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Wearable Computer for Experience Recording

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Abstract

This is a fundamental study on the recording of subjective experience using a wearable computer. In this paper, we have stated that the potentials of an experience recording using a wearable computer from the perspective of memory structure and current recording capacity. Then we have categorized and stated the elements; emotion, location, vision, audio and ambience, which should be recorded and could be recorded objectively inducing subjective experience when recalled later. Putting the findings of previous experiments into account, the experiment was performed to verify elements we have categorized.

Key words: Wearable Computer, Experience Recording, Sensing devices, Subjective Recording

1. Introduction

Today, the wearable computer is becoming a reality due to the significant downsizing of computer devices. It has received a great deal of attention, mainly due to the effectiveness of outdoor information display devices. [1] However, wearable computers also hold great potential for sensing and recording real time information of the immediate surroundings and ambience around the user because they fit the human body closely at any moment. Focusing on this characteristic of wearable computer, we study the potential of recording individual experience, which contents are close to human memory. Our final goal of this study is to construct a vicarious media system to recall one's subjective experience with realistic sensation. We think wearable computer is suitable to record experience in more intimate way than any other recording function we have today.

2. Experience Memory and experience recording

First, we discuss the definition of experience memory and experience recording. Experience memory is stored information that a person unconsciously possesses through own behavior. Sense organ is the first gateway for this process and our senses scan every event which occurs. The second gateway is the short term memory which compresses and refines the sensed information and transfers the information to the long term memory. The information stored in the long term memory is recalled when the individual has the same or a similar experience on another occasion. A conventional experience recording is stored information which an individual consciously records using a recording device such as a memo pad, camera or video camera. Generally, this externally recorded information is useful simply as a trigger to pull up memorized information.
At present, only an event or object to which an individual pays close attention is recorded as a part of the overall experience. As time passes, it becomes more difficult to recall an event fully even if the individual has experienced it before, because there is not sufficient memorized or recorded information to recall it as our memory becomes weaker with age.

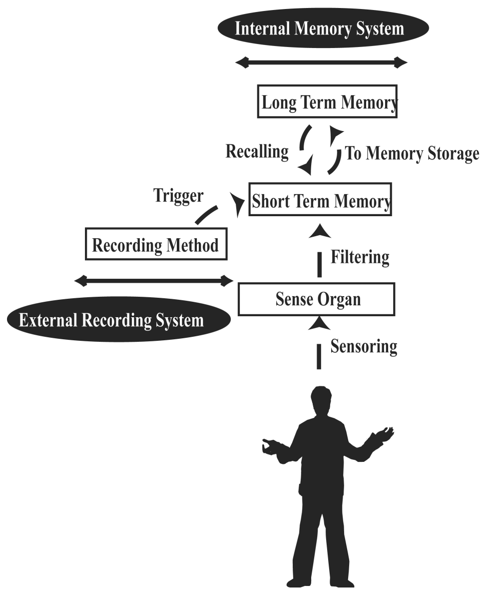

Figure 1 Experience Memory and recording

3. Hypothesis

Before talking about the wearable computer for experience recording, the elements which should be recorded for subjective experience objectively are to be discussed. We hypothesize those being consciously recognized and unconsciously sensed are made up of a subjective experience. In previous experiments, we analyzed conscious attention rate of a person and concluded that the average attention rate in the experience is about 23%. We focus on five senses of human being, which is vision, audio, gustation, olfation and tactile senses as basic elements of receptors to construct subjective experience. Some of the senses listed here is still not realistic to record routinely. Therefore complementary as well as supplemental data to evaluate experience is necessary. We paid attention to physical movement as a source to include subjectivity. For example, the physical movement like where a person stands, how he/she moves, whether he/she pauses a walk or not, those unconscious movement includes a lot of information to induce subjectivity. Considering these facts, we defined five categories, Emotion, vision, audio, location and ambience as a fundamental elements which make up of experience.

