Determination of Neighbor Node in Consideration of the Imaging Range of Cameras in Automatic Human Tracking System

Kozo Tanigawa, Tappei Yotsumoto, Kenichi Takahashi, Takao Kawamura, Kazunori Sugahara

***Abstract*—**A automatic human tracking system using mobile agent technology is realized because a mobile agent moves in accordance with a migration of a target person. In this paper, we propose a method for determining the neighbor node in consideration of the imaging range of cameras.

***Keywords*—**Human tracking, Mobile agent, Pan/Tilt/Zoom, Neighbor relation.

I. Introduction

In recent years, in order to protect security of our society, various kinds of systems, such as entrance and exit management and discovery of trespasser, are introduced. The supervising system using cameras has become the most widely used. In the supervising system using cameras, operators have to fix their eyes on two or more cameras to find suspicious person. However, considering the ability of the operators, the maximum number of cameras should be two or three for one operator. Therefore, when there are many cameras or many people to track, it is difficult for an operator to continue monitoring all the situations. Moreover when an operator loses sight of the suspicious person, the operator has to go over two or more cameras to capture the suspicious person, and has to bear a heavy load. For this reason, the system which tracks a target automatically using two or more camera images is being proposed. However, there are two problems in these systems, that is, the load for target tracking concentrates on one server, and another problem is that the case of changing image range of cameras is not considered.

We propose the automatic human tracking system based on mobile agent technology. This system consists of cameras, tracking servers, mobile agents, and surveillance terminals. A tracking server is installed in each camera, and it analyzes the images received from the camera. A mobile agent is generated for a target being tracked, and has information about the person’s physical features. The mobile agent migrates among tracking servers according to the movement of a target person. The person's automatic tracking is realized by detecting a person's physical features with two or more cameras made to cooperate. By checking an agent’s condition at the surveillance terminal, the operator can grasp the places of all tracking targets. In this way, an operator’s load can decrease, and the load of image analyzing processing which can be distributed to a tracking server will be moderate.

However, if many cameras are installed for eliminating dead angle, costs will become high. As a solution to this, it is realistic to install cameras at specific places, such as entrances of a building or rooms and passage crossings. In this case, the imaging range of one camera does not necessarily overlap with other cameras, so there will be a situation where a tracking target cannot be viewed by any cameras. Moreover, if the target is analyzed by all of the cameras, the cost of processing will increase according to the number of the target persons. Therefore, we have to limit the numbers of the tracking persons by the processing ability of one camera simultaneously. Therefore, a target person is narrowed by predicting which camera is next on the route which a target can move.

K.Tanigawa and T. Yotsumoto are with the Melco Power Systems Co., Ltd, Kobe, Hyogo 652-8555 Japan (e-mail: Tanigawa.Kozo@ zx.MitsubishiElectric.co.jp, Tappei.Yotsumoto@zb.MitsubishiElectric.co.jp).
K. Takahashi, T. Kawamura and K.Sugahara are associate professor and professors of Graduate School of Engineering, Tottori University, Tottori 680-8552 Japan (e-mail: takahashi/kawamura/sugahara@ike.tottori-u.ac).

II. Related Research

Y. Shiroi [1] and others proposed the example of research for pursuing multiple persons who move and the technique by cooperation of multiple cameras as correspondence to occlusion. Moreover, N. Kawashima [2] and others proposed the tracking technique of the movable object strong against noises, such as a shadow, by using a dispersion matrix while improving the background subtraction method and it has realized tracking of a movable object with multiple cameras. However, these are the researches which heightened a person’s detection accuracy by using multiple cameras, and did not deal with the case of tracking a target across multiples cameras.

D. Mori [3] and others proposed the technique of tracking a person in the environment where multiple cameras were installed so that the imaging range might overlap in the same area by unifying the observed information from multiple cameras which operate asynchronously. A. Nakazawa [4] and others proposed the mechanism for combining multiple persons feature information acquired by a vision agent. Moreover, A. Ukita [5] proposed the system for increasing the efficiency of exchange of the information by a vision agent. These researches are premised that the imaging ranges of cameras are overlapped. Therefore, it didn’t respond to the situation where the imaging ranges of cameras do not overlap.

Y. Tanizawa [6] and others proposed the system which provides a service which specialized for a target by logical movement of a mobile agent on a network connected to movement of the target. However, the determination of the movement places was left to the mobile agent and the mechanism was not mentioned. T. Tanaka [7] and others also proposed the person track technique by a mobile agent. However, the determination method of predicting which camera catches the target person next was not examined.

