A Positioning Method Combining Specification of User's Absolute Position and Dead Reckoning for Wearable Augmented Reality Systems

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Abstract

This paper describes a positioning method for wearable augmented reality systems. To realize augmented reality systems, the position and orientation of user's viewpoint should be obtained in real time. In the proposed method, the system measures the orientation of user's viewpoint by an inertial sensor and the user's position by combining specification of the user's absolute position and dead reckoning. This paper also describes prototype of wearable augmented reality system using the proposed positioning method.

1 Introduction

Since computers have made remarkable progress in resent years, a wearable computer can be realized[1, 2]. At the same time, augmented reality(AR), which merges the real and virtual worlds, has received a great deal of attention as a new method for displaying location-based information[3, 4, 5, 6]. Nowadays, augmented reality systems with wearable computers attract much attention because these systems can be used in many practical applications[7, 8, 9, 10]. To realize such applications, it is required to measure the user's position and orientation in real time. Therefore, some methods of measuring the user's position and orientation have been proposed as the progress of this field.

To realize AR systems, the position and orientation of users viewpoint are needed for aligning the real and virtual coordinate systems. Usually, a Global Positioning System (GPS) is used to measure the users position outdoors. In AR systems which use the GPS, a real time kinematic GPS[9] or a differential GPS[10] is used to measure the users position accurately. However, since both of them need radio communication to correct GPS data, the hardware configuration of the system will be complicated. Moreover the GPS data can be obtained only once a second.

In indoor environments, image markers or tracking sensors are used for estimation of the user's position and orientation. When we measure the user's position using image markers[11], the user's position can be measured at the same frequency as that of input images. On the other hand, when we use tracking sensors just like electro-magnetic sensors[12] or ultrasonic sensors, the user's accurate position (and orientation) can be measured some dozens of times or more every second. However, when we apply the positioning method using image markers for wide environments, so many image markers must be set up. When we try to apply the positioning method using tracking sensors for wide environments, we have to set up a lot of expensive instruments in indoor environments.

In this paper, we propose a positioning method which can be applied for wide areas easily. The proposed method measures the user's position by combining the user's absolute position data which are specified at discrete points and the user's dead reckoning data. To specify the user's absolute position, we use a GPS outdoors, and IrDA markers[13] in indoor environments. Dead reckoning is realized by using a pedometer. The pedometer measures how many steps and what direction the user walks to estimate the user's relative movement.

This paper is structured as follows. Section 2 describes the proposed positioning method based on combining the specification of the user's absolute position and dead reckoning in detail. In Section 3, examples of wearable augmented reality systems using the proposed method are described. Finally, Section 4 summarizes the present work.

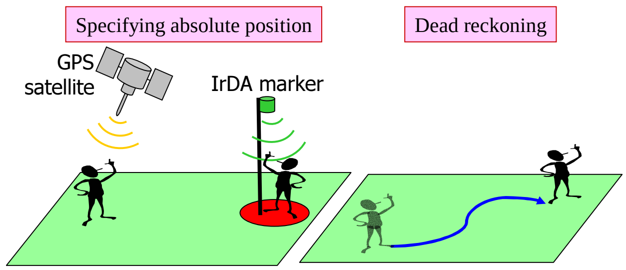
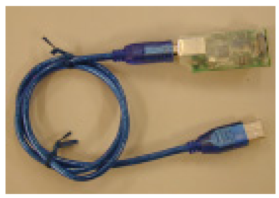


Figure 1. The proposed positioning method.

(a) IrDA marker.



(b) IrDA receiver.

Figure 2. IrDA sensors.

2 Positioning Method Combining User's Absolute Position and Dead Reckoning

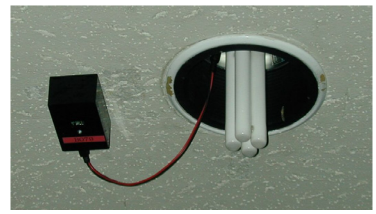
In this section, the proposed method of measuring the user's position for wearable augmented reality systems is described. In our method, the user's position is measured by combining specification of the user's absolute position and dead reckoning data as shown in Figure 1.

2.1 Specification of user's absolute position

The user's absolute position is measured using a GPS outdoors and IrDA devices indoors. IrDA devices consist of IrDA markers and IrDA receivers. Figure 2 (a) and (b) shows an IrDA marker and an IrDA receiver, respectively. IrDA markers are set up on the ceiling sparsely and always send their unique position IDs. Figure 3 shows an example of arranging IrDA markers. The user equips an IrDA receiver which can identify IrDA markers. When the user comes into the infrared ray range of the IrDA marker, the user's position is identified by receiving the position ID with the IrDA receiver. The infrared ray range of an IrDA marker is a cone whose diameter is about 3 meters and height is about 5 meters since the infrared ray has the directivity. Therefore, when IrDA markers are set up to the ceiling in indoor environments as shown in Figure 3, the infrared ray range is a circle whose diameter is about 1.5 meter at floor level. Consequently, the system can specify the user's position automatically by passing under an IrDA marker.

Figure 3. An example of arranging IrDA markers.

(a) A power supplying unit.



(b) An example of arranging an IrDA marker with the power supplying unit.

Figure 4. Power supplying unit for IrDA markers.

Our present IrDA markers are supplied electric power from batteries. It will be an obstacle to applying our proposed method for wide area easily. Accordingly, we are developing electric power supplying units from fluorescent light lamps on the ceiling. Figure 4 shows a power supplying unit and example of arranging the power supply unit on the ceiling. By using this power supplying unit, we can arrange and maintain a lot of IrDA markers easily.

