Image Analysis Technologies for Understanding Human Behavior and Examples of Their Applications

HARADA Noriaki, ISHIDERA Eiki, OAMI Ryoma, NAKAO Toshiyasu

Abstract

Previously, image analysis software for human behavior was considered to be an optional extra. Recently, however, image analysis software acting as a business supporting tool has been gaining importance, and the scale of video monitoring systems is becoming larger with the spread of monitoring cameras and trends toward networked equipment.

We at NEC, as well, aim to realize a video monitoring system for security which supports operators watching video monitors to become aware of abnormal states. In order to realize the system, we are attempting to put analysis technologies for human behavior into practical use. For automatically detecting prohibited activity and dangerous behavior, persons are automatically detected among the images captured by monitoring cameras, and these persons are tracked by the monitoring cameras. The obtained information is analyzed in real time in accordance with the rules preset for monitoring.

This paper explains the technical problems related to the analysis of human behavior and our approaches to solving these problems. In addition, we would like to introduce examples of the applications of analysis technologies working in conjunction with associated systems.

Keywords

video monitoring, extraction and tracking of a person, multi-camera analysis of human behavior, monitoring suspicious persons and cars

1. Introduction

Recently, it has been no longer rare to see video monitoring cameras installed in towns. Cameras are installed particularly in public facilities and areas where the general public gathers, including traffic terminals, shopping malls, etc. With the diffusion of video surveillance and monitoring systems, the number of monitors to be watched by operators is increasing. As a result, it has become difficult to immediately respond to and properly judge situations only by a human's visual confirmation.

Anticipating the movement toward larger-scale monitoring systems in which cameras spread through various facilities and areas are connected via a network, we at NEC are making efforts to develop a system to analyze human behavior in order to support security service providers in offering more advanced services.

This paper describes elemental technologies to commercialize systems for understanding the situations and behavior of persons by analyzing images captured by monitoring cameras in real time. The systems also support operators watching video monitors to become aware of abnormal states.

2. Technologies to Analyze Human Behavior

We at NEC are developing a system to analyze human behavior in which multi-camera systems and authentication sensors using RFID (Radio Frequency Identification), etc. are combined (**Fig. 1**). The system can be used for security purposes, job analysis and information collection for marketing.

In order to understand human behavior with a high degree of accuracy using images captured by monitoring cameras, it is necessary to consistently detect only persons and extract them while eliminating the effects of environmental variations such as changes in lighting. In the case of indoor facilities such as offices and their premises, it is necessary to

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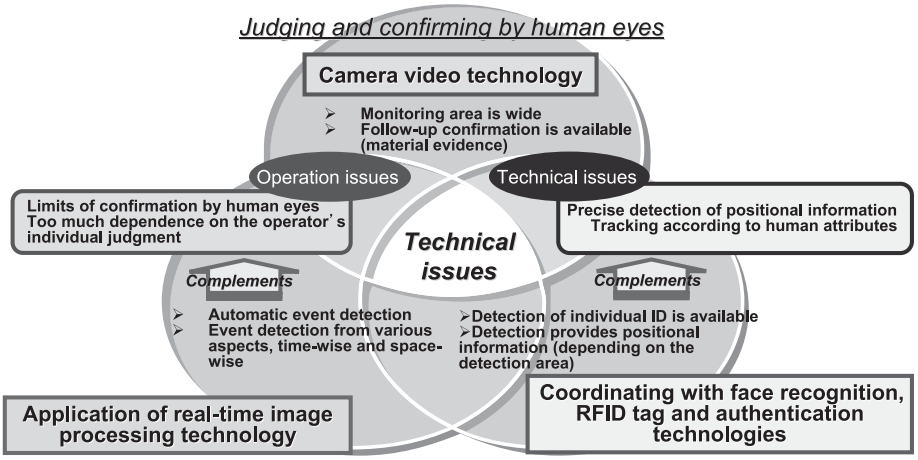

Fig. 1 Human behavior analysis system concept.

