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시각기반 센서 네트워크를 이용한 이동로봇의 위치 추정

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Mobile Robot Localization using Ubiquitous Vision System

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Abstract - In this paper, we present a mobile robot localization solution by using a Ubiquitous Vision System (UVS). The collective information gathered by multiple cameras that are strategically placed has many advantages. For example, aggregation of information from multiple viewpoints reduces the uncertainty about the robots' positions. We construct UVS as a multi-agent system by regarding each vision sensor as one vision agent (VA). Each VA performs target segmentation by color and motion information as well as visual tracking for multiple objects. Our modified identified contractnet (ICN) protocol is used for communication between VAs to coordinate multitask. This protocol raises scalability and modularity of thesystem because of independent number of VAs and needless calibration. Furthermore, the handover between VAs by using ICN is seamless. Experimental results show the robustness of the solution with respect to a widespread area. The performance in indoor environments shows the feasibility of the proposed solution in real-time..

1. Introduction

In the recent years, mobile service robots in environments such as houses, offices, hospitals, are introduced widely. Simultaneously, rapid advances in low cost, high performance computers and sensors have spurred a significant interest in ubiquitous computing. Researchers are now talking about throwing in a lot of different types of sensors in our homes, work places and even on people. They hope that the wealth of information from these sensors when processed and inferred carefully would significantly enhance mobile service robot capacity to bring better services.

We use these techniques for our development of a mobile robot localization solution. An idea of distributed vision system (DVS) is required to realize these techniques in a widespread area. DVS can be used to help an agent for which it is difficult to notice one's location by oneself in a complicated or variable environment. Recently, researches for a system that track and surveillance a widespread area are increasing. Each vision agent (VA) that constitutes the system is made up of one camera and an image processor. The system can monitor widespread area in real-time because an image that is acquired from a camera is processed in each VA. Redundant information can occur because many VAs exist in DVS. This can contribute more reliability to system [1].However, if there is no coordination for redundant information, it cannot get proper result and can result in overloading in a network [2]. Nakazawa et al. [3] propose a method that usesa state transition map (STM) and an action rule as tracking a person in DVS. They successfully coordinates several cameras but considers tracking for only one person. In [4], they advance the system to be able to track multiple persons. Ng el al. [5] proposesa method that synthesizes a person simultaneously taken by using many omni-directional vision sensor. Matsuyama and Ukita [6] propose a method that tracks multiple objects by cooperation between VAs, regarding DVS as a multiagent system. However, the methods that is used in [3], [4], [5], and [6] need calibration in coordinating between VAs. This is a barrier in raising modularity, scalability, and system speed.

In this paper, we develop ubiquitous vision system (UVS) for location-awareness of multiple objects. We construct UVS as a multi-agent system by regarding each vision sensor as one VA. Here, each VA can perform target segmentation by color and motion information, and visual tracking for multiple objects. We propose the identified contract net (ICN) protocol by modifying the contract net protocol as a protocol for communication between VAs that can coordinate multitask. One object is tracked in one VA and coordination is performed for handover between VAs. Therefore, although redundant information is occurred, calibration between VAs is not needed. This results in raising speed, scalability, and modularity of UVS. The remainder of this paper is organized as follows. In the following section, we briefly introduce object localization algorithm. Details for solving the features equations associated with camera coordination are provided. Architecture of UVS and proposed ICN protocols are presented in section 2.2. Experimental results are shown in section 2.3 while the paper is concluded in section 3.

2. Localization

2.1 Pose estimation system

This section presents a brief summary of the POSIT algorithm for coplanar points. Assume that we have M_i are the feature points of the object and (M_0u, M_0v, M_0w) is object coordinate frame of reference while i, j, k are unit vectors of camera coordinate system (Fig. 1).

