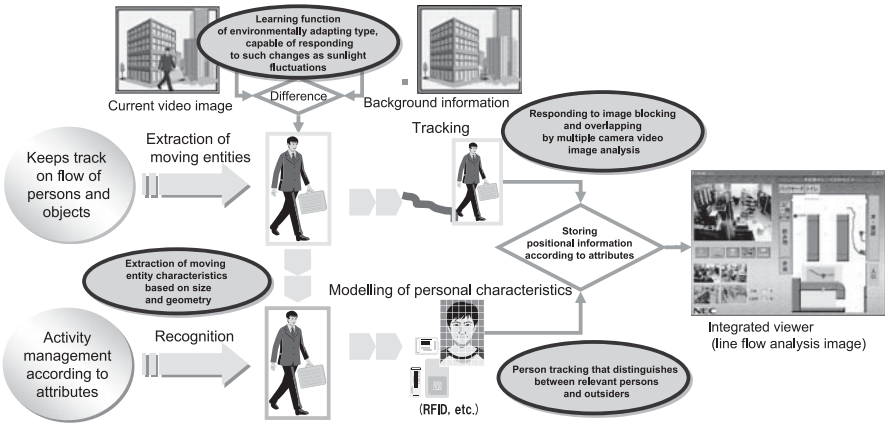


Fig. 2 Overview of person extracting and tracking technology.

captured by multiple cameras in a highly accurate manner and the position of each individual person is identified, which makes it possible to steadily track them even under circumstances when coverage is overlapped by multiple cameras or hidden behind obstacles. Furthermore, by integrating with authentication sensors, such as RFID tags, the system can be used to gain flow line information that describes the characteristics of persons and what they are doing, as well as their condition, by gaining an understanding on the movements of specific individuals.

2.1 Person Detection and Tracking Technologies

In order to detect persons from camera images in a highly accurate manner, it is necessary to reduce the impact of environmental changes, such as lighting or sunlight, while distinguishing individuals from obstacles and people moving in the background. NEC therefore developed the likelihood based background subtraction method [1] . This method makes it possible to identify moving entities, such as persons only, by sequentially learning the patterns that occur in the background and the entities other than the relevant moving entity the system is tracking and compares them against the camera images (**Fig. 2**).

Next, it is necessary to identify the extracted moving entity to verify that it is indeed the individual the system is tracking. In order to identify the person more accurately, the system extracts characteristics using the normalized amalgamation type of gradient orientation characteristics extraction [2] and

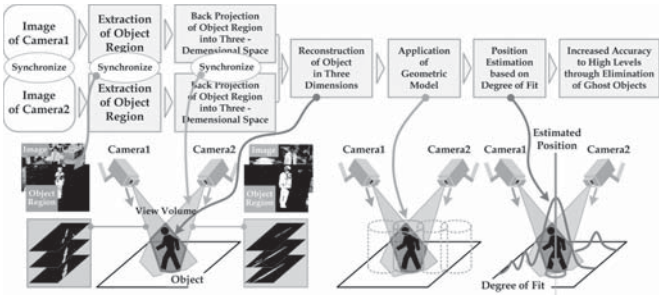


Fig. 3 Overview of person position estimating technology.

seeks to improve the recognition accuracy by linking it with the learning type characteristics database using the Generalized Learning Vector Quantization (GLVQ) [3] . This enables model geometry and the characteristics of persons, in order to automatically determine in real-time whether or not the detected individual is a person or a specific object.

2.2 Person Position Estimating Technology

When tracking the movements of a person based on video images captured by a single camera, stable tracking of the individual becomes difficult when such a targeted person becomes hidden behind obstacles, such as racks or cargo. NEC therefore developed a technology [4] that estimates the positions of individual persons by linking up the information of images captured by multiple cameras to reproduce a three-dimensional person geometry, as in real space (**Fig. 3**). This

makes it possible to sustain stable tracking even when the targeted individuals overlap by passing each other. Furthermore, the positions where persons are standing, as well as their trajectory can be estimated with a high accuracy rate of within ±25cm.

