WINFO+: *Identification of Environment Condition Using Walking Signals*

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***Abstract*—In this paper we describe a prototype system of identifying environment condition utilizing signals emitted by people. Many people move around in many places such as urban and mountain areas. If each person emits information about identifying the state of the place where he/she and all the information is collected to one site, we can know the state of an area. Based on the idea, we have extended WINFO, a previously developed system, to accommodate reading people's walking conditions obtained by pressure signals at the people's feet. We show an architecture of the prototype system and a result of acquiring walking patterns in an urban area.**

***Index Terms*—body sensors, human, walking analysis**

I. Introduction

We have recently seen many kinds of applications for wearable computing. In addition, sensors with wireless communications have been miniaturized and mixture of these sensors and wearable computers can be expected. If we assume that a person wears a sensor with wireless communications and Global Positioning System (GPS), we can obtain sensed data at a point. By aggregating the data emitted by many people, a distribution map of sensed data is created. Based on the idea, we developed Wearable Micro-INFOrmation broadcaster (WINFO) in the past[4]. In WINFO, we set three goals: device scalability, information scalability, and resource scalability. Device scalability means that client devices can acquire the amount of information depending on their screen size and CPU power. A device with richer resources will present finer information on its display. Information scalability is dealing with the dynamic behavior of data. If the data has a large change either in temporal and spatial axes, the granularity of the data should be small. Finally, resource scalability determines the frequency of sensing and transmission depending on the available left battery energy. To enhance the scalability, we also consider data compression for sensed data. We extended WINFO to accommodate pressure information from a person's feet based on our previous work of AoK[2]. The extended system is called WINFO+. The contribution of this paper is showing a preliminary result of classifying walking conditions on roads and possibility of associating the condition with a location. The rest of the paper is organized as follows: Section 2 gives the design of analysis of walking by AoK, a device we have developed. Section 3 describes the architecture of WINFO+. Section 4 shows a preliminary result of experiments. Sections 5 and 6 present related works and conclusion, respectively.

II. Analsis of Walking

In this section, we describe a device of analyzing walking pattern we developed, a method of compressing data, and some analyzed results.

A. AoK Device

In AoK, we focus on collecting the distribution of pressure on slippers and exploring the feasibility of acquiring higher-level information about the state of a person. Therefore, the function of creating summarized states is not included in the slippers; signal processing is performed at the AoK_Server for feasibility study. The hardware of the AoK mule consists of a mule, MicaZ Motes, and three pressure sensors on the surface of the mule. The output signal of the pressure sensor is connected to the Mote and converted to digital data. By installing three pressure sensors on the surface, the distribution of the pressure can be observed. Fig. 1 shows the prototype system. As seen in Fig. 1, the pressure sensors are put onto the forefront, the middle, and the back on the surface. However, only the forefront and the back were used to extract signals after several trials. The digitized pressure information is sent to an AoK_Server via wireless communication of the Motes.

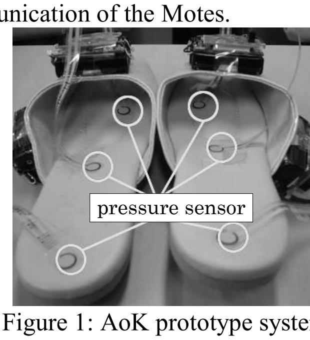

Figure 1: AoK prototype system

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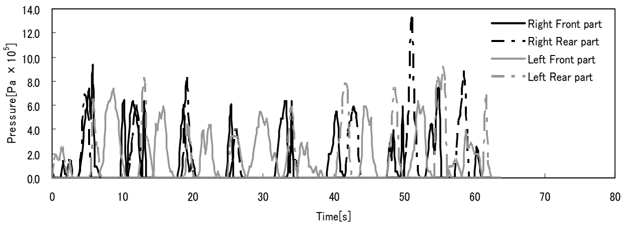
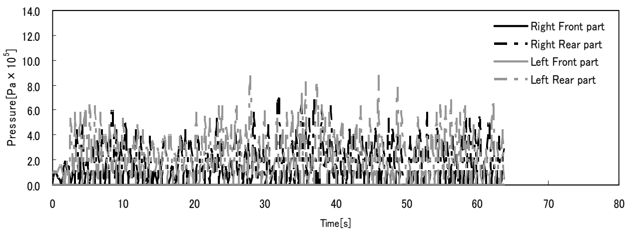
B. Data Compression

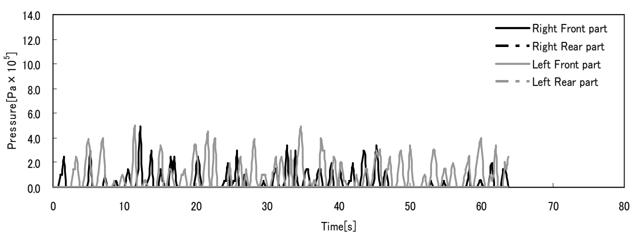
The acquired raw data for normal, shuffle, and forward-bending walking is shown in Fig. 2. Since preserving the raw data requires enormous storage, we consider compressing the raw data .