We hypothesize by inter-affecting these elements construct a unique experience consequently for each person. Therefore even if people have an experience under same situation, all of them have a different memory about it. In this paper, we discuss the results of performed experiment using prototype wearable computer which has a function to record these five elements. As there is no specific reality index to prove recorded material is worthwhile to digitalize objective experience, we analyzed variance of data recorded in each experiment as well as extracted characteristic experience to evaluate if there is any different aspect to recall experience by increasing recorded data.

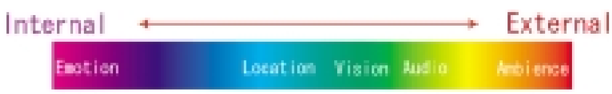

Figure2 Spectrum of five categories

4. Previous Experiments

4.1 Emotion

Since a memory of an experience is considered to be a very subjective record which directly reflects a person's mental status, a record of the person's mental status at the time of the event will be an effective index for inducing realistic sensations when recalled later. Adopting mental factors from a perspective of interface design is discussed in human-computer interface field. [2] As predecessors' research revealed that there is a strong relationship between external condition and mental condition which mean that human being is affected by atmosphere. We conducted experiment to study effectiveness of recording mental status. As a way of recording mental status, we calculated RRV(R-R wave variance) for evaluating stress. For monitoring humanfatigue, excitement or drowsiness, electrocardiogram(ECG) is calculated as physiological index. RRV is one of the ways to monitor the physiological change. RRV is to count the inter cycles between R wave and successive R wave. The variance of interval time series is measured for stress index. The higher the RRV value becomes, the less stress a person holds and vice versa. In order to record R-R intervals, we used photodiode sensor to detect the change of blood flow by detecting optical volume. Figure 3 shows the RRV change and excerpts of recorded vision. The striking change of RRV value can be detected in the latter of the experiment. This change occurred when a pedestrian approached unexpectedly to a wearer when the wearer's stress reached to the peak and her leaving jumped to the less stress condition, while the RRV data dropped rapidly again by facing other pedestrians coming close to the sight.