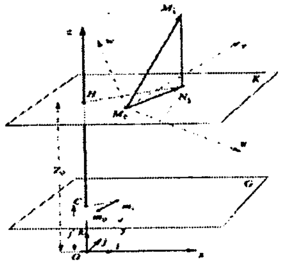

Fig. 1 Camera coordinate system

We define an exact pose as an object pose for which the object points M_i fall on the lines of sight of the image point m_i This condition can be expressed by the equalities.

$$x_0 = f\frac{X_0}{Z_0},\quad x_i = f\frac{X_i}{Z_i}$$

and similar equalities for the *y coordinate*

$$x_i = f\frac{M_0M_i\cdot i + X_0}{M_0M_i\cdot k + Z_0}.$$

A division of both terms of the fraction by Z_0 leads to

$$x_i = \left(M_0M_i\cdot\frac{f}{Z_0}i + x_0\right)\Big/\left(\frac{1}{Z_0}M_0M_i\cdot k + 1\right).$$

Therefore, a necessary and sufficient condition for a pose defined by **i, j,** x0, y0 and Z0 (where x0 and y0 define the location of the image of the object origin) to be an exact pose is that these quantities satisfy, for all points *Mi,* the equation

$$M_0M_i\cdot I = x_i(1+\varepsilon_i) - x_0,\quad (2)$$
$$M_0M_i\cdot J = y_i(1+\varepsilon_i) - y_0\quad (3)$$
$$\text{with } I = \frac{f}{Z_0}i,\ J = \frac{f}{Z_0}j,\ \varepsilon_i = \frac{1}{Z_0}M_0M_i\cdot k\quad (4)$$

and $k = i \times j$.

The basic idea behind the proposed method is that if values are given to i, Eq. (2) and (3) provide linear systems of equations in which the only unknowns are respectively the coordinates of I and J. Once I and J have been computed, i and j are found by normalizing I and J, and Z_0 is obtained from either the norm of I or J.

2.2 Ubiquitous Vision System

We propose a UVS that is made up of independent VAs. Here, techniques explained in section 2 are loaded in VAs. The aim of this system is that a system is aware of location of objects from location information that each VA computes.

Our UVS is made up of VAs that are connected by wireless computer network each other and consist of one camera and an image processor. And, there is a directory vision agent (DVA) for interface with user.

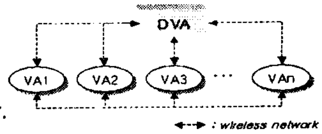

Fig. 2 Our UVS architecture

Indeed, centralized solutions are generally more effic ient. However, in case of our UVS, distributed computa tion is more efficient because each VA independently s urvey, tracks, and performs location-awareness in its vi sible area. We want to get optimal result by interaction from communication between agents. The basic steps i n the ICN protocol are the following.

2.2.1. Request Propagation (RP) If an object in agent (master) needs cooperation with other agent (slave) that is handover, the master agent informs slave agents of a message that is an ID for the object and a task.

2.2.2. Bid Feedback (BF) Slave agents evaluate the message. Some of these slave agents submit bids.

2.2.3. Contract Propagation (CP)Evaluating the bids, the master agent award a contract to the most appropriate slave agent.

2.2.4. Acknowledgement Feedback (AF) An awarded slave agent sends an acknowledgement to DVA. At this time, DVA perceives handover for an object.

A VA perceives a need of handover if a tracking object disappears in its visible area. At this time, coordination between VAs is occurred. At first, a master agent sends RP to slave agents. The slave agents check whether an object corresponding to the RP exists or not in their visible area. Slave agents that have the object in their visible area send BF to the master agent with distance between the object and centre of visible area. The slave agent that receives the CP sends an AF that means a contract that is handover with the slave agent to DVA. The slave agent with which the master agent makes a