(a) Normal walking



(b) Shuffle walking



(c) Forward-bending walking

Figure 2: Temporal change in pressure

As seen in other research areas, data compression needs to be focused on the characteristics of signals. For compression of still images in JPEG, high frequency components are removed by utilizing insensitivity of human eyes. In the same context, we need to consider the characteristics of walking on compressing the raw data.

Our approach focuses on the movement of peak values of pressure. Let us define an epoch as a period of contacting a floor. We extract the peak values of the forefront and the rear for the same epoch. Fig. 3 shows a diagram of the two values. Acquired data are grouped into the following four categories:

Group A: This group indicates that peak values of both the forefront and the rear within an epoch are high. This suggests that the movement of a body is smooth and normal walking corresponds to this group.

Group B: This group categorizes high peak values for the rear and low values for the forefront. This corresponds to shuffle walking.

Group C: The opposite characteristics are shown in this group. This group corresponds to forward-bending walking.

Group D: Peak values of both the forefront and the rear within an epoch are low.

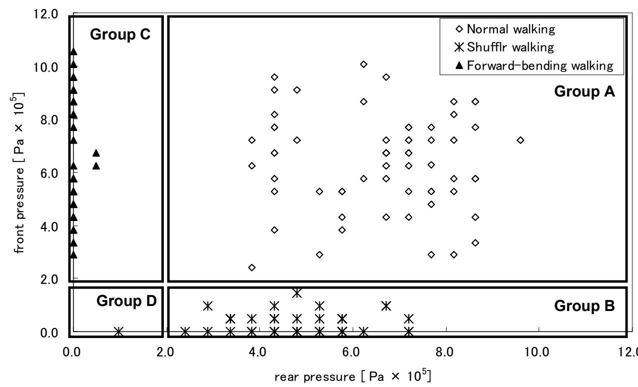


Figure 3: Front-rear diagram

Algorithm 1 Classification of Pressure Data on one step Algorithm.

```
1:procedure classification
2:  var
3:     frontData:array[dataNum] of integer; // front foot pressure data
4:     rearData:array[dataNum] of integer; // rear foot pressure data
5:     gravity:array[dataNum] of integer; // center of gravity data
6:     frontPoint:array[pointNum] of integer;
                                   // maximum Center of Gravity point
7:     rearPoint:array[pointNum] of integer;
                                   // minimum Center of Gravity point
8:  for i:=0 to dataNum-1 do gravity[i]:=frontData[i] - rearData[i];
9:  for i:=0 to pointNum-1
      do function frontPoint[i]:=extractFrontMax(gravity[i]);
         // extract maximum Front Foot Center of Gravity point
10: for i:=0 to pointNum-1
      do function rearPoint[i]:=extractRearMax(gravity[i]);
         // extract maximum Rear Foot Center of Gravity point
11: repeat
12:    if frontPoint[i] > threshold for classification
          and rearPoint[i] > threshold for classification then Group A;
13:    else if frontPoint[i] > threshold for classification
          and rearPoint[i] < threshold for classification then Group B;
14:    else if frontPoint[i] < threshold for classification
          and rearPoint[i] > threshold for classification then Group C;
15:    else if frontPoint[i] < threshold for classification
          and rearPoint[i] < threshold for classification then Group D;
16:    i:=i+1;
17: until i equals to pointNum-1
18: end procedure
```

Figure 4: Classification of groups

Figs. 4 and 5 show algorithms for classification and compression, respectively.

Algorithm 2 Data Compression in Group Algorithm.

```
procedure Group A
  for i:=0 to dataNum-1 do function calculate gravity();
  repeat // search changing point of gravity
    if this center of gravity value is changing point
      // compressed pressure data is changing point of gravity
      then compressedData:=gravity[i];
           timeStamp:=i;
           i:=i+1;
  until the number of repeat is more than compress point num;
end procedure

procedure Group B, C, D
  var
    selectAlgorithm:boolean; // select algorithm from 2 algorithm
  // case of rear foot pressure data or front pressure data is small.
  selectAlgorithm:=false;
  //if group is B
  if case of rear foot pressure data is large.
    then selectAlgorithm:=true;
  //if group is C
  if case of front foot pressure data is large.
    then selectAlgorithm:=true;
  //if group is D
  if case of rear foot pressure data and front pressure data is large.
    then selectAlgorithm:=true;
  if selectAlgorithm is false then // search changing point of gravity
    for i:=0 to dataNum-1 do function calculate gravity();
    repeat // search changing point of gravity
      if this center of gravity value is changing point
      // compressed pressure data is changing point of gravity
        then compressedData:=gravity[i];
             timeStamp:=i;
             i:=i+1;
    until the number of repeat is more than compress point num;
  else if selectAlgorithm is true then
    // search changing point of front data and rear data
    repeat
      if this front foot presure value is changing point
        then compressedData of front foot:=front Data[i];
             timeStamp of front foot:=i;
      if this rear foot presure value is changing point
        then compressedData of rear foot:=rear Data[i];
             timeStamp of rear foot:=i;
             i:=i+1;
    until the number of repeat is more than compress point num;
end procedure
```

Figure 5: Algorithm of compression

III. ARCHITECTURE OF WINFO+

In this section, we describe the architecture of WINFO+. The system of WINFO+ is based on a client-server model and composed of WINFO+ client (WIC) and WINFO+ server (WIS) as shown in Fig. 6.