2.3 Linked with Authentication Sensor

To understand human actions and behavior from images captured by cameras, flow line information with more value can be provided by pairing up the targeted individuals with attribute information. By separating the staff wearing tags in a store from the customers, it is possible to understand flow lines within the store of customers and "visualize non-purchasers behavior," which is difficult to grasp with POS and other such systems. By integrating with systems that can estimate the age and gender of a person from facial characteristics, it is possible to understand the flow line of customers in categories and in detail.

3. Flow Line Analysis System

3.1 Overview

The flow line analysis system takes measurements on the positional information of persons and vehicles in motion and recognizes individuals as being the same individuals within a chronological change, as well as outputs the statistical values relating to the positional information for each individual.

3.2 Features

The flow line analysis system offered by NEC has the following features:

First, the acquisition of position information can be achieved with a higher degree of accuracy, in comparison with positional measurements taken by wireless systems, through measurements of position information on moving entities using the images captured by the cameras. Second is the capability to recognize that an entity is indeed the very same object based solely on information acquired from images captured by the cameras. The matching of temporal and spatial conditions, information relating to brightness and gradient characteristics, color information characteristics, as well as geometry, are used to gain the identities of entities. Third aspect is integration with technologies to identify entities by means other than the analysis of images from video imagery captured by the cameras. In an environment where unique identification details can be obtained from IC cards or RFID tags, for example, such information can be used in a proactive manner. Fourth aspect is that video images captured by generally popular surveillance cameras can be used and no special field angle or installation methods are necessary.

There are three benefits can be gained from these features:

(1) Reduced implementation costs

Since existing surveillance cameras can be used, it is possible to limit the initial investment costs. Furthermore, no special hardware is used for the image analysis equipment and software can be run on general purpose servers. It is possible to custom build applications for customers by utilizing the output results of such software.

(2) Reduced operating costs

The analysis of images from video imagery captured by cameras is the basis of the system and devices attached or carried by the targeted object is not presumed. Additional work operations, such as fitting and removing equipment, are not required for operations. Furthermore, no additional costs are required when the targeted objects increase or when changes occur.

(3) Improvement of return on investment

The installation of cameras with special specifications at specific locations is not required and existing surveillance cameras can be used. Thus it is possible to use the standard security prevention functions. By adding image analysis the existing infrastructure of surveillance cameras and expand their utility into new uses, thereby increasing the return on the investment.

4. Application Examples

4.1 Plant Process Management

In plants of the heavy machinery manufacturing industry, where large parts and materials are manufactured, assembled and processed, there is a need to understand the progress of the current manufacturing processes by keeping track of the positions of parts and materials relocated by cranes and conveyor belts.

In plants where metallic parts and materials are used, however, radio waves are reflected therefore it is difficult to keep track of the positions using conventional RFID tags and damage to the tags during welding and other such processes is also

Flow Line Analysis Technology for "Visualizing" Human Behavior and Utilization Examples

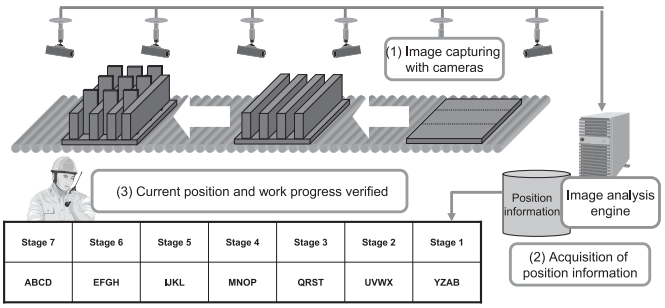


Fig. 4 Image diagram of process management system.

an issue. Furthermore, the work sites where parts and materials are handled are enormous and the situation is such that the process management involving the manual passing on of instruction slips, referred to as the Kanban method, is complex and difficult.

By keeping track of the positions and flow lines of parts and materials with video images captured by cameras, management can be performed without the use of RFID tags and other such items for where risk of damage exists and the automated tracking of processes using a system that does not involve manual work becomes possible (**Fig. 4**).

Plant process management using video images captured by cameras makes it possible to keep track of the changes in the geometry of parts and materials in real-time through a unique brightness and gradient characteristics learning technology, which ensures the recognition and tracking of parts and materials even when the geometry gradually changes with the addition of parts, etc. Furthermore, when a portion of the geometry of parts and materials is hidden behind heavy machinery being operated, such as cranes, a determination is made on whether or not shielding is currently occurring based on a judgment made according to the "certainty" of geometry, with recognition and tracking continuing after such shielding has been removed. Furthermore, it is also possible to maintain the recognition of any given part or material without the influence of changes in brightness, such as welding arcs, external light or lighting.