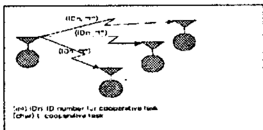

Fig. 3 Request Propagation

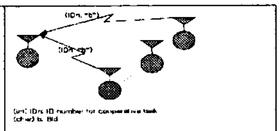

Fig. 4 Bid Feedback

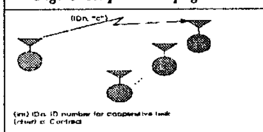

Fig. 5 Contract Propagation

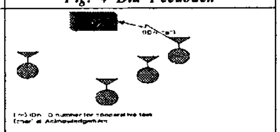

Fig. 6 Acknowledgement Feedback

contract tracks the object from this time and the result is transmitted to DVA. This contract means that a system hands over an object that an agent tracks to other agent. We can use this protocol for multiple objects tracking, including ID for an object in a message header

2.3 Experiment Result

At first, we implement the elementary techniques that constitute our UVS. The result of the target extraction algorithm that we develop is shown in figure 7.

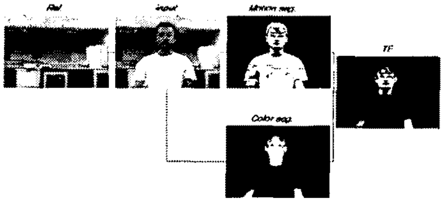

Fig. 7: The result of our color extraction

Secondly, we use a yellow green ID card in ourexperiment. That is, we make a color model for yellow green and perform tracking and *location-awareness based on the color model.* The yellow green color model is shown in figure 8. Average of hue, average of saturation, standard *deviation of saturation, and standard deviation* of hue with respect to intensity are represented to the clockwise rotation from left-top graph.

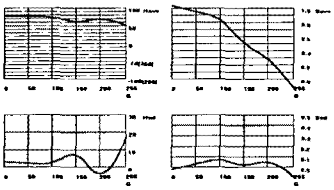

Fig. 8 Yellow green color model

We make an experiment for UVS by using these elementary techniques. We constitute UVS in 6m × 4.5m space. A VA is made up of one color camera and an image processor. We constitute VA with an IMI-TECH IMC-80F IEEE 1394 color camera and Intel Pentium M Processor 1.6GHz laptop computer. And, we use Intel Pentium 4 3.4GHz CPU PC as DVA. We arrange 12 VAs and one DVA as shown in figure 9.

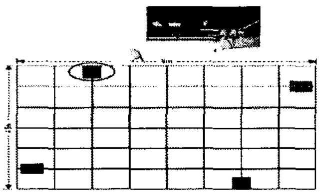

Fig. 9 Experimental environment for UVS

We make a system tracking a yellow green ID card. Thus, the goal of this experiment is aware of location of persons that wear this card. The results are shown in figure 10. They show a result of location-awareness for one object and for two (multiple) objects, respectively. Note that our visual tracking algorithm for multiple objects has an average of 0.190913 second through about 50 experiments. It is noted that our UVS can be aware of location in real-time. Also, accuracy of location-awareness means deviation from the traffic line of a person is 3.671209cm in average. Considering uncertainty of movement, this result is very accurate.

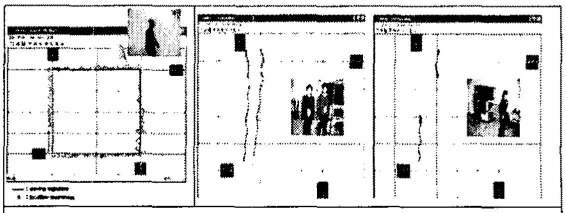

Fig. 10 A result of location-awareness

3. Conclusion

In this paper, we implement a DVS for location-awareness in a widespread area by using a vision-based sensor network thatis UVS. UVS needs a rule for handover when an object goes and comes through areas that VAs cover. We propose the ICN protocol for this rule. This protocol raises scalability and modularity of a system because it is not only independent of number of VA but also doesn't need calibration between VAs. We use a target segmentation algorithm and an approach for real-time for visual tracking of multiple objects as elementary techniques that constitute VA. Each VA can track multiple objects in real-time by using these elementary techniques. From many experiments, we verify that our UVS can be aware *of location with high accuracy in* real-time. Ubiquitous age is comingsoon. This paper verifies that a ubiquitous system can be implemented by using vision-based sensors.

4. Reference

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