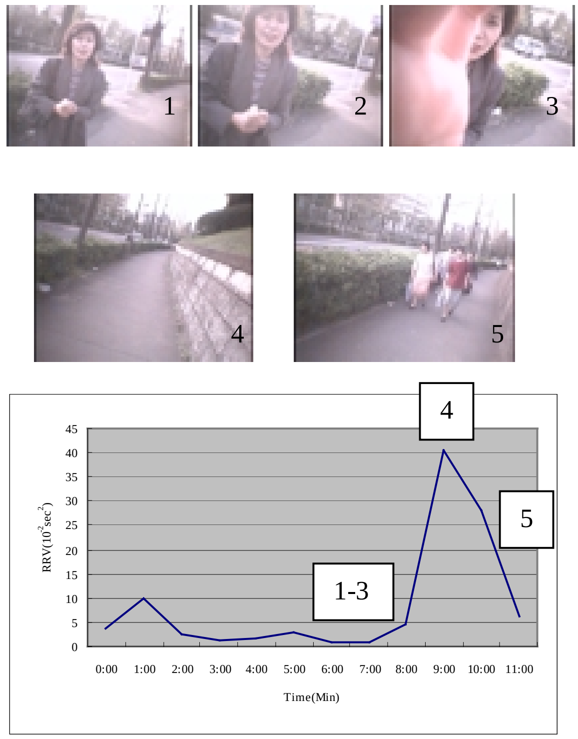

Figure 3 RRV and recorded vision

4.2 Location

In experience recording, location data is considered to be an objective behavioral data to be able to trace back an individual experience. As location and experience is strongly related when to be constructed memory, it is effective to record location. We have been evaluated the location logging system using RF tags and receiver, Global Positioning System(GPS) or GPS with supplementary system. RF tags and receiver system can be detected an adequate positioning data within the limited area. On the other hand, GPS type detection system does not restrict detecting area. Thus recording location within unlimited area like experience recording, GPS type detecting system is adequate. Figure 4 shows GPS type position detecting prototypes.[3] Left image shows a single GPS detection system and the right image shows the differential GPS system with supplementary system embedding magnetic sensor and a pedometer to detect location and distance when no GPS update data is possible. Besides, measurement physical movement relevant to location will possibly be an index to evaluate a wearer's interest. Figure 5 shows a result of the experiment which shows the extracted images based on the wearer's pausing position while bold line on the map shows the walking route of the wearer plotted based on GPS data. As a wearer's pausing and interest correlates strongly, [4] this extraction means to abstract part of the interest from experience recording.

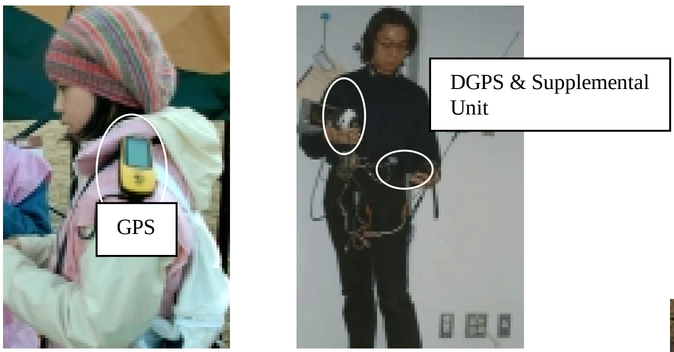

Figure 4 Location detection prototypes

Figure 5 Route map and recorded vision

4.3 Vision

As it is said that human being acquires about 80 % of information through vision, it is clear that a great amount of information in experience memory is acquired through vision. In terms of vision relevant study, we have performed experiments recording a wearer's conscious attention and point of view[5], and recording vision for construction omnidirectional images. Figure 6 shows distribution of interest of a wearer. The bar graph shows continuity of interest and images show the images of interest at the point. Also figure 7 left shows a wearable prototype system for omnidirectional image recording and figure 7 right shows prototype images constructed by those recorded with the prototype.

Figure 6 Distribution of interest and recorded vision

Figure 7 prototype of omnidirectional image recording and constructed model

4.4 Ambience

In experience recording, to record the atmospheric information which is received through skin sensitivity is important as an additional sensational data of experience. However atmospheric information is subtle so that even a person doesn't know consciously whether he/she is affected by atmospheric change. As a trial, we studied temperature as a potential atmospheric information which can be recorded objectively. [6]

Figure 8 shows temperature data recorded three different places at different time. Experiment #1 and #3 are the result of 16 minutes walk and #2 is the result of 12 minutes walk. This result shows temperature data is unique atmospheric information taken objectively. (average temperature: #1 29 centigrade #2 26.4 centigrade #3 27.6 centigrade) In terms of rate of change, #1 and #3 experiments were recorded outside and range of temperature is 1.4 centigrade. On the other hand, #2 experiment was recorded both inside the building and outside. Then the range of temperature is about 3.5 centigrade. The temperature change may cause the effect on skin sensitivity of human being which ends up with affecting experience memory.