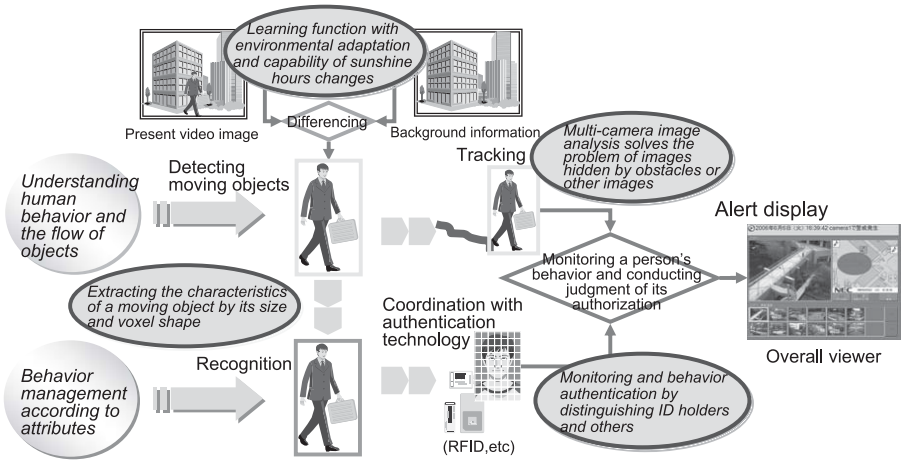

Fig. 2 Explanatory diagram of the human behavior recognition system.

continue tracking persons even if their figures are hidden by desks, cabinets, racks and so on. We at NEC have successfully developed image analysis technologies which make it possible to continue tracking persons with a high degree of accuracy even under such circumstances. In addition, by using these technologies in conjunction with authentication sensors using RFID, etc., we have developed technologies to remotely identify the persons in the images captured by monitoring cameras and extract their motion paths. These technologies make it possible to understand who is acting and how and where the persons are. These technologies can be used for security purposes such as entrance and exit management. Moreover, it is possible to utilize these technologies as a marketing tool aiming at customers visiting stores (**Fig. 2**).

2.1 Technologies for Extracting Paths and Tracking Persons

In order to extract the path of a person quickly with a high degree of accuracy using the images captured by monitor cameras, it is necessary to detect moving persons while suppressing the false detections caused by sudden changes of sunshine,

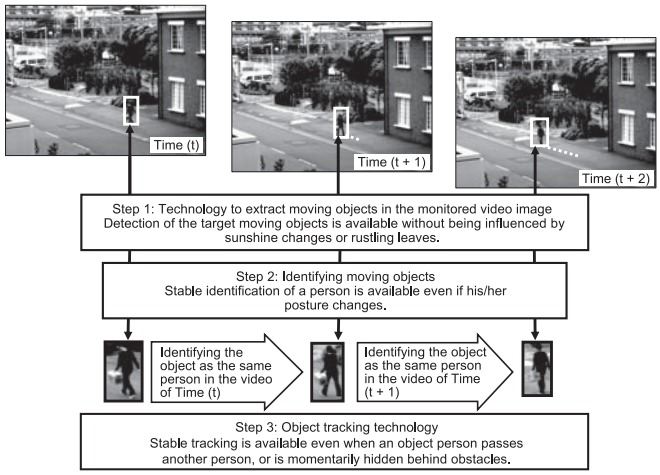

Fig. 3 Technologies to extract a path and track a person.

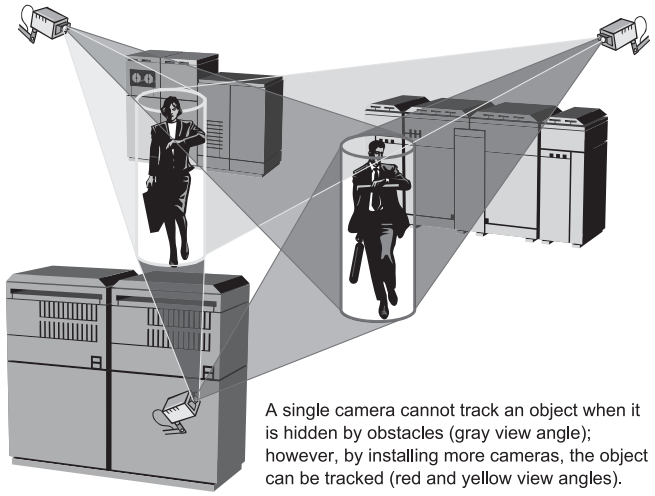

Fig. 4 Multi-camera coordination.

lighting, shadows cast by rustling leaves and so on. In order to respond to the problem, we have a "likelihood-based background differencing system [1]" to detect a moving object with a high degree of accuracy by using a learning function in which environmental adaptation is taken into account. The next problem is to determine if the captured objects are persons or not (i.e., differentiating persons from other objects). In order to identify persons more accurately, we have succeeded in improving recognition accuracy by extracting the characteristics of moving objects using "SEIKIKA YUGO-GATA KOBAI-HOKO TOKUCHO (gradient direction characteristics integrating normalization) [2]." In addition, for the enhancement of accuracy, we use a characteristics database of moving objects constructed using the learned results obtained using GLVQ (Generalized Learning Vector Quantization) [3]. Additionally, in order to correctly track the path of a person even if the person is hidden by other objects, while avoiding tracking the wrong person, we have developed a practical tracking process which fully utilizes the moving speed and characteristics of a person (**Fig. 3**).

