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Road Observation System in Residential Areas for Supporting Pedestrian

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Abstract

We have been developing the Robotic Communication Terminals (RCT), a mobility support system developed to assist elderly and disabled people who suffer from impaired mobility. In this paper we describe a road observation system, which is a component of the RCT and which monitors roadways that are atypical, have many disturbances, and are often used by pedestrian. Moving objects and obstacles are constantly monitored, and the data compiled are presented to users. We implemented the recognition part of this system using plug-in modules of the Windows DLL format, thus making it easy to change the algorithm depending on the time of day and the weather conditions.

Moreover, it is shown by experiments in the real-world that this system can detect speeding vehicles and send the proper warning messages to alert users to the impending danger.

1 Introduction

We have been developing Robotic Communication Terminals (RCT) as a comprehensive mobility support system in order to enhance the mobility of people who are physically challenged or suffer from sensory disabilities [1, 2, 3].

There are variable elements to support mobility, and to assist recognition of the environment is also indispensable. Moreover, it is necessary to provide not only static information, such as obstacles and landmarks, but also dynamic information, such as approaching vehicles. An effective method to comprehend the wide-range of environments that surround users is to send appropriate information that delineates the environment to the users. The predominate method of environment comprehension is to set cameras on the roadside and introduce road observation technology.

However, roadways that adjoin pedestrian routes are hard to make simple model for and they have many disturbances. In this paper, we explain a road observation system for these roadways. This system divides recognition process into three parts. In each part plural recognition modules are prepared and the appropriate modules are dynamically selected.

We first present the overview and the significance of RCT. Then, we explain a road observation system that recognizes cars, trucks, bicycles, motorcycles, and pedestrians and provides this information to a user. Moreover, we show how to use this system as one component of RCT. We also describe the performance of this system by some experiments.

2 Concept of Robotic Communication Terminals

We propose RCT as a mobility support system for elderly and disabled people.

Figure 1 illustrates the RCT system. The RCT consists of three types of terminals and one server as follows:

- environment-embedded terminal placed on the sides of roads and at railway stations
- user-carried mobile terminal
- user-carrying mobile terminal
- server for geographic information system

These elements communicate and collaborate with each other, and assist users in reaching their destinations more easily and while moving with a higher degree of safety and freedom.

Moreover, these terminals and servers are connected to the Internet. Thus, users can access a variety of information outside the RCT system.

The *environment-embedded terminal* is a kind of antenna fixed in the pavement and at railway stations, etc. This terminal monitors the roadways and detects emerging obstacles and events, such as motor vehicles, bicycles, and on-going construction hazards. Results of detection are broadcasted to mobile terminal users in the surrounding area, and are stored to be also accessible to other users in remote areas.

The *user-carried mobile terminal* is an intelligent navigation system for elderly and disabled people that is either a wearable or hand-held computer. The real-world information detected and accumulated by the environment-embedded terminal and the information from the Internet (such as maps, guides, and emergency information) are put into a format accessible to users, and are supplied to them by mobile terminals.

The *user-carrying mobile terminal* is an intelligent wheeled vehicle for elderly and disabled people that resembles an electric wheelchair equipped with joysticks,

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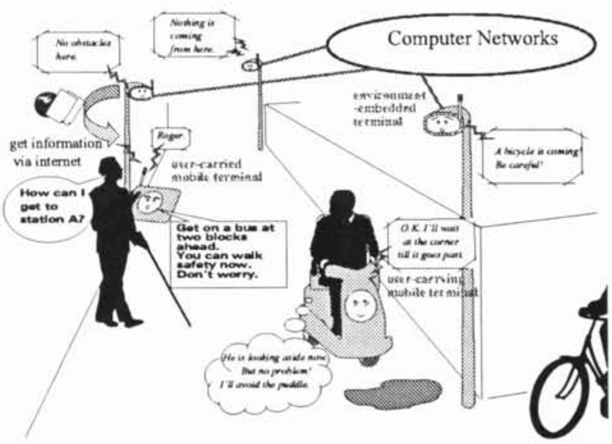