The starting and ending points of manufacturing processes are verified by combining the unique technology for recognizing and tracking targeted objects in a stable manner with the results after determining the shapes of specific parts and materials, as well as a determination of specific positions. Practically fully automated tracking from beginning to the end of a given manufacturing process is possible through such means.

4.2 Flow Line Management of Work Personnel

Resolving bottlenecks and improving the efficiency of work operations can be achieved through the collection of flow line information pertaining to work personnel at manufacturing plants and distribution warehouses in order to analyze the working hours and moving distances. The effects of existing improvement activities can be "visualized."

Overloading, wastefulness and irregularities can be resolved in standardized work operations at manufacturing plants by sorting out the work operation processes and rules to detect irregularities with work procedures. For example, irregularities can be detected by standardizing the work operation flow line for replenishing parts from storage to the production line. The implementation of ordinary process improvement measures on non-standard work operations, such as those in distribution warehouses, is difficult and responses are usually made on the spot based on the know-how of individuals. It is not possible to implement improvements to work operations in any uniform manner in such cases and since problems are resolved by the know-how of particular individuals, thus making it difficult to verify any improvement.

This system copes with such situations as keeping track and analyzing the flow line of each individual by linking RFID tags, and makes it possible to make comparative verifications that are not affected by the amount of materials or know-how of individuals. To make this happen it is necessary to allocate RFID readers within the work place to ensure that as much, if not all of the work flow line can be captured. This makes it possible to take measurements of the work hours and moving distances of each working personnel member within a work place, for each time frame (**Fig. 5**). Comparing and verifying the work hours and moving distances for a given work load can be achieved by adding information onto the work load of the day. Changing the work layout has actually been proven to reduce the working hours by an average of 20% and the flow line distance by an average of 22%. The efficiency of the work operations can be improved through an examination of the effects of improvement measures in this manner, which enables the PDCA cycle to engage even in areas where improvements were difficult to implement previously.

IT conversions, such as the implementation of this system, are essential for examining such improvement effects. Comparative evaluations through measurements taken over a certain period are necessary for examinations however measurements taken manually cause issues, such as the burden of costs and have an impact on routine work operations. This system

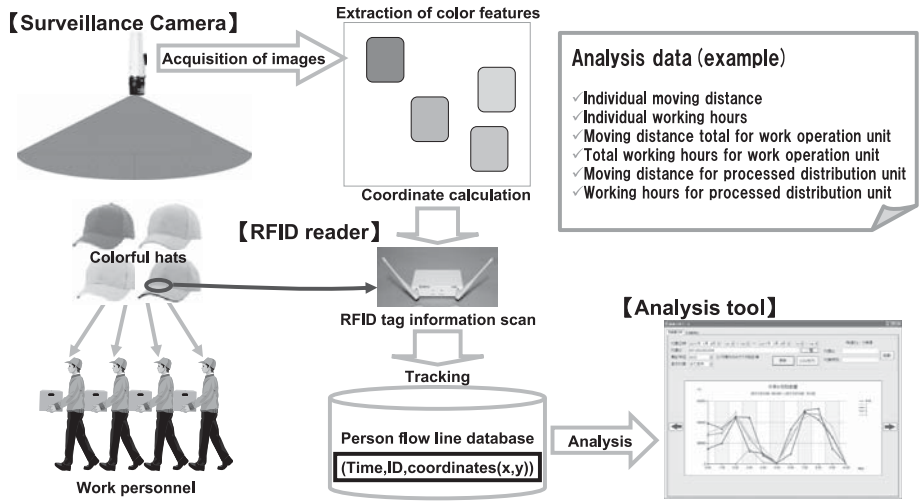


Fig. 5 Image diagram of work personnel flow line analysis system.

utilizes video images captured by cameras and makes it possible to analyze the flow lines of work personnel as they wear RFID tags. The system is considered to be suitable for flow line management at manufacturing plants and distribution warehouses, since it creates no operation costs and no special operations are necessary.