WINFO+ Client (WIC)

WIC is a device attached to a person. It consists of a central computer, probe shoes, GPS, and wireless interface. The central computer obtains the raw information about pressure values at the probe shoes. The data is tagged with the GPS timestamp and transferred to Data Control. In the Data Control, the raw information is compressed into the group type and formed into a tuple of latitude, longitude, the group type, and timestamp. The tuple is transmitted to WIS through the wireless interface. In the prototype of WINFO+, PHS is being used.

WINFO+ Server (WIS)

WIS receives tuple data from multiple WIC and stores the tuples to a database. The database is connected to a map information. Upon a request for data in a certain area from a WIC, the WIS returns the corresponding data.

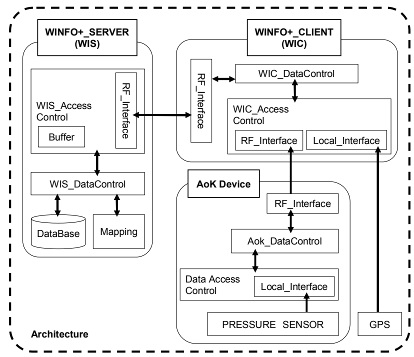


Figure 6: Architecture of WINFO+

IV. EXPERIMENT

In this section we describe a result of classification using a WIC. The WIC used in the experiment is shown in Fig. 7. As shown in the figure, walking shoes are used for probing instead of slippers. We took the pressure data on feet inside downtown Tokyo where flat land and stairs are intermingled.

The raw data taken at the experiment are shown in Fig. 8. Different patterns compared with the AoK experiment are observed in the figure. The classified fore-rear diagram in Fig. 9 indicates that walking at flat areas and at stairs is distinguishable. Although this preliminary experiment we did not associate the classified data with the location, our original plan of massive collection of classified data and its corresponding location seems promising.

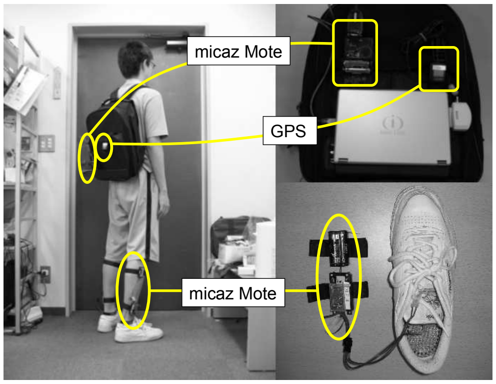
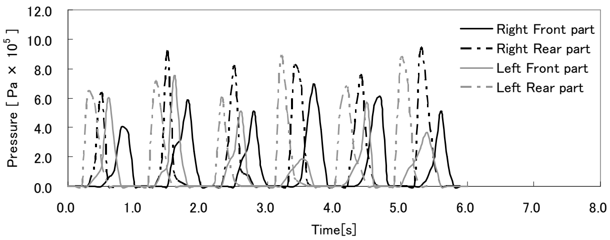
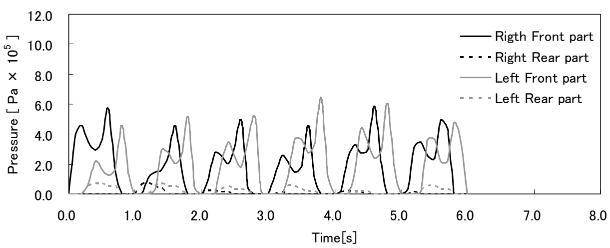


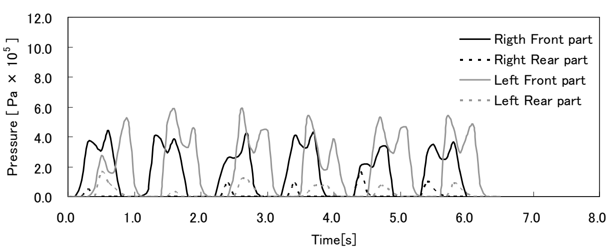
Figure 7: Installation of WINFO+



(a) in flat areas



(b) stairs (upward)



(c) stairs (downward)

Figure 8: Raw data emitted by WIC