Figure 1: Outline of Robotic Communication Terminals

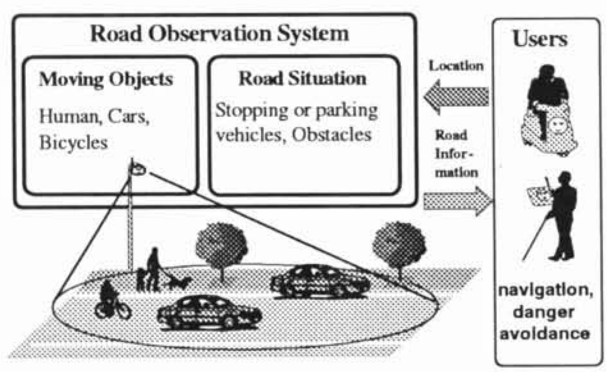

Figure 2: Outline of Environment-embedded Terminal

or an electric scooter with a handlebar. In addition to the functions of the user-carried mobile terminal, the user-carrying mobile terminal has a driving support function, for example, auto-avoidance of detected obstacles using sensors mounted on the body.

The *geographic information system server* is designed for a pedestrian. This system includes information about pavements and paths, and they are linked to barrier information and barrier-free information. The server is connected to the above-mentioned terminals via the Internet and information is updated as often as is needed.

3 Road Observation System

3.1 Environment-Embedded Terminals

Environment-Embedded Terminals (EET) is one component of RCT. These terminals assist environmental recognition of slow-moving users, such as wheelchairs and pedestrian, which includes elderly or disabled people.

Figure 2 shows an overview of the EET system. The EET constantly monitors the

- trajectory of cars and trucks, bicycles, motorcycles, and humans on the road

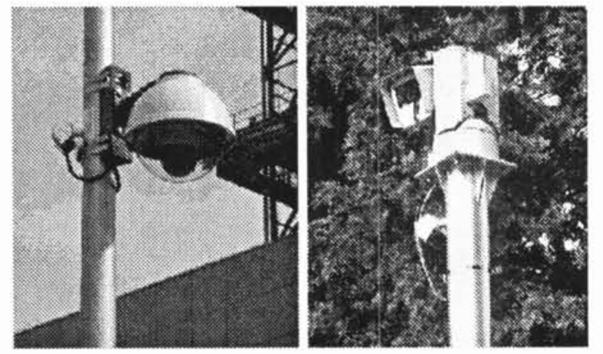

Figure 3: Two outdoor camera installations of EET system

- changes of the road environment caused by dynamic obstacles, such as parked or stopped vehicles

by a camera located on the sides of roadways and in railway stations, and provide the information obtained to users upon demand.

In addition, the EET can estimate the collision probability using this data and the position information of users. If the EET concludes that there is some probability of a collision between a user and a moving object, the EET send warning message to the user.

In this section, we first explain the EET hardware system and provide an overview of the EET software system, and then describe each processing step.

3.2 EET Hardware System

The EET hardware system consists of an outdoor camera mounted so as to observe a roadway or railway station and a PC set that processes the images captured by the camera.

The camera is mounted about 5 meters above the ground, and its angle and amplification can be controlled. The camera is located in a place that can encompass rather small areas of pavement and paths or a railway station. **Figure 3** shows an example of the camera used in the EET system.

3.3 EET Software System

The EET control software consists of four components with the following functions:

- moving objects recognition
- system management
- communication control
- danger estimation

In addition, there is a road region extraction part. This part is called when a user starts this system, and the user set the region that is supposed to move various objects.

The moving object recognition component can also be divided into modules. Plural algorithms are prepared for each module and they are dynamically selected according to the time of day or night and the weather conditions. The system management component works as an algorithm selector.

We use Windows 2000 as the OS, and each module is implemented as a Windows DLL format plug-in module.

We describe each component below.

