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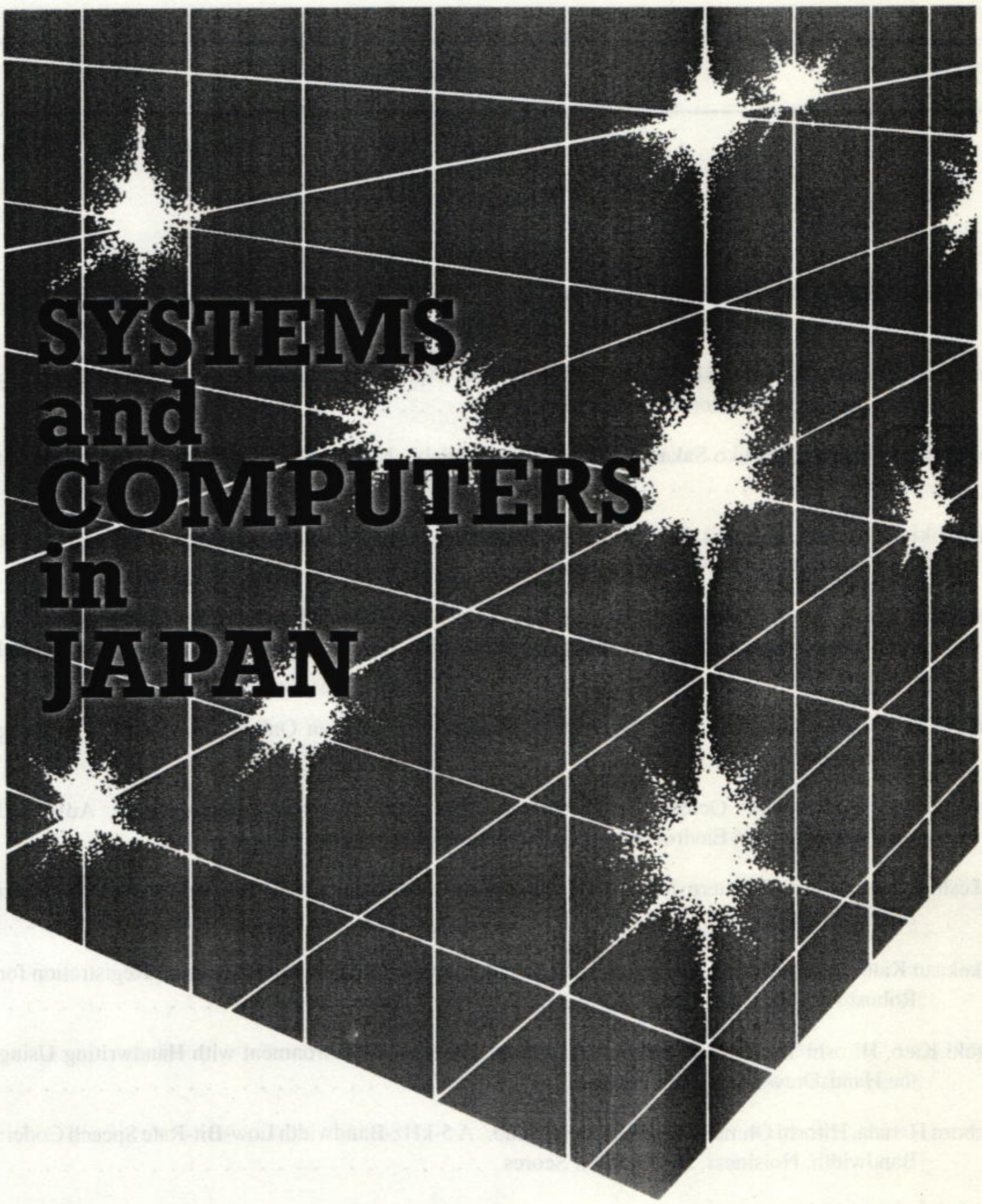

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Cooperative Distributed Registration for Robust Face Recognition

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SUMMARY

This paper describes a cooperative distributed registration system for efficient acquisition of a set of facial images required in realization of robust face recognition. In this system, a lot of agents consisting of a camera and a processor are arranged, and the person detection and tracking as well as registration of facial images are integratively realized. By configuring the cooperative mechanism of this system into a three-layer structure, the required communication capacity is reduced and efficient cooperative operation is realized. In the first layer, each agent independently performs the detection and two-dimensional tracking of the target person. In the second layer, the robust three-dimensional tracking is realized by cooperating agents themselves who are tracking a particular target person within an agency. In the third layer, by the cooperation among agencies, the agency configuration is dynamically changed in accordance with the position and registration conditions of the target person, and the effective registration is realized by changing over the target person of each camera. We will present the experimental results based on a system constructed with eight cameras and confirm the effectiveness of the proposed technique. © 2002 Wiley Periodicals, Inc. Syst Comp Jpn, 33(14): 91–100, 2002; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/scj.1179

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Key words: cooperative distributed vision; cooperative distributed registration; person tracking; facial recognition; facial image registration.

