Walking aids based on wearable/ubiquitous computing – aiming at pedestrian's intelligent transport systems

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ABSTRACT

As contemporary transport system including developing Intelligent Transport System (ITS) is vehicle centered, pedestrians especially elders and disabilities are always threatened. This paper proposes a new pedestrian-centered traffic system concept named "Pedestrian's ITS" (P-ITS) based on ubiquitous and wearable computing techniques. P-ITS consists of various components including wearable computers for people in special needs and distributed computers to sense and control environments. This paper presents two example components, that is, Intelligent Cane, a wearable computer for the Blind, and a ubiquitous computing system to obtain and visualize traffic flow of Pedestrians.

1. INTRODUCTION

The concept of Intelligent Transport Systems (ITS) is first presented in 1996 (Tokuyama et al 1998). ITS is expected to give safer and more convenient environments for drivers through intelligent vehicles communicating with smart way. However, as ITS is vehicle centered concept, ITS benefits few pedestrians, especially so-called "the weak in traffic system" including the elders and the disabilities.

Sasaki et al (2000) proposed "Pedestrian's Intelligent Transport Systems (P-ITS)", which gives safer and more convenient environments for pedestrians, especially the weak in the traffic system, with intelligent walk-aids (wearable computers) communicating with smart way (Ubiquitous Computing Environment).

P-ITS consists of various components including wearable computers for people in special needs and distributed computers to sense and control environments. This paper presents two example components, that is, Intelligent Cane, a wearable computer for the Blind, and ubiquitous computing system to obtain traffic flow of pedestrians.

The blind faces to many dangers while walking. Therefore, foregoing walk-aids try to give information of surrounding situation as much as it obtains. However, unnecessarily much information confuses user in many cases. This paper presents Intelligent Cane introduces the concept of surrounding presumption (Sasaki et al 2000).

The person with walking difficulties wants to escape streams of people, as he/she cannot walk in a same speed as the stream goes. A visualization of traffic flow may help him/her to escape such streams. This paper proposes a ubiquitous computing system to sense and to visualize traffic flow of pedestrians.

2. PEDESTRIAN'S ITS

The basic Infrastructure of ITS is the communication between smart vehicles and smart way. The vehicle and the smart way obtain and exchange the surroundings and their own conditions through innumerable sensors and produce smooth traffic by fitting themselves to the surroundings.

The P-ITS is based on the same framework as shown in Fig. 1. The P-ITS consists of street terminals and the wearable computers and conventional ITS infrastructure. The wearable computers and the street terminals communicate via short-range wireless communication, such as Bluetooth (Bluetooth 2000). The street terminals and the wearable computers obtain the surroundings and its own or user's conditions respectively, and exchanges them each other. The wearable computer navigates the user considering the information from street terminals and itself. On the other hand, the street terminal changes the traffic infrastructure such as traffic lights and moving walks depending on the information given by neighboring wearable computers. Through this configurations, the P-ITS provides some services for smooth and comfortable environment for pedestrians. For example, P-ITS may give substitutions of impaired senses of a certain person by translating information obtained by sensors on street terminals, P-ITS may realize pedestrian-centered traffic system with dynamic control of traffic infrastructure, such as traffic signals or moving walks as demonstrated by Nippon Road (2000), and P-ITS may produce mutual understandings and avoid unnecessary troubles among people by producing information as shown by Sasaki (2000).

The remarkable characteristic of this system is that the total infrastructure is applicable for other commercial and social applications not only for the disabled but also for any people. Therefore, the infrastructure can be realized under commercial requirements.