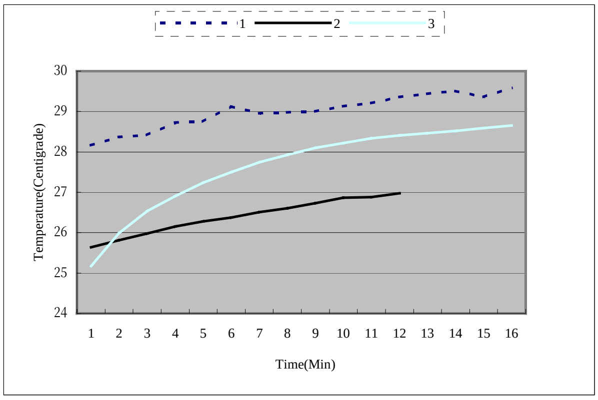

Figure 8 Temperature Record

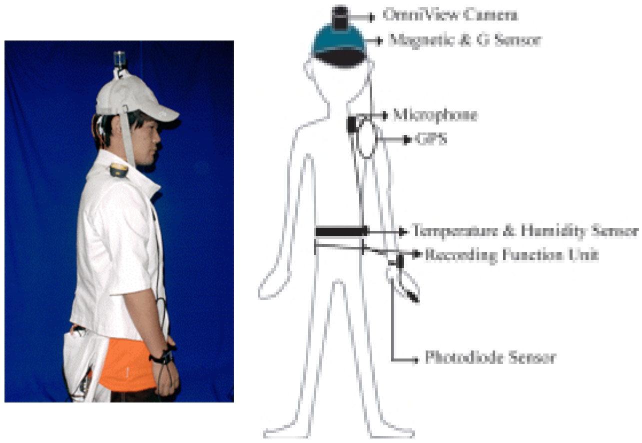

Figure 9 A wearer and system alignment

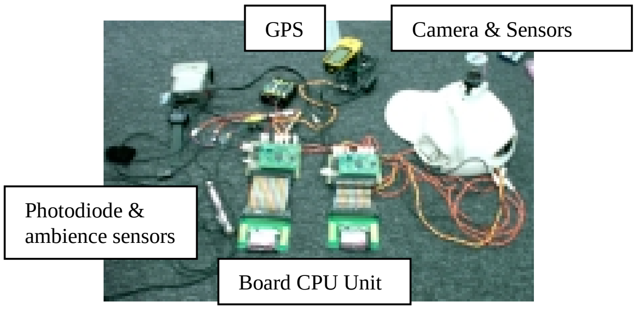

Figure 10 Hardware configuration

5.Experiment

5.1Purpose

In this experiment, we selected several sensors from each of the categories discussed before and examined the possibility of recording subjective experience in a objective manner. In this experiment, omni view camera was used for visual recording. By recording omni view vision, it becomes possible to record field of view as well as perceptive vision. Also, in this experiment, we used magnetic sensor and two axis gravity sensor to record head direction and gradient as an objective physical data. And along with temperature, humidity is recorded to calculate discomfort index for measuring air change of which output is more close to the feeling of skin sensitivity.

5.2System

Figure 9 shows a wearer and system alignment of the prototype. Table 1 shows system outline of each sensor. Total weight of the prototype is about 2.5 kg. Vision and audio data are recorded by DV recorder. Other sensed data are recorded by compact flash memory controlled by board CPU expanding its address bus to 24 bit to acquire 16MB memory area. This function was adopted for realizing simple caching method for an extended time period as well as less weight for embedding as a part of a cloth in the future.

Table 1. System Outline

element	sensor	specification
Emotion	Photodiode Sensor	Interval time of Heart beat /5msec
Location	Global Positioning System(GPS)	Location data/1 sec
	Magnetic Sensor	Physical Direction/1 sec
	G sensor	Physical Gradient/1sec
Vision	Omni view camera	Environmental vision, 30 flames/1sec
Audio	Condenser microphone	Environmental audio
Ambience	CMOS Sensor	Temperature data/1sec

5.3Experiment

A user wearing the prototype system took walks outside while the sensory information was recorded automatically. For initiating recording, a user pushes starting button, which controls power unit of the system. By 5 second lightning LED attached to the button, the user was informed that the system was working properly. After memory caching is full, LED lights again to inform of a user that no more recording is possible.

5.4Result

Magnetic Sensor embedded in the baseball cap detects a wearer's head direction and two-axis gravity sensor detects up/down and side tilts. Though these data are not applied for overlaying purpose so that the output is not necessary to be too sensitive for accuracy, we are concerned for error of magnetic sensor when to be inclined as well as geomagnetic inclination. Both concerns cause to detect wrong direction. For correcting this error, detected G sensor output is used to apply for transformational function. In terms of geomagnetic inclination, this is permanent inclination caused by geographical position. In Japan it is said that magnetic line is not horizontal on the ground but directed to the ground, which causes angle of depression between direction of magnetic line and horizontal surface. The angle of depression is about 50 degrees. Assuming the angle of depression is expressed as θ here, the vector of magnetic line $\vec{m}$ is expressed as follows.