The combination of these elemental technologies makes it possible to extract the paths of a person in real time with a high degree of accuracy using the images captured by monitoring cameras.

2.2 Multi–camera Coordination System

In the case that only one monitoring camera is used for the security of indoor facilities such as offices and their premises, it is difficult to track the path of a person if the person is hidden by desks, cabinets, racks and so on. In order to respond to this problem, we have developed technologies to efficiently coordinate multiple cameras. These technologies make it possible to track a person even if the person is hidden by other objects when switching the cameras to be used for tracking.

The multi-camera coordination system developed by NEC makes it possible to presume three-dimensional shapes based on the information provided by multiple cameras, and it is possible to estimate the position of a person with an accuracy of level of ± 25 cm even in crowded conditions and stores having a lot of obstacles such as shelves. In addition, the system has made it possible to display the positional information of multiple persons in real time by displaying the monitoring area and the monitored persons' positions on a map (**Fig. 4**).

2.3 Technologies to Coordinate Authentication Sensors

By matching the ID information obtained by RFID or face recognition devices with a system for detecting and tracking multiple persons in the images captured by monitoring cameras, it becomes possible to understand the behavior of a specific person. For example, if only inside personnel wear active RFID tags, it will be possible to analyze in real time the behavior of only outsiders who do not wear RFID tags. In addition, even if the positional information or ID information of specific persons is lost or fragmented, it is possible to continuously track the motion paths of these persons.

It is also possible to conduct precise sensing of human

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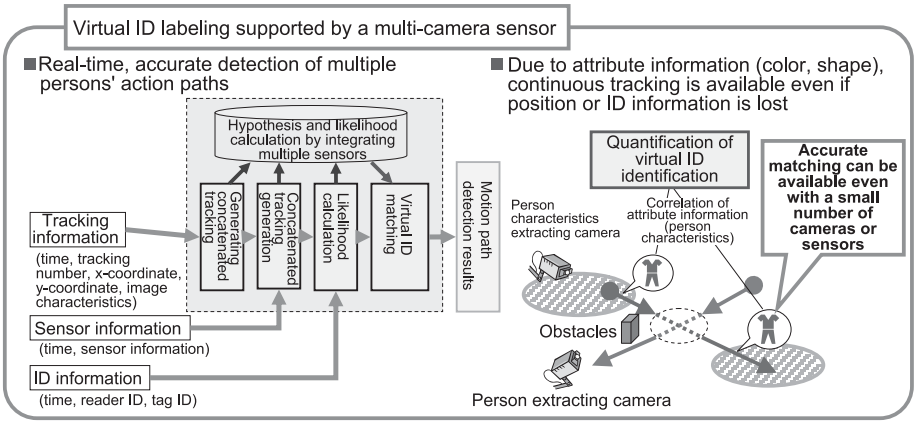

Fig. 5 Outline of the model for a human tracking system coordinating multiple sensors.

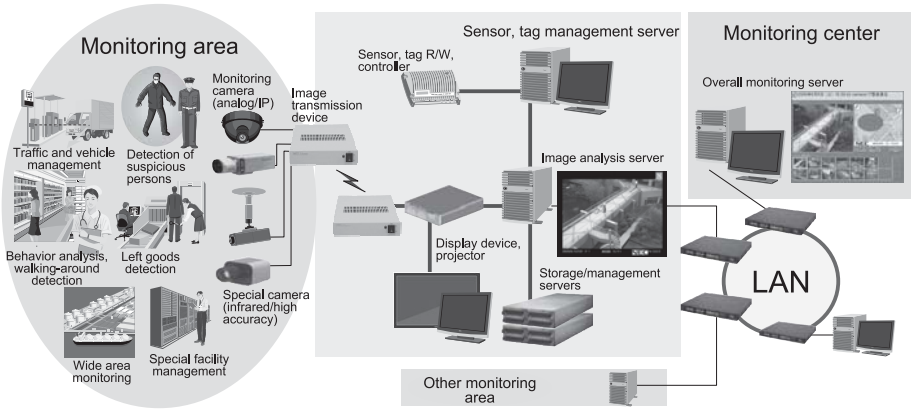

Fig. 6 Explanatory diagram of the human behavior analysis system.

behavior by matching the information obtained by various sensors with the persons in the images captured by monitoring cameras without relying on a specific tag system or a special sensor (**Fig. 5**).