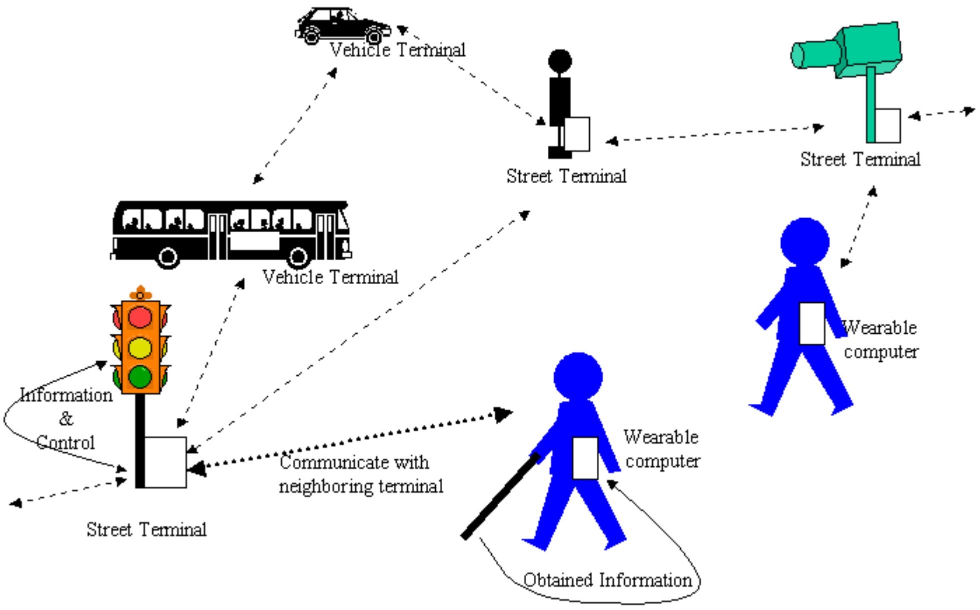

Figure1. *The Infrastructure for Pedestrian's ITS*

3. THE WEARABLE COMPUTER FOR THE BLIND

P-ITS consists of various components. Especially, the wearable computer has wide variation depending on its user. This paper focuses on the wearable computer for the blind, one of the weakest in traffic system.

Japanese law requires the blind to have a cane with them whenever they go out. Therefore, foregoing walking aids with many sensors requires its user to hold two items, that is, the walking aids and a cane. It is troublesome for the user to wear two items appropriately. Additionally, most of foregoing walking aids, which gives the raw data obtained by certain sensors such as ultrasonic range sensors converted into tone or volume of noise, may confuse its user with the flood of information. Sasaki (2000) proposed to compose all the walking aid into a cane and to give "surrounding presumption" function on the cane-shaped wearable computer. This paper develops a prototype of such wearable computer named “Intelligent Cane”, and evaluates effectiveness of the situation presumption.

P-ITS provides the surrounding presumption function on the cooperation among street terminals and pedestrian’s terminals (wearable computers). However, to provide minimum safety information, a pedestrian’s terminal should know its surroundings and presume surroundings with this minimum information.

The most possible danger for the blind is obstacles, which cannot be obtained through a cane, that is, downward gaps and objects, which isn’t connected directly to ground like signboards and load-carrying platforms of tracks. This paper concentrates to obtain the downward gaps.

Figure 2 shows the prototype system of the Intelligent Cane. The cane equips a slope sensor (INTERSENCE corp. INTERTRAX2) and an original active-stereo range sensor (Fig. 3) composed of 3 laser pointers (kantum electric corp. LD263-031) and a CCD Camera (WATEC corp. WAT-240R). The sensor system obtains the positions of three points on an obstacle or floor where the user heading to in 30 Hz. The mean square error of obtained position is 0.51cm and maximum error is 2cm inside target area. As the gap between roadways and sidewalks are no less than 5cm, the developed system holds enough accuracy for practical use.

The cane presumes whether the user heading to normal floor, downward gap, downward stairs or standing obstacle using “floor-wall strategy” (Sasaki 2000) from obtained data. A Simulation cleared that maximum speed to let the cane to presume downstairs is 16.4km/h. As usual walking speed of human beings is less than 8km/h, the refresh rate of the cane is frequent enough for practical use.

The cane gives the presumed situation via voice and tactile signals. Three vibration devices embedded into grip of the cane as shown in Fig. 4 gives the tactile signals.

The output interface is examined by virtual walkthrough test. 15 subjects including two blinds asked to walk through virtual street shown in Fig. 5 using the Intelligent Cane. A subject swings the cane and an avatar walks along the virtual street depends on the swinging speed. The subject asked to stops when he/she notices any obstacles in front of him/her, and to report what he/she is heading to. Table 1 shows the experimental result. The subjects notice faster with tactile signals and understand better with voice signals. Additionally, the blind subjects claimed that they feel uneasy to use voice signals as it may disturb them to obtain other information, such as horns of cars. Thus, the experimental results indicate that the display system of the Intelligent Cane should have both voice and tactile channels.