$\vec{m} = (0, k\cos\theta, -k\sin\theta)$

Here, k means the size of vector of magnetic line. And suppose the 3 dimensional coordinates are expressed as follows; horizontal surface *x*, magnetic north is y and upper direction *z*. Magnetic sensor has two axis, both X and Y. Each axis outputs voltage signal which converts the value of inner product of vector of magnetic line and vector of direction of itself which is expressed as yaw angle(ϕ). Assuming head's up/down inclination is expressed as pitch angle(η) and side inclination is expressed as roll angle(φ). For finding corrected X and Y vector, the following functions are applied for correcting axis outputs. For Y vector, finding *x'y'z* coordinates rotated ϕ degrees centering z axis and then rotating φ degrees centering x' axis transforms Y vector $\overrightarrow{e_y}(0,1,0)$ to $\overrightarrow{e'_y}(-\sin\phi\cos\varphi, \cos\varphi\cos\phi, \sin\varphi)$. As in the case with X vector, finding x'y'z coordinates rotated η degrees centering Y' transforms $\overrightarrow{e_x}(1,0,0)$ to $\overrightarrow{e'_x}(\cos\phi\cos\eta, \cos\eta\sin\phi, \sin\eta)$.

By finding the value of inner product of $\vec{m}$ and corrected vector, direction of a wearer's head is calculated.

However as figure 11 shows, tilting of η angle is jolty as a trait of sensing head movement. (SD of η is about 12 degrees, whereas that of φ is about 5 degrees.) So this function is suitable to be applied to correct the steady misalignment of the sensor output which arises due to head position and movement. We calculated the steady misalignment as –16 degrees for η and 4 degrees for φ by averaging 120 second data taken from the person wearing the sensor embedded cap.

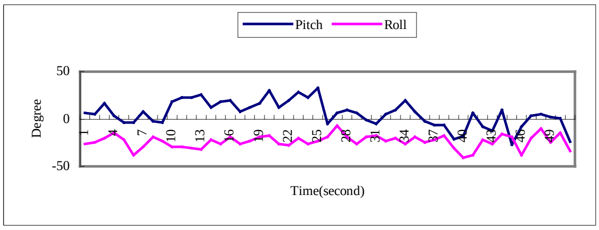

Figure 11 Pitch and Roll angle(walking)

For calculating feeling temperature, we used following equation. This is used for calculating skin sensitivity of temperature by combining temperature and humidity.[7] Output is regarded as discomfort index. The durability against heat is different from nations because of the difference of seasonal climate. In Japan, 70 of discomfort index is considered as cool circumstance and 75 is regarded that 30 % of people feel discomfort and 80 is sweating hot and 85 is very hot.

$$DI = 0.81T + 0.01U(0.99T - 14.3) + 46.3$$

Here DI is an abbreviation of Discomfort Index and T is temperature and U is relative percentage of humidity.

Average DI is 84.32 and mode is 85.52 by performing the experiment in August. Inside the building, the average is about 80 and while raining the average is about 82.9. And average rate after raining with sun shining is about 85.5.

Figure 12 presents the result of the experiment. Images show the extract of experience vision and other recorded data added. And the route is shown bold line on the map. Physical movement and discomfort index and RRV are shown as time-series data.

6. Conclusion

In this experiment, we evaluated the experience recording method using defined five parameters. We reached the conclusion that it is successful to record experience objectively by expanding parameters. We need to increase the number of parameters taken to get close to our final goal realizing subjective experience recording wearable computer. Besides, to study the system to arrange the recorded multi-data is also an important issues for experience recalling.