3. Human Behavior Analysis System

3.1 Outline

Combining the elemental technologies explained in Chapter 2, we have developed a human behavior analysis system using multiple fixed cameras and sensor tag devices.

This system makes it possible to detect a person exhibiting suspicious behavior based on analysis of the images captured by monitoring cameras without relying on a specific camera or function. In addition, the analysis is matched to the attribute information collected from sensor tag devices in order to make it possible to understand and manage human behavior and the flow of objects (**Fig. 6**).

3.2 Features

(1) Support for Multiple Cameras

Behavior analysis and position management for multiple persons can be carried out in real time by coordinating multiple cameras installed in the area to be monitored. By understanding the positions of specified persons simultane-

ously captured by multiple cameras, it is possible to reduce the false recognition which tends to occur when monitored persons are hidden by other persons or when the monitored persons move to cameras' blind spots.

It is possible to confirm positional information on persons and their attributes in the area to be monitored in real time via a viewer. Our system makes it possible to carry out such image analysis processes on a general-purpose personal computer, and it does not require replacing currently-used monitoring cameras with special cameras. Introducing additional camera(s) makes it possible to understand and manage the motions of people and the flow of objects.

(2) Readiness for Changes in Environment

We have employed a learning-type image analysis engine for our system in order to suppress the effects of environmental variations such as changes in weather and sunshine hours. The system precisely defines the size of a moving object (i.e., a person) based on the distance between the object and the cameras, and also estimates the shape of the object in order to identify the person. Thus, the system has realized highly precise human detection.

(3) Easy-to-Configure Monitoring Policy

It is possible to configure the areas to be monitored and the events to activate an alarm via a policy configuration screen. The shape of the areas to be monitored can be determined arbitrarily, and an alarm is activated when detecting unusual behavior such as trespassing in the monitored areas and unauthorized loitering in the area.

(4) Understanding Human Behavior Based on Personal Attributes

It is possible to monitor human behavior in accordance with access authorization by matching attribute information collected from sensor tag devices with the person captured by monitoring cameras.

(5) Confirmation of the Occurrence of Trouble

When prohibited behavior is detected, an alarm sounds and alarm messages are activated, and the operators watching the monitors become aware of the event. By selecting the images from the cameras capturing the event via the monitoring screen of a viewer, the captured images are replayed from the time point right before the occurrence of the event so that the operators can immediately confirm the situation.

4. Examples of Applications

4.1 Monitoring Persons Showing Suspicious Behavior

At special facilities such as power plants and data centers which require a high level of security management, it is necessary to constantly monitor the behavior of visitors during their stay in the facility, in addition to strict management at the time of their entrance and exit. In the case of monitoring broad areas such as rivers, airports, ports and harbors, it is necessary to instantaneously detect unauthorized intrusions or dangerous behavior.

The introduction of a human behavior analysis system for such facilities makes it possible to automatically detect prohibited behavior and trouble using the images captured by a vast number of monitoring cameras. The system is useful to prevent security personnel from overlooking an alarm and it helps them to become aware of an alarm.

In addition, it is possible to automatically track a suspicious person by using the system in conjunction with a movable camera. The system records and stores only the data which is determined to be recorded.

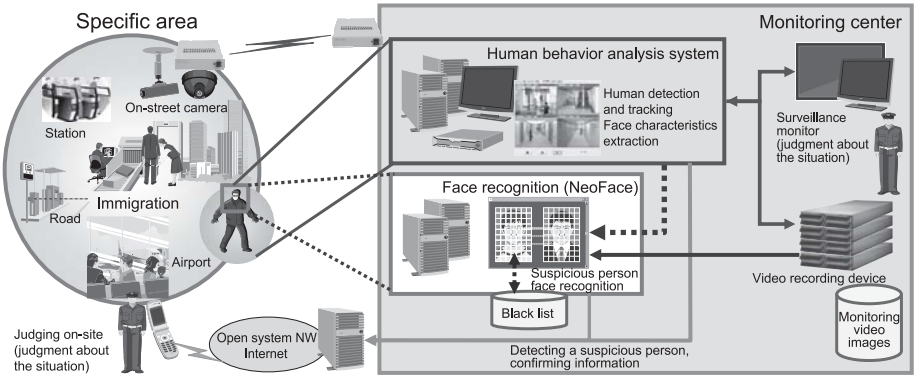

Fig. 7 System to monitor a person showing suspicious behavior.