When the GPS is used solely for specifying the position in outdoor environments, the error fluctuates between 5 meters and 50 meters which is caused by various reasons: the number of captured GPS satellites, the weather, and so on. In environments which have no high-rise buildings, the error of the standard GPS is within 20 meters. On the other hand, IrDA sensors can specify the user's absolute position with the error of less than 1.5 meters[13] because the user can receive the same position ID when the user is in the infrared ray range of the IrDA marker. The GPS and IrDA markers can specify the user's position at 1Hz and 250Hz, respectively.

(a) DRM-III (Point Research Corporation)   (b) MDP-A3U9 (NEC-TOKIN)

Figure 5. Pedometers.

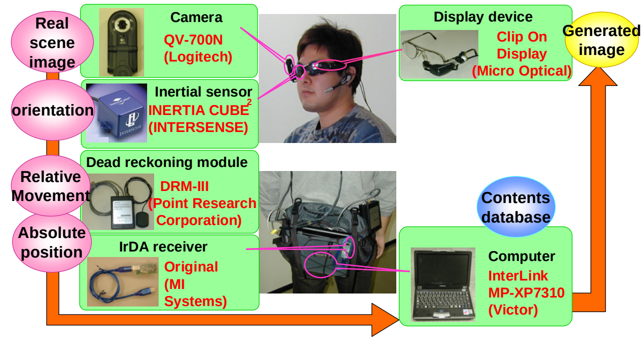


Figure 6. Example of wearable augmented reality system.

2.2 Estimation of user's relative movement

We can estimate the user's relative movement using a pedometer represented by the dead reckoning module, "DRM-III (Point Research Corporation)" as shown in Figure 5 (a) both indoors and outdoors. The "DRM-III" estimates the user's relative movement by integrating these three data: the user's average pace which is input beforehand, the detection of the user's walking action, and the user's walking direction. The cheap and small sensor just like "MDP-A3U9 (NEC-TOKIN)" (Figure 5 (b)) which is composed by acceleration sensors and a digital compass also can estimate the user's relative movement. The "MDP-A3U9" can measure the acceleration of the user's waist to detect the user's walking action using the acceleration sensor and measure the user's walking direction using the digital compass.

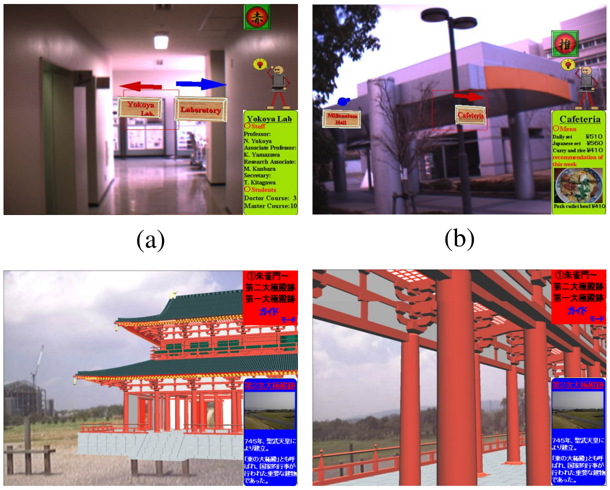
The user's position can be measured at user's step rate by using the dead reckoning method with specifying the user's absolute position. Therefore, the user's position can be measured with the same timing as the user's movement. However, the accumulative error occurs according to the user's walking distance when we use the proposed dead reckoning method. The accumulative error includes two kinds of errors mainly. One is the difference between the user's actual pace and the user's average pace estimated in advance, and the other is the difference between the actual walking direction and the user's waist direction. Both of them are accumulated according to the user's walking distance. In our method, the accumulative error of dead reckoning is canceled whenever the system receives the position IDs from IrDA markers or receives the GPS data.

2.3 Combining the absolute position and dead reckoning

In the proposed method, the user's position is measured by combining the user's absolute position which is measured by the GPS or IrDA devices and the user's relative movement which is measured by the pedometer. In outdoor environments, even when the accuracy of the GPS drops temporarily, the user's current position is measured by using past GPS data and dead reckoning data. Thus the positioning accuracy is defined as the sum of the GPS accuracy which is included the standard GPS data, NMEA data and 5% of the distance traveled. The system calculates the value for GPS data at every moment and adopts the position data whose value of positioning accuracy is minimum as the user's position. In indoor environments, the user's position can be measured in the whole area by combining dead reckoning with the absolute position. In indoor environments, the user's position is specified whenever the position IDs are received from IrDA markers.

3 Example of Wearable Augmented Reality System

This section describes a prototype of wearable augmented reality system using the proposed positioning method[13]. The prototype system can present location-based information to the user by displaying virtual object overlaid images using augmented reality techniques. In this system, the user's orientation which is the other indispensable information for realizing augmented reality is measured using an inertial sensor attached to the user's head. Figure 6 shows an example hardware configuration and data flow of such systems. Figure 7 shows examples of generated images which are presented to the user. Figures 7(a) and (b) show a position-based annotation overlay image indoors and outdoors, respectively. Figures 7(c) and (d) show images on which a virtual building is overlaid on the real scene of the ruin of the building.



(a) (b)

(c) (d)

Figure 7. Examples of generated images.

4 Summary

This paper has described the positioning method combining specification of the user's absolute position and dead reckoning. In the proposed method, the user's absolute position is specified by the GPS or IrDA sensors. Dead reckoning is realized by measuring the user's pedestrian data. This paper has also described and example wearable augmented reality system using the proposed positioning method.

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