1. Introduction

The surveillance of persons using cameras is important for realizing not only a security system but also a natural interface between humans and the environment. In the case of performing surveillance of persons in a wide space such as an entire building as the observation range, since it is difficult to observe the entirety using only one camera, it is necessary that the observation be performed using multiple cameras and to identify the person observed by each camera. In a real environment, use of the person's inherent information such as fingerprints is difficult in the case of identifying a freely moving person. Accordingly, in this research, we perform person identification by means of the face which can be photographed without the awareness of the target person.

Various face recognition techniques have been proposed to date [2, 4, 7]. With these techniques, a certain degree of recognition can be performed if the facial images of all views for the target person to be recognized are registered in a dictionary. However, when the target person to be recognized cannot be specified beforehand, since the facial image cannot be registered in advance, a method of registration becomes important. Namely, when an unregistered person is observed, a system becomes necessary for performing the detection and tracking as well as the registration newly. In the conventional research on face recognition, it is assumed that the facial images have been registered sufficiently beforehand under a limited environment, and the registration under a real environment has not been studied sufficiently. Accordingly, in this paper, we will propose a cooperative distributed registration which deals integratively with the detection and tracking as well as registration of persons under the framework of cooperative distributed vision [3].

In the cooperative distributed registration, because the multiple cameras (agents) arranged distributively perform the cooperative operation mutually, effective registration is realized while tracking multiple persons. In this case, since the purpose is in the effective registration, it becomes important to acquire a set of registration images for the realization of robust face recognition by appropriately changing over the target person registered by each camera in accordance with the position, posture, and registration conditions of the target person. In order to appropriately select the target person of each camera, the cooperative operation of all cameras is necessary; however, when the system scale becomes larger, the amount of communication required in cooperation becomes huge and there is a danger that the system may fail. Accordingly, the amount of communication can be reduced by appropriately limiting the range of cooperative operation using a cooperative distributed registration system with a three-layer structure.

2. Cooperative Distributed Registration System with Three-Layer Structure

2.1. Agent and agency

The cooperative distributed registration system is composed of an active camera which can control pan, tilt, and zoom; a processor with image processing function and communication function; and a network. As shown in Fig. 1, the set of active camera and processor is treated as a constituting unit and called an agent. Each agent can operate autonomously and the cooperative operation can be realized by communication.

The set of agents with the same purpose will be called an agency. On the other hand, the agent making up the agency will be called the member agent. As shown in Fig. 2, there are two kinds of agencies in the cooperative distributed registration system. The agency with a fixed observation range for detecting a person newly appearing is called the detection agency and its member agent is called the detection agent. On the other hand, the agency tracking a certain specified person and registering the facial image is called the tracking agency, and its member agent is called the tracking agent.

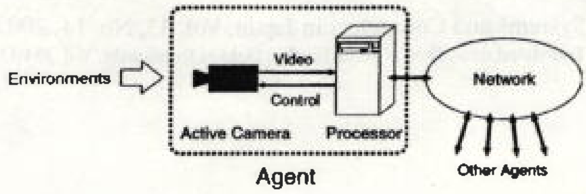

Fig. 1. Configuration of agent.

There exists a special agent called the agency master in each agency. The agency master works as a representative of the agency and is responsible for the management of member agents and the communication with other agencies.

In the initial state, only the detection agency exists and all agents belong to the detection agency. When a detection agent detects a new person, a tracking agency with that agent as an agency master is newly generated and begins tracking of the person. Moreover, when all member agents can no longer track the target person, that tracking agency ceases to exist.