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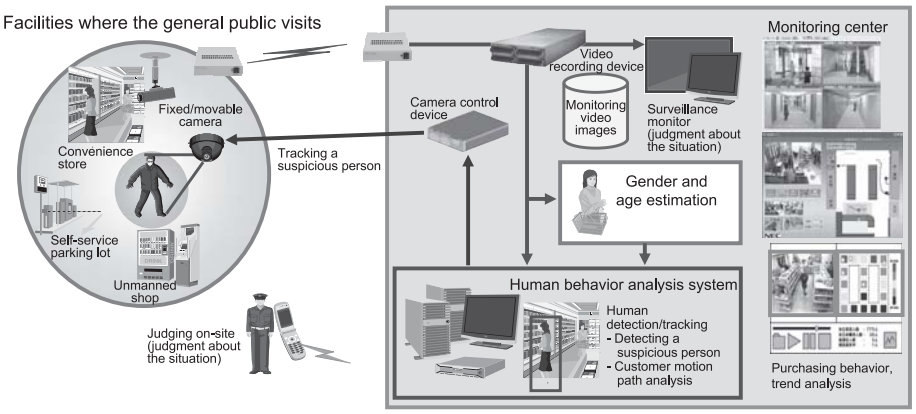

Fig. 8 System to manage customers visiting stores.

At facilities such as transport terminals and commercial facilities where the general public visits, extraction of the face of a suspicious person is carried out in conjunction with identification using a face recognition security system. The information obtained by security cameras is cross-checked with the data in the list of suspicious persons registered in advance.

The system also aims to reduce the burden of security personnel by configuring the rules for monitoring in accordance with the time period and carrying out automatic detection in accordance with the situation (**Fig. 7**).

4.2 Job Site Visualization for Plants

At shipbuilding yards, large-scale plants and construction sites, a miscellaneous crowd of workers and components coexists, and accidents tend to frequently occur with certain working processes. In the case of the above-mentioned facilities, what is to be monitored is not only the inside of buildings; it is also necessary to extensively monitor the whole premises. At present, however, it is difficult to immediately respond to an alarm which is activated when detecting that an unauthorized outsider has entered a prohibited area.

It is possible to operate a security system in accordance with security levels set respectively for each facility and area by introducing the human behavior analysis system for such facilities where various workers and components coexist and by configuring the rules for monitoring in accordance with operation processes and facility usage. In addition, when the system is not activating an alarm, it can be used as a tool to analyze the work done by workers and to support the enhancement of assembly efficiency.

4.3 Management of Customers Visiting Stores

At commercial facilities such as convenience stores, chain stores and mega-stores where a lot of persons visit, the occurrence of incidents and accidents might cause serious damage. At such facilities, it is necessary to detect a person showing suspicious behavior as soon as possible and to notify patrolling security guards of the situation so that they can take action before an incident or an accident occurs or to minimize secondary damages.

The human behavior analysis system makes it possible to compare the person among the captured images with the information on suspicious persons registered in advance. In addition, the system makes it possible to automatically detect a suspicious behavior, such as wandering in a store, and contributes to preventing the occurrence of an accident. In addition, when the system is not activating an alarm, it can be utilized in conjunction with gender and age estimation systems to work as a tool sensing the behavior of a customer visiting a store. The system makes it possible to visualize the moving and staying time of visitors, and the obtained data can be utilized for marketing purposes (**Fig. 8**).

5. Conclusion

As can be known from the above, it will become possible to carry out a huge variety of analyses of human behavior with a

high degree of accuracy by integrating heterogeneous information (i.e., information obtained by multiple monitoring cameras and sensors). At present, we are working hard to build a platform (IVCP: Information Value Creation Platform) supporting coordination among related analytical engines in addition to further enhancing analytical engines for human behavior. The objectives of IVCP are not only creating new values by supporting coordination among engines, but also facilitating the construction of a system by modularizing engines on an appropriate scale. IVCP makes it possible for modularized engines to exchange data in a common format; therefore, different applications can use the same engine. All in all, the engine is expected to reduce system construction costs and to make it possible to use the engines in many different areas. We will continue to further promote the development of IVCP in order to utilize these technologies in a wide range of areas.

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Authors' Profiles

HARADA Noriaki
Senior Manager
Platform Strategic Marketing Division

ISHIDERA Eiki
Manager
Ubiquitous Solutions Group
Advanced Technology Solutions Division

OAMI Ryoma
Principal Researcher
Information and Media Processing Laboratories

NAKAO Toshiyasu
Principal Researcher
Service Platforms Research Laboratories