In this way, all these researches did not consider the cases where the imaging ranges of cameras do not overlap and also changes. Therefore, research of a human tracking system is not enough.

III. The Proposed Automatic Human Tracking System

In the human tracking system using cameras, in order to reduce an operator's load, the human tracking system using a mobile agent is proposed. In this system, a mobile agent tracks a target. The tracking status of the target by the mobile agent is all displayed on a surveillance terminal. Thereby, the operator can check multiple persons' track conditions, without changing the surveillance cameras. Moreover, these mobile agents move through tracking servers in accordance with the movement of the person, and conduct the image analysis for recognizing a person at the place that person has moved to. As a result, the load for tracking a person can be balanced.

A. Overview of Automatic Human Tracking System

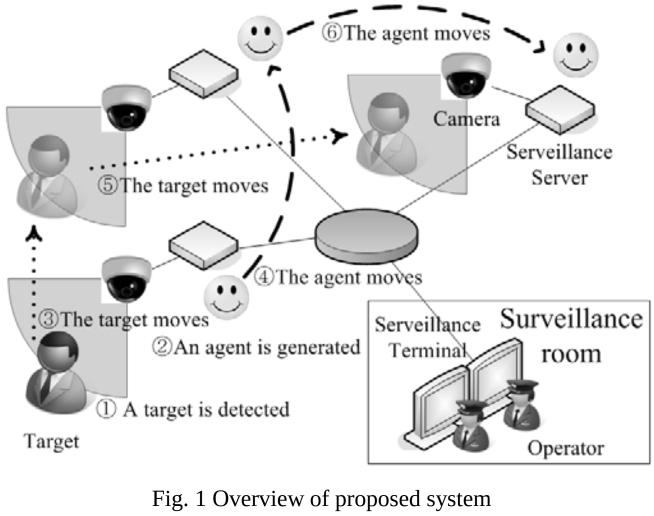

Fig. 1 Overview of proposed system

The overview of our automatic human tracking system is shown in Fig. 1. Our system consists of cameras, tracking servers, mobile agents, and surveillance terminals. In this system, one camera is discretely installed in one surveillance area and a tracking server is prepared for each camera. The camera has an automatic-transmission function of the image to a tracking server, and a function of pan/tilt/zoom by which an imaging range can be changed. The tracking server has an execution environment of a mobile agent, the function to analyze the image received from the camera, and the function to determine the neighbor nodes of the camera. All the agents' condition is displayed on a surveillance terminal. The operator only looks at a surveillance terminal, and can grasp the current position of all targets. The mobile agent is generated for a target person, and has information about the person's physical features.

If the target comes in the surveillance area, the tracking server will check whether the agent which tracks the target exists in the tracking server. If it exists, the agent will track the person. If it does not exist, the mobile agent for tracking the person will be generated.[1] The generated mobile agent analyzes the person's image, and grasps the feature information. When the target goes out of the imaging range of a camera and cannot be seen in the camera, the mobile agent dispatches its own copies to other tracking servers which manage the cameras that may possibly catch the target next. Dispatched copy agents analyze the images of the cameras periodically and check whether the target is viewed. If one copy agent catches the target person, it will inform its original agent and other copies that the target person was detected. Then the copy agent which detected the target becomes the original agent, and the former original the agent and other copy agents will be erased. By repeating above process, an automatic tracking of the target across multiple cameras can be realized.

B. Algorithm to Determine Neighbor Nodes

When considering the locations for camera installation, it is more realistic to install cameras at specific places, such as where there are building entrances, rooms, or passage crossings, rather than installing cameras so that all areas can be viewed. Therefore, there must exist to a location which is not viewed by any cameras. Thus, it is difficult to continue to view a target at all times. For this reason, when a target goes out of the imaging range of a camera, it is necessary to identify the next camera from the imaging range of each camera, and the route which a person can move.

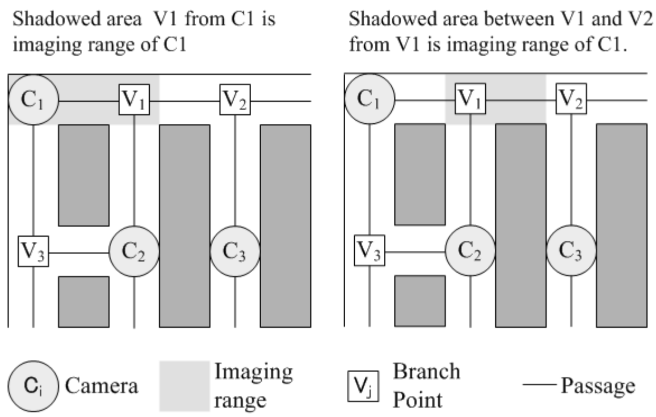

Fig. 2 Imaging ranges of Camera C1

In order to first define the path which a target person can move, the point where a path crosses is defined as a branch point. The install point of a camera is defined as a camera point. Next, the imaging range of a camera is defined. The imaging