4.3 Management of Visitors at Stores

Implementation of the system at retail stores and supermarkets, where merchandise sales are conducted, makes it possible to analyze the flow line of customers within stores to promote effective sales promotions and eliminate missed sales opportunities. Conventional POS systems perform a customer behavior analysis based on purchase history, but it is also possible to gain an understanding regarding the customer behavior inside stores. Visually verifying customer behavior inside stores or surveys that involved the collection of data with the consent of customers results in extra costs, such as personnel expenses or incentives given to customers, thus continuing such efforts over a long period of time or repeating them over a number of times to analyze data is difficult to achieve.

Collecting customer flow line information through this system enables an understanding regarding the movement history of customers inside stores, as well as the number of visitors to stores by time frame. A heat map can then be prepared based on such information and compared against the sales information to identify the shelves where opportunities for sales are

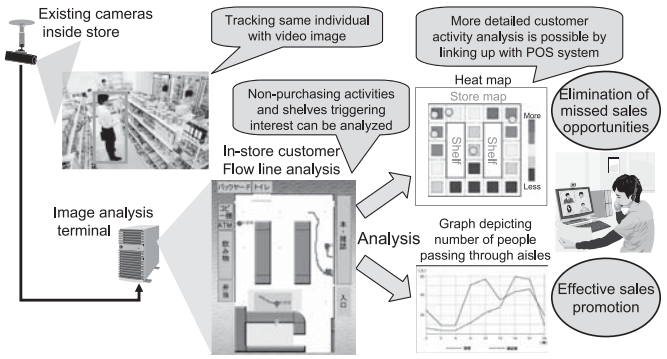


Fig. 6 Image diagram of store visitor management system.

being missed and aspects for improvement measures can be extracted. More effective sales promotions can be implemented through such means by setting discounted products in line with the changes of activity patterns according to time frame by analyzing the number of people passing through each aisle (**Fig. 6**).

Furthermore, through the combined use of other video image analysis systems available from NEC, a potential exists for more effective functional expansion. Through the utilization of the NeoFace facial recognition system, for example, the faces of individuals considered suspicious by a store or security personnel can be registered on a black list so that an alarm can be triggered whenever such a person revisits the store. The current position of such individuals can then be tracked using the

flow line analysis system and strict monitoring can be implemented between an onsite security personnel and the surveillance room.

Furthermore, through the combined use of FieldAnalyst, an automatic gender and age group estimation system, flow line information tagged with gender and age group, determined at the entry of the store, can be collected and the information utilized as a sales promotional tool that indicates what merchandise interests particular customer groups.

4.4 Presence Management of Office Personnel

Electric power conservation intended to reduce the emission of carbon dioxide has become an issue that must be undertaken promptly by enterprises, regardless of the business line. A reduction in the consumption of energy in office buildings is required particularly in Japan, through such requirements as the "Act on the Rational Use of Energy" under the Ministry of Economy, Trade and Industry, as well as the ordinance on the "Environmental Preservation to Secure the Health and Safety of Citizens of the Tokyo Metropolitan area" in the Metropolis of Tokyo. Effectively reducing the consumption of energy can be expected through the implementation of effective control of facility equipment, such as air conditioners and lighting that responds to the presence of persons in an office.

Motion sensors and non-contact type IC cards and tags are commonly used to detect the presence of persons in an office. In order to gain a detailed understanding on the conditions of persons, however, such sensors must be spread over small intervals and installed in large quantities. The flow line analysis system can be used to effectively control facility equipment, such as air conditioners and lighting in response to the presence of persons in a room, by gaining an understanding of the presence of persons in specified areas within an office using video images captured by surveillance cameras in the office. For example controls, such as switching air conditioners to intermittent operations when the number of people present within an area falls below a certain number, or turning lighting off whenever there are no persons remaining in the area, can be performed (**Fig. 7**).

A field experiment was conducted in the offices at NEC, where a 25% reduction in the electric power consumption occurred in comparison with the electric power prior to the implementation, except for the electric power consumed by the system used to control the facility equipment.