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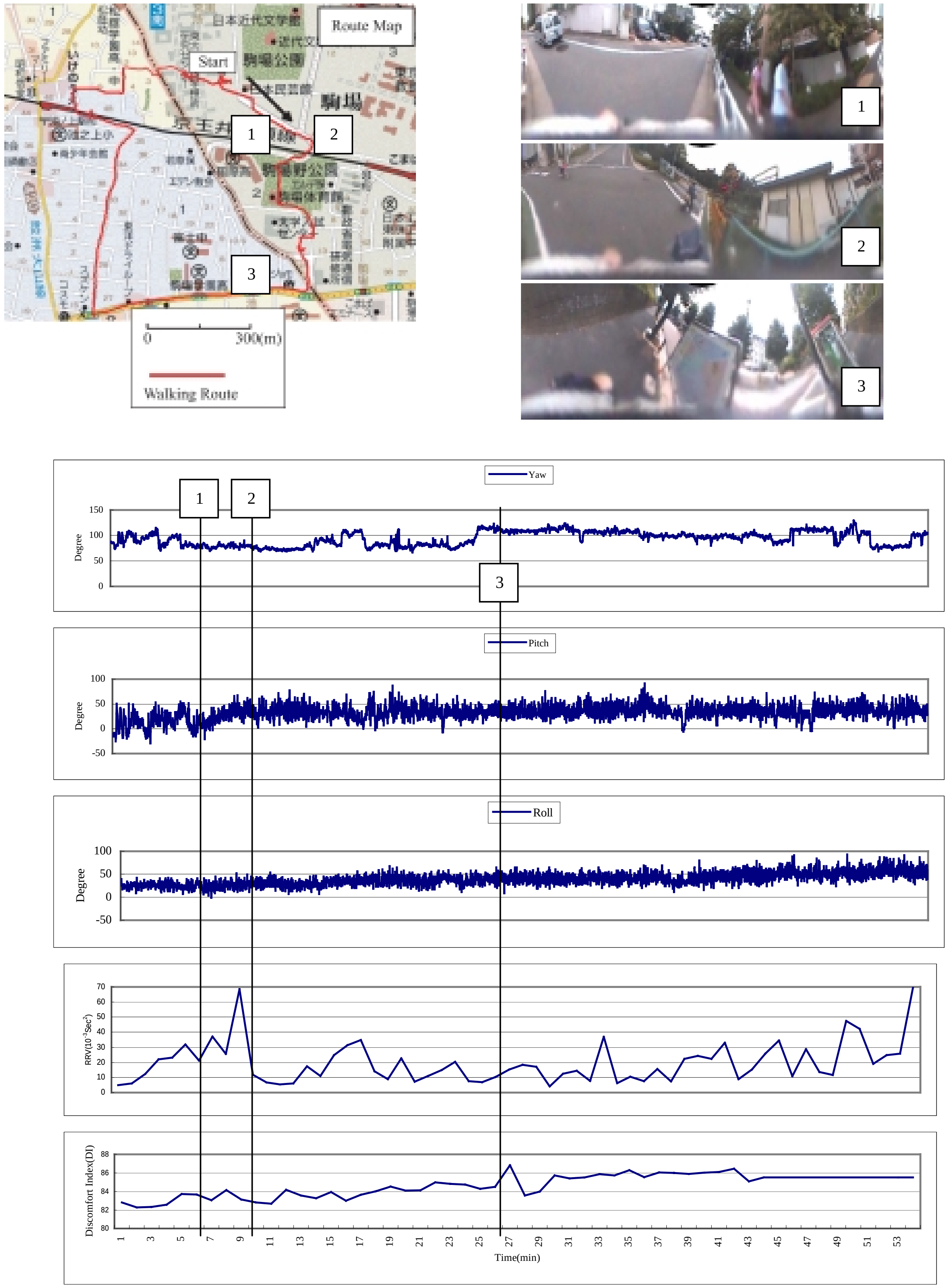

Figure 12 Result of the experiment