3.4 Moving Object Recognition

The process of recognizing moving objects is as follows:

1. Extract moving objects
2. Calculate characteristic values of extracted moving objects
3. Decide correspondence between objects in current frame and in previous frame
4. Categorize moving objects

These steps are done by three modules: *Extraction DLLs* cover steps 1 and 2, *tracking DLLs* cover step 3, and *object recognition DLLs* cover step 4. Multiple DLLs are prepared for each module: they are classified by time (daytime and night) and weather (clear, cloudy, and rainy). The system management component dynamically decides and selects the appropriate DLLs.

In *Extraction DLLs*, first the changed regions are extracted by calculations the difference between the current image and the background image smoothed by using a Kalman Filter. Then the DLL selects the regions which have more pixels than some threshold and calculates characteristic values (color distribution, real size, shape, etc.) of each region.

An EET camera is often placed obliquely, so the size of an object in an image varies substantially according to its position in the image. Therefore, we calibrate the camera beforehand using values of latitude and longitude of the site provided by the map server. The real sizes of objects are calculated from the coordinates and sizes of objects in images.

Tracking DLLs decide the correspondence between objects in the current frame and in the previous frame using these characteristic values. Units of a correspondence search are not pixels but the region obtained by the extraction DLL.

At first, the coarse correspondences are decided by the size and color distribution of the regions. Moreover, fine correspondences are searched by using moving history and knowledge: for example, no object suddenly appears in the center of the roadway, no object moving at a high speed suddenly changes direction, etc.

Object Recognition DLLs categorize these regions into human, bicycle, motorcycle, car, truck, etc. by referring to real size and velocity.

3.5 System Management

The appropriate algorithms for moving object recognition vary according to the changes of time and weather. Therefore, our system implements the recognition component as plug-in modules, as described above. This makes it easy to change the recognition algorithm dynamically.

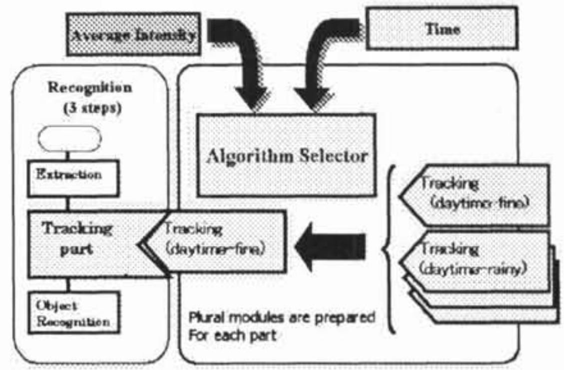

Figure 4: Dynamic Algorithm Selection in Moving Object Recognition Part

The current system has a database of sunrise and sunset times. Moreover, the system constantly calculates average intensity of background image. Appropriate DLLs are selected based on this information (**Figure 4**).

In the current system there are four DLLs in each part: for fine daytime, rainy daytime, twilight, and night.

3.6 Communication Control and Danger Estimation

The danger estimation component judges whether users are in the danger of collision. This component gets the location and velocity of moving objects from the moving object recognition component, and gets those of the users via communication control component. Then, the trajectory of each object is estimated as a sector. If the sector of a user and that of a moving object intersect, the system sends an alert signal to the user.

4 Experiments using Environment Embedded Terminals

We developed the following RCT prototypes:

- six EETs (three in Koganei City, two in Kasugai City and one in Kamakura City)
- two user-carrying terminals (called Intelligent City Walkers: ICW)
- a Barrier-Free Map (BFM) for Koganei City

These elements are connected to the same network and can communicate with each other.

In this section we describe the following two experiments:

- recognition performance test of EET
- auto-avoidance of ICW by communication between ICW and EET

BFM system is used to calibrate EET system at startup.

Now, we will describe the details of these experiments.