2.2. Three-layer structure

In the cooperative distributed registration system, each agent observes only a limited range and the observation of the entire scene is realized by cooperative operation among agents. Here, for robust person tracking, a real-time processing is required and effective cooperation among agents becomes necessary. On the other hand, for effective registration, it is necessary to consider the registration state, position, and posture of all target persons, and the cooperation in the entire system becomes important. However, when the entire system is closely coupled, the communication required becomes huge and there is a danger that effective cooperation cannot be realized. Accordingly, as

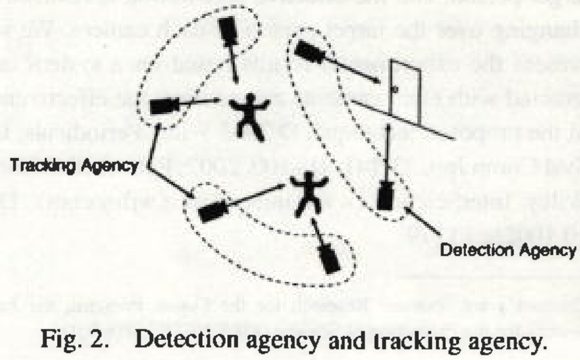

Fig. 2. Detection agency and tracking agency.

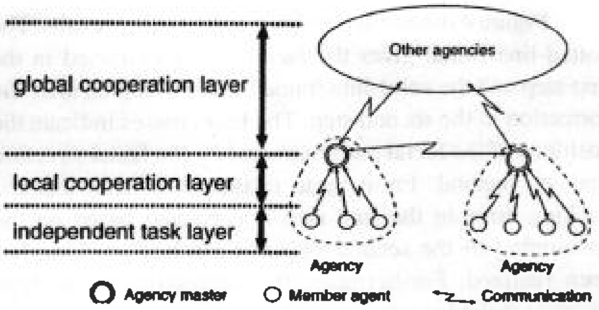

Fig. 3. Three-layer framework.

shown in Fig. 3, a three-layer structure is introduced and the other party each agent is cooperating with is limited to an appropriate range according to its purpose.

Independent task layer

Each agent operates autonomously, and the detection and tracking of the person's face are performed without information sharing and synchronization among agents. The details of agent operation in the independent task layer is described in Section 3.

Local cooperation layer

The member agents themselves within an agency cooperate locally to realize the agency's purpose. In the tracking agency, robust tracking is realized by sharing the position information of the target person within the agency. In the detection agency, the observation range of the agency is divided and assigned to the member agents. The details of the cooperative operation is described in Section 4.

Global cooperation layer

Effective registration is realized by global cooperation among agencies and control of the operation of the entire system. The required communication in the entire system is reduced by performing the communication among agencies with the agency masters as representatives. The details of the cooperative operation in the global cooperation layer is described in Section 5.

3. Person Detection and Tracking in Independent Task Layer

Below we describe the autonomous process of each agent in the independent task layer.

3.1. Detection of person's face by detection agent

The detection agent detects the facial region of the person newly appearing. In the facial region detection, both the subspace method [6] and the facial structure analysis [5] are used. The facial structure analysis is a technique for detecting the facial region by extracting the facial parts (eyes, nose, and mouth) and verifying their positional relations; it can achieve high-accuracy detection but is weak regarding background variations, and the time taken in processing when the search range is wide becomes a problem. Accordingly, several facial region candidates are detected by the subspace method and then the facial structure analysis method is applied for each candidate region.

3.2. Tracking of person's face by tracking agent

In order to perform the stable person tracking by controlling the pan and tilt of the camera, processing at the frame rate is required. On the other hand, since the facial images are used in registration and recognition, high-accuracy positioning of the facial region is required. Accordingly, high-speed and high-accuracy tracking of a person's face is realized by the following two-step processes.

(1) Using the facial region obtained in the preceding frame as a template, the rough positioning of the facial region is performed by template matching. Employing this result, tracking is realized by controlling the pan and tilt of the camera such that the facial region keeps in the center of the image.

This method is capable of high-speed processing; however, it is difficult to determine a high-accuracy position and there is a problem that the position slips accumulate due to the successive updates of templates. These errors and position slips are corrected by step (2).

(2) For the facial region obtained in the preceding step, high-accuracy positioning is performed by applying the facial structure analysis method. The positions of the respective facial parts are determined by the facial structure analysis method; based on the position information of the obtained facial parts, the position, direction, and scale of the facial region are corrected. The facial images are extracted based on this result and used in registration and recognition. In addition, the template of step (1) is corrected. Moreover, the detection of the facial region is performed similar to Section 3.1 at the start of tracking and the failure of tracking.

The tracking agent classifies the facial image being tracked according to the direction of the face; after performing the normalization by affine transformation, the facial image is cut out and registered along with the information