Real-time Dense Communication among Agents for Active Tracking

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ABSTRACT

For multi-target tracking, we realize the increase in number of simultaneously trackable objects and tracking stability by improving the way of communication proposed in [1] so that agents exchange all detected information with each other without increasing network traffic as follows: (1) an agent that provides information of observed objects for multiple agencies (an agency is a group of agents that track the same target) and (2) a vacant-agency that receives information of its target from agents tracking other objects.

Categories and Subject Descriptors

I.4.8 [**Image Processing and Computer Vision**]: Scene Analysis—*Tracking*

General Terms

Design

Keywords

Target tracking, Tracking by multiple active-cameras, Real-time communication

1. INTRODUCTION

Object tracking with distributed cameras (see [2, 3], for example) is one of the most important and fundamental technologies for realizing real-world vision systems (e.g., visual surveillance systems, ITS and so on). We have proposed a multi-target tracking system that can be applied to various tasks and can cope with dynamic situations in a complicated scene[1]. This system consists of multiple Active Vision Agents (AVAs), where an AVA is a logical model of a network-connected computer with an active camera. Spatially distributed AVAs allow us to acquire the 3D information of observed objects and track them continuously in a wide area. In this system, however, minimum information required for tracking is exchanged among AVAs. This insufficient communication results in the following defects:

- The system cannot simultaneously track objects that are greater in number of than the AVAs.
- Most of the object information observed by AVAs is not used for tracking.

For actual applications, a system with a small number of cameras for tracking many objects is desired. In addition, the system should acquire a large amount of information of each object observed from various directions in order to improve tracking stability.

In this paper, we realize the increase in number of trackable objects and tracking stability by improving the way of exchanging a large amount of information among AVAs without increasing network traffic.

2. AUGMENTED COMMUNICATION SCHEME FOR ACTIVE TRACKING

2.1 Dense Communication via Supporter-AVAs

In the previous system[1], each AVA can belong to one agency and send information of detected objects only to the agency. The previous system is designed as mentioned above in order to implement the following functions:

- An AVA can belong to only one agency as a member-AVA: Each AVA has its active camera that is controlled to observe high resolution images of its target. If an AVA belongs to multiple agencies, they may control the camera inconsistently in tracking their targets.
- A member-AVA sends the information of detected objects only to its agency: To suppress network load, a member-AVA sends the information of detected objects only to the agency that definitely requires the information, namely, the agency that the member-AVA belongs to.

If the system employs static sensors (e.g., [2, 3]), the former problem is not raised. In the system with active cameras, on the other hand, a sophisticated mechanism for resource allocation is required. Our objective is to realize this mechanism by the cooperative tracking protocols.

Multiple objects can be observed even when a member-AVA controls its camera to gaze at its target. In this paper, we augment the system so that a member-AVA can provide object information to multiple agencies while only a single agency, which the member-AVA belongs to, can control the camera of the member-AVA. A member-AVA providing object information to agency$_s$, which is not the member's

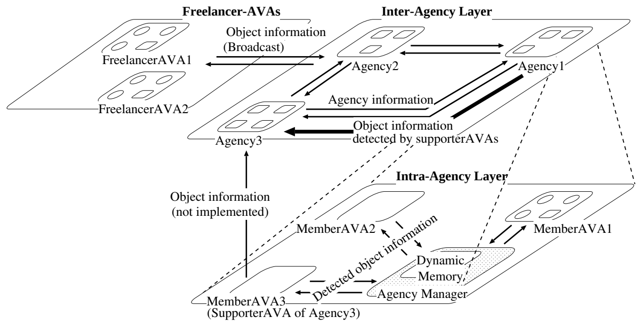

Figure 1: Communication between supporter-AVAs and their supported-agencies.

agency, is called a *Supporter*-AVA of that agency$_s$. This agency$_s$ is called a *Supported*-agency of the supporter-AVA.

In our system, member-AVAs in an agency exchange information through its agency manager (AM). An AM is a software agent generated and halted dynamically. It is necessary for another agent to know the information regarding one-to-one communication with an AM via a network (e.g., hostname and port numbers) in order to exchange information with the AM by a small amount of messages because broadcasting is easy but incurs large network load. Every member-AVA is informed of the information regarding one-to-one communication with its AM when it becomes the member, because it has to send the information of detected objects to its AM. In addition, all AMs are required to communicate with each other through one-to-one communication in order to perform the cooperative tracking protocols. The above two types of one-to-one communications ("communication between a member-AVA and its AM (intra-agency layer)" and "communication between agencies (inter-agency layer)," which are indicated as *Detected object information* and *Agency information*, respectively, in Fig. 1) are inevitable functions for our cooperative tracking with the three-layered architecture and have been implemented in the previous system[1]. To realize newly required communication between a supporter-AVA and its supported-agency, one-to-one communication between them is necessary. However, the direct communication between them results in the following problems:

- All member-AVAs must receive messages from all agency AMs and handle the information for communicating with them dynamically. In the previous system[1], a member-AVA communicates only with its AM.
- If a member-AVA establishes object identification independently and moves between agencies based on the result of the identification, the information of the target and the agency organization may be inconsistent among the member-AVAs in an agency and its AM.

Thus, the information from a supporter-AVA to its supported-agency is sent via its AM as indicated by "Object information detected by supporter-AVAs" in Fig. 1.

Accordingly, the difference in communication mechanisms between the new system and the previous one[1] is merely the forwarding of object information from an AM to another AM (indicated by a thick line in Fig. 1).

2.2 Tracking with Vacant-agencies

Supporter-AVAs enable each agency to obtain a large amount of information of its target, which can improve tracking stability. However, the system cannot simultaneously track targets that are greater in number of than the AVAs under the following conditions: (1) there is a one-to-one correspondence between a target and an agency and (2) each agency has at least one member-AVA. Here we consider the necessity of these two conditions for our objective:

1. An agency (AM) manages all information of its target object exclusively and performs object identification of the target by itself. The one-to-one correspondence is, therefore, essential.
2. An agency that tracks an object whose priority is higher should have several member-AVAs, and conversely, a small number of AVAs should track an object that is accorded lower priority. In the previous system, at least one member-AVA belongs to an agency for gazing at its target continuously. However, continuous observation of a target that is given a fairly low priority is not necessarily required; intermittent observation by AVAs tracking other targets is sufficient. All agencies, therefore, do not have to possess a member-AVA.

Based on the above discussion, we newly define an agency without any member-AVA, which is called a *vacant-agency*. A vacant-agency acquires the information of its target from member-AVAs in other agencies.

With the ideas of employing supporter-AVAs and vacant-agencies, we can realize the increase in number of simultaneously trackable objects.

3. CONCLUSION AND FUTURE WORK

This paper proposed the way of dense communication among AVAs by augmenting the previous system[1]. The proposed system is endowed with the following augmentations by a dense communication mechanism for exchanging the information of detected objects between agents:

- Improving tracking stability by diverse observations
- Elimination of the restriction on the number of simultaneously trackable objects

We are implementing the augmented version of the cooperative tracking protocols proposed in [1] to incorporate supporter-AVAs and vacant-agencies into the system.

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