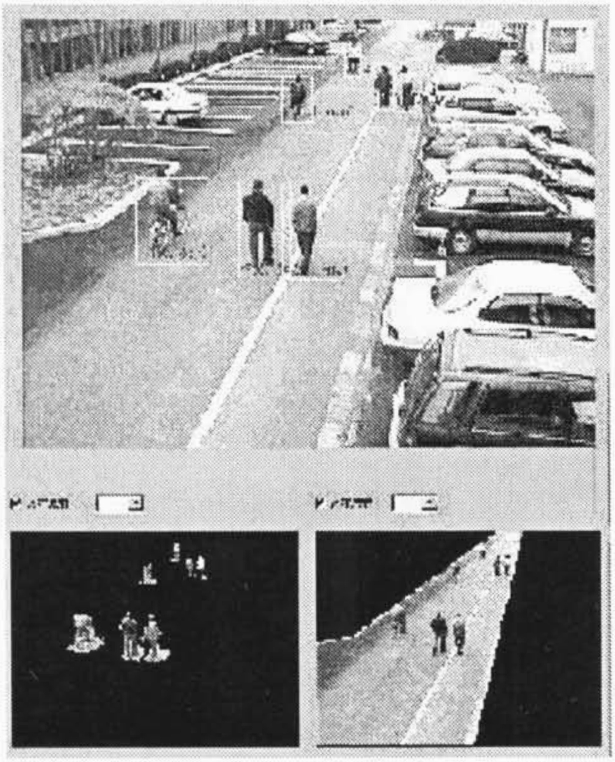

Figure 5: GUI of Environment-Embedded Terminal

4.1 EET Recognition Performance Test

We checked the recognition performance of EET in Koganei City and Kamakura City. In this experiments the EET recognized humans, bicycles, cars, and trucks moving along a road.

The PC sets used had a Pentium III 933 MHz (Dual), and Windows 2000 OS.

Figure 5 shows an example of an EET GUI image. The lower right frame shows the area in which the locations of moving objects should be calculated. In the lower left frame, drawn image parts are areas where there may be moving objects. The upper big frame shows the detected moving objects with rectangles.

The current system can process five images per second when the number of moving objects in inputted image is lower than ten.

4.2 Auto Avoidance of Danger by Integrated System

An auto-avoidance of danger experiment was done with a prototype of the user-carrying mobile terminal shown in **Figure 6**. The location of the ICW was determined by an on-board GPS, and the data was sent to the EET by a wireless IP device. When a near miss condition was determined from the result of the detection of a speeding car and the location of the ICW, the EET informed the ICW of the danger. Then, the mobile terminal stopped automatically and avoided colliding with the speeding car.

The experiment was performed in daytime, and the detection of moving objects and transmission of alerts were done successfully except for one case of miss-recognition that occurred as a result of the camera vibrating by blow.

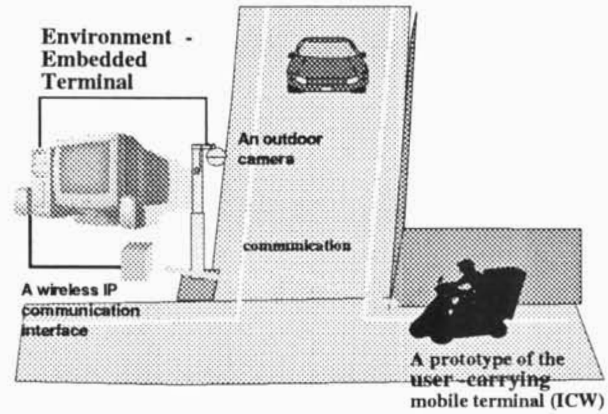

Figure 6: Experiment judging degree of danger

It takes about two to three seconds from detection of a speeding car by the EET to the display of an alert and the stopping of the ICW.

5 Conclusion

In this paper we described the concept of Robotic Communication Terminals (RCT), which is a mobility support system for the elderly and the disabled. We also described the system structure of an EET, which recognizes road conditions and moving objects.

Moreover, we have been constructing a system that will work in the real-world and did performance experiments. We also described these experiments in this paper.

It is necessary for a real-world system to act robustly in various environments under different weather conditions. Therefore, we adopted a method to prepare various recognition algorithms and change them dynamically for the road recognition system.

Future work is to advance the recognition performance of each terminal. The EET system especially needs to make more recognition algorithms, corresponding to changes of time and weather and to refine the method used for algorithm selection: e.g., a system to decide the timing of an algorithm switch dynamically by observing the frequency of recognition failure.

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