Figure 2. *The prototype of Intelligent Cane.*

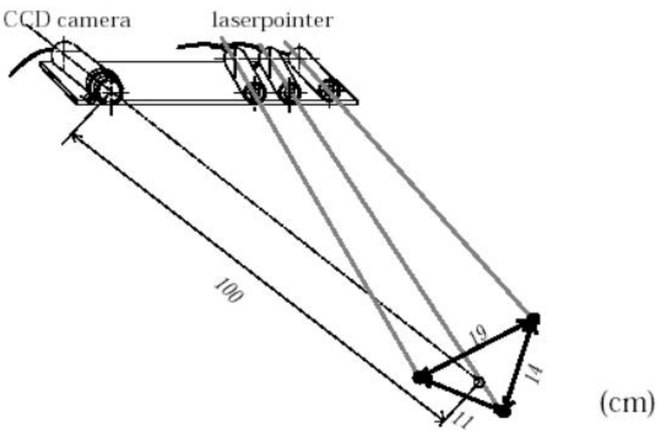

Figure 3. *The design of active-stereo range sensor*

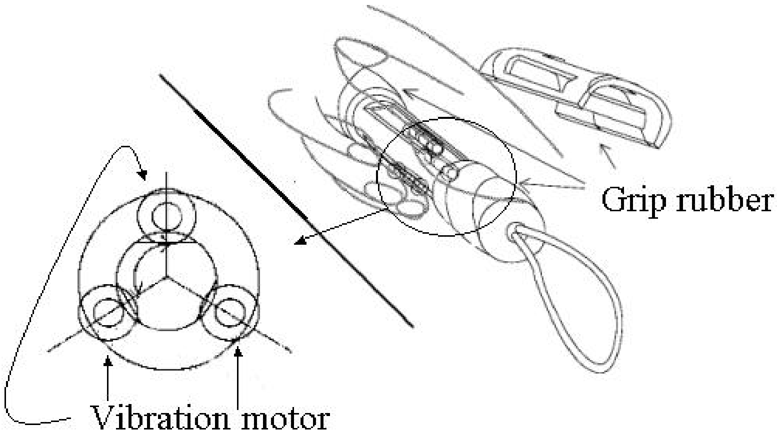

Figure 4. *The design of tactile display*

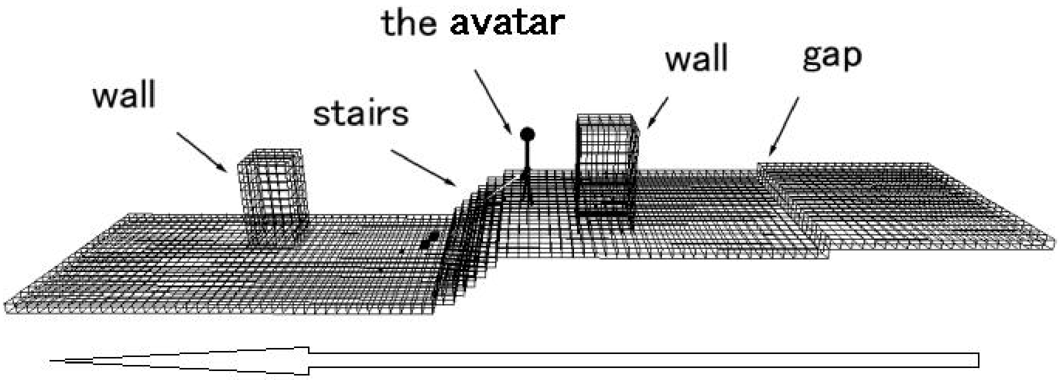

Figure 5. *The virtual street for walk-through test*

Table 1. *The experimental result of walk-through test*

	Average distance to obstacle when the avatar stops (cm)	Percentage of correct answers for obstacles' names (%)
Tactile signal	100	86
Voice signal	50	94

4. A UBIQUITOUS COMPUTING SYSTEM FOR THE PERSONS WITH WALKING DIFFICULTIES

P-ITS system is to produce pedestrian-friendly traffic environments under collaboration among ubiquitous computers. The authors developed an example prototype for feasibility study of the proposed concept. The person with walking difficulties wants to escape streams of people, as he/she cannot walk in a same speed as the stream goes. A visualization of traffic flow may help him/her to escape such streams. This paper developed a ubiquitous computing system to sense and to visualize streams of pedestrians.

Figure 6 shows the conceptual design of the proposed system. The proposed system consists of street terminals to obtain size and direction of streams of pedestrians (sensor terminal), and information integration terminal to visualize obtained information on a street map (display terminal).

In order to obtain information of wide area, a sensor terminal equips a fish-eye-lens mounted camera. Figure 7 shows diagram to obtain target streams. A sensor terminal extracts person by differential imaging and estimates the head position of stream from a point on the contour of extracted region nearest to the image center. Fish-eye-lens lets the sensing terminal to work out via quite simple equation. The size of stream is worked out from the size of extracted region.

The prototype system is placed on a corridor of NAIST. Cameras are placed at height of 3m. In order to keep estimation error of distance less than 0.5m, the effective range of a street terminal comes to 6m according to Fig. 8. As the coverage of street terminals should have overlaps to hand over obtained regions, the authors placed street terminals every 8m. The evaluation result shows that the prototype system can estimate sizes and directions of streams properly when the street is not crowded. Although, further refinement of the prototype is required to make it applicable for crowded street, the result shows that the proposed system can obtains essential information to control P-ITS.