This system makes it possible to detect whether or not any persons are present in predetermined areas and the number of people are present. Detailed tracking of a person's position is possible by setting a target area to each individual desk in the office. Detection of persons seated is difficult particularly in offices, due to the presence of OA equipment on desks, etc. This system resolves such issues by gaining an understanding of the seated conditions of persons in combination with tracking the results of such individuals leading up to, approaching and sitting at a desk.

Existing surveillance cameras in the office can also be used with the system and each camera can cover a wide range of

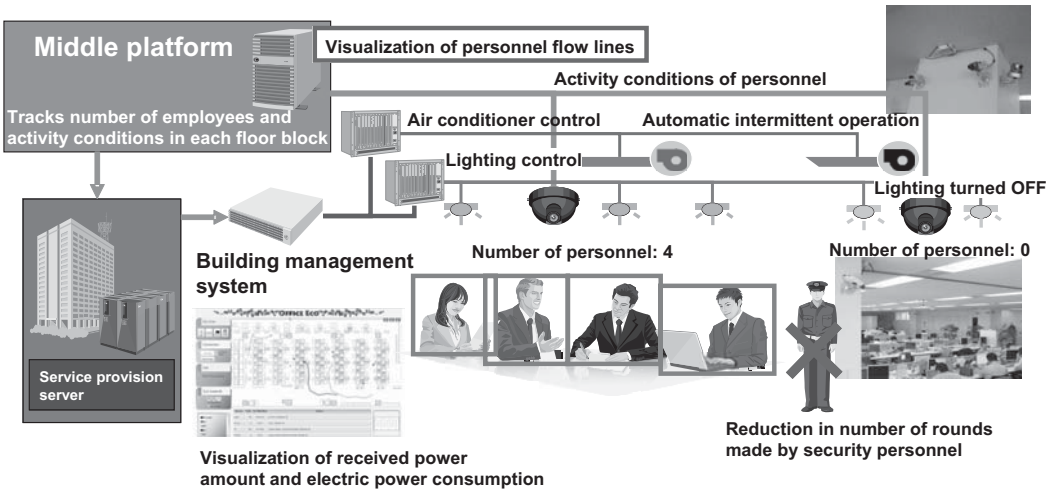


Fig. 7 Image diagram of office eco system.

areas, enabling a cost effect better than those of motion sensors.

5. Conclusion

The advancement of an image analysis technology brought about a potential for the adaptation of video imagery captured by surveillance cameras installed at various facilities, not only for security operations but also as a visualization tool for a diverse range of applications.

This paper introduced the features of the image analysis technology available from NEC in connection with "visualization" at work places and introduced application examples at plants, distribution warehouses and stores. We intend to promote various facilities to become smarter by expanding the application field of such technologies to offices, as well as through the accelerated practical implementation of such advanced technologies.

A portion of this activity is derived from the results of the "Network Integrated Control System Standardization Promotion Project (standardization of intermediate and management platform interface for the popularization of services that contribute to a reduction in the environmental burden)" project sponsored by the secondary budget of the Ministry of Internal Affairs and Communications as amended for FY2009.

Authors' Profiles

HARADA Noriaki
Senior Manager
Platform Strategic Marketing Division

AOKI Masaru
Manager
Platform Strategic Marketing Division

MIKAMI Akiko
Manager
Platform Strategic Marketing Division

MINESHITA Satoshi
Assistant Manager
Platform Strategic Marketing Division

SAITO Shigetsu
Platform Strategic Marketing Division

Information about the NEC Technical Journal

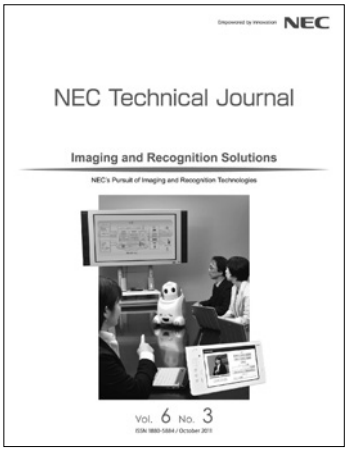
Thank you for reading the paper.
If you are interested in the NEC Technical Journal, you can also read other papers on our website.

Link to NEC Technical Journal website

Japanese

English

Vol.6 No.3 Imaging and Recognition Solutions



Vol.6 No.3
October, 2011

Special Issue TOP