[1]When a target moves in the dead angle of a camera and the agent is captured at unexpected camera, a new agent for tracking the target will be generated. If each mobile agent has the same physical features at same camera, their mobile agent judge that the lost target appeared in front of other camera. Then their agents are merged.

range of a camera is defined not only by the point where the camera is installed. It is also defined by whether the installation point includes a branch point or not. Moreover, an imaging range changes by pans, tilts or zooms, for example, as shown in Fig. 2 installation.

As for the imaging range of the camera C1, various cases can be considered, such as between the V1 and V2 from V1, and also V1 from C1. For this reason, the imaging range of a camera cannot express only at a branch point and a camera point. Therefore, in order to express an imaging range, the viewing point is made either between a branch point and a camera point, between two branch points, or between two camera points. Using these points, in matrix X of |C| x |P|, the imaging range of each camera is expressed, as shown in (1). Here, C is each camera and P's are branch points, camera points, or viewing points.

$$\mathrm{X} = \begin{cases} = 0 \; Pi \; is \; not \; neighbour \; of \; Pj \\ = 1 \; pi \; is \; neigheibor \; of \end{cases} \tag{1}$$

Moreover, in matrix Y of |P| x |P|, the connection relationship of a branch point a camera point and a viewing point is expressed, as shown in (2). At this time, the camera with which the imaging range has overlapped calculates (3), and it is proven to check the element which is Dij>=1.

$$Y_{i,j} = \begin{cases} = 0 \; Pi \; is \; not \; neighbour \; of \; Pj \\ = 1 \; pi \; is \; neigheibor \; of \end{cases} \tag{2}$$

$$D \; = X \cdot X^T \tag{3}$$

In the same way, (4) is calculated and the element which is Eij>=1 is checked, and proves that the imaging range of the camera Cj has overlapped with the point of remaining (n-1) points from the imaging range of the camera Ci.

$$E \; = X \cdot Y^n \cdot X^T \tag{4}$$

Therefore, the next camera which may capture the target can be calculated from the matrix X expressing the imaging range of the camera which changes dynamically. However, an imaging range is different by the angle of cameras. For this reason, there is no way to find how many points there are until next camera. Then, the point which is not included in the imaging range of all the cameras is eliminated, and all the points are put into an imaging range. Thereby, the matrix X is extended so that all neighboring cameras may be found at the n=1.In order to realize this, matrix X' and Y' are generated. Matrix X' is generated by eliminating all the column j which is (5) from the matrix X.

$$\sum_{k=1}^{m} X_{k,j} = 0 \tag{5}$$

Moreover, Matrix Y' is generated by eliminating all the column j and row j which is (5) from matrix Y. At this time, two points connected through an eliminated point are connected which prevents a path from being cut off by elimination of a point. The next camera is founds by calculating (6) using the matrix X' and the matrix Y'.

$$E' = X' \cdot Y' \cdot X'^T \tag{6}$$

C. The Update of Neighbor Node

The imaging range of a camera changes by pans, tilts and zooms, which will change the points (a camera point, a branch point and viewing point) in the imaging range. Then, an adjacency re-calculation will be applied if there is a camera which has the same imaging range with the point or over that. When a new adjacent camera is found as a result of the re-calculation of an adjacency, it notifies the mobile agent which is supervising the camera of the adjacency change. The mobile agent can respond to change of the imaging range of a camera by dispatching a copy agent to the newly found adjacent camera. A person's automatic tracking is realized from these, corresponding to change of an imaging range dynamically.

IV. Examination

In order to verify the effectiveness of the proposed method, this proposed method was implemented in the mobile agent execution environment as a bundle based on the spec of the OSGi framework. The experiment was conducted by installing 11 cameras in a surveillance area of 21.0m x 13.5m. The camera angle pans, tilts and zooms irregularly. The agent moves at a 1.5m/s velocity inside the surveillance area. The simulation was carried out 10 times in the following conditions:

1) Two target persons appear at the same time, and disappear at the same time.
2) There is no dead angle in the imaging range of the cameras.
3) When a target person appears, he/she is always detected.
4) A detection of a target person is always successful.

The simulation result for 1 person is shown in Fig. 3. The Y-axis is the tracking server of the area when the target moves, and X-axis is the elapsed time. The dotted line shows the movement of the person being tracked, and the continuous line shows the tracking result by the mobile agents. An arrow shows where the camera angle changed.[2]The calculation result shows that the mobile agent was able to detect that the target person appeared in the surveillance area at the 11th second by tracking server 9. Then, the target person moves to tracking server 11, tracking server 6 and tracking server 5. When the target person moves to tracking server 10atthe 43rd second, camera angle of tracking server 10 was changed, but the experimental result shows that the target person can be tracked continuously until the target moved out of the surveillance area at the 130th second.

As a result of carrying out this simulation for 24 hours, it verified that an agent could track a target without missing even if a camera changes the value of pan / tilt / zooming during a tracking.

[2]A copy agent moves to the next camera. Then, a copy agent detects a target and an own agent moves. For this reason, an agent moves after a move of a target.

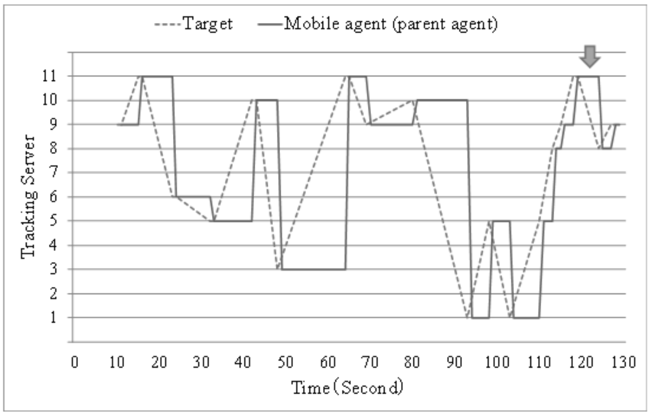

Fig. 3 Experimental result

V. Conclusion

We propose the automatic human tracking system using a mobile agent technology. In this system, the mobile agent corresponds with a move of a person, and moves with a tracking server, and tracks the person. In this paper, the method for determining the dynamics of the tracking server which the mobile agent moves in consideration of the imaging range of cameras is proposed. By determining the place to move of a mobile agent dynamically, it can flexibly copy with a change of the imaging range of cameras. This proposed system was implemented as a bundle based on the spec of the OSGi framework, and the experiment by a simulator was conducted. The evaluation result shows that the person can be tracked, coping flexibly with the change of the imaging range of cameras. The feature task is to show the practicality by performing the human tracking experiments in real environment.

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K. Tanigawa was born in 1972. He graduated Hyogo technical High school, Kobe, Japan, in 1991, and has joined Melco Power Systems Co., Ltd, Kobe, Japan from 1991. He was a team leader in Engineering Section 3 of the company in 2001. He is now researching the mobile agent technologies and automatic human tracking system as a member of Tottori University.

T. Yotsumoyo was born in 1975. He graduated KagoshimaNational College of Technology, Kagoshima, Japan, in 1996, and has joined Melco Power Systems Co, Ltd, Kobe, Japan from 1996. He is now researching the mobile agent technologies and automatic human tracking system as a member of Tottori University.

K. Takahashi received the B.E., M.E. and D.E. degree in Computer Science and Electrical Engineering, Kyushu University in 1999, 2001 and 2004, respectively. From 2004 to 2010, he worked at Institute of Systems & Information Technologies/KYUSHU as a researcher. Now he is an associate professor of Department of Information and Electronics at Tottori University. His research interests include security, ubiquitous computing and multi-agent system. He is a member of IEICE, IPSJ and IEEJ.

T. Kawamura was born in 1965. He obtained his B.Eng., M.Eng. and Ph.D. degrees in Computer Engineering from Kobe University, Japan in 1988, 1990 and 2002, respectively. Since 1994 he had been in Tottori University as a research associate and has been in the same University as an associate professor in the Faculty of Engineering since 2003. His current research interests include mobile-agent systems and distributed systems. Dr. Kawamura is a member of IPSJ and IEICE.

K. Sugahara received the B.Eng. degree from Yamanashi University in Japan in 1979 and M.Eng. degree from Tokyo Institute of Technology, Japan, in 1981. In 1989, he received the D.Eng. degree from Kobe University, Japan. From 1981 to 1994, he was staff of the Department of Electronic Engineering, Kobe City College of Technology. In 1994, he joined Tottori University as an associate professor of the Department of Electrical and Electronic Engineering and he is a professor of the Department of Information and Knowledge Engineering. His current interest lies in the fields of mobile-agent system applications, computer architectures and hardware realizations of 1D and multidimensional signal processing algorithms. Prof. Sugahara is a member of IEICE and IPSJ.