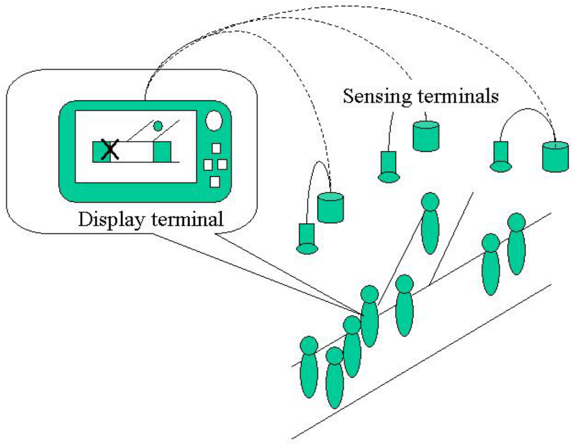

Figure 6. *The conceptual design of traffic flow sensing system*

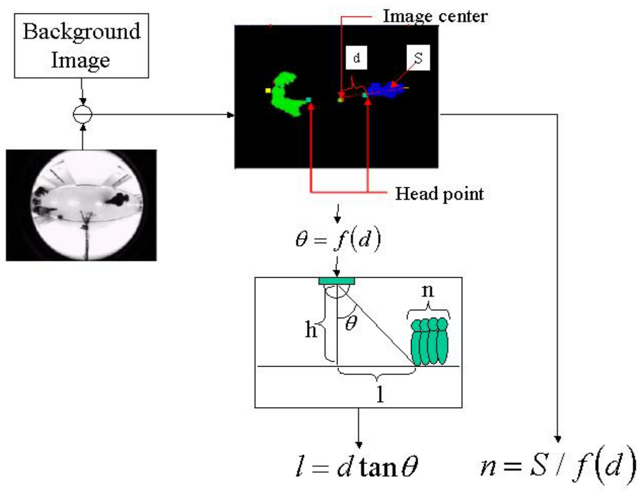

Figure 7. *Process flow to obtain head position (l) and size (n) of crowd*

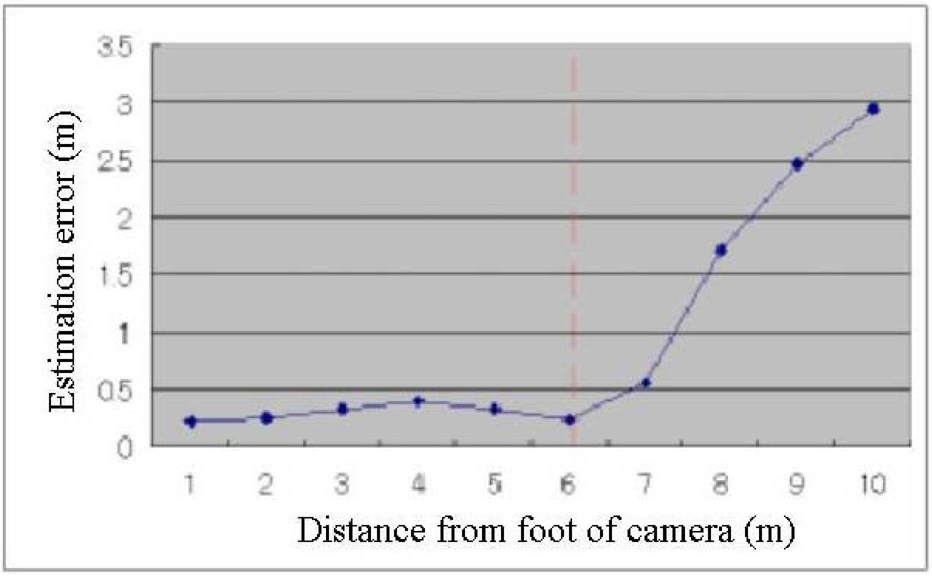

Figure 8. *Estimation error along head position*

5. CONCLUSION

This paper presents the concept of Pedestrian's Intelligent Transportation System (P-ITS). P-ITS provides several services for barrier-free and smooth environments for pedestrians under the cooperation of street terminals and pedestrian's terminals.

This paper introduces a wearable computer for the blind as one example of pedestrian's terminal. The wearable computer presumes surroundings to provide minimum safety information using range sensor and direction sensors. The prototyping and experiment using virtual environment clears that the proposed system can gives proper information for the Blind via voice and tactile display.

This paper proposes a ubiquitous computing system to obtain traffic flow of pedestrians, which is essential information to control P-ITS system, using fish-eye-lens mounted camera. The prototype shows that the proposed system may obtain required information under limited conditions.

In order to demonstrate the feasibility of proposed framework, the further simulation based on real traffic flow obtained by the developed prototypes are essential. The authors are continuously developing prototypes of P-ITS and studying feasibility of the proposed system. The authors believes that this continuous development realizes the P-ITS system in a very near future and provides the environment, which makes human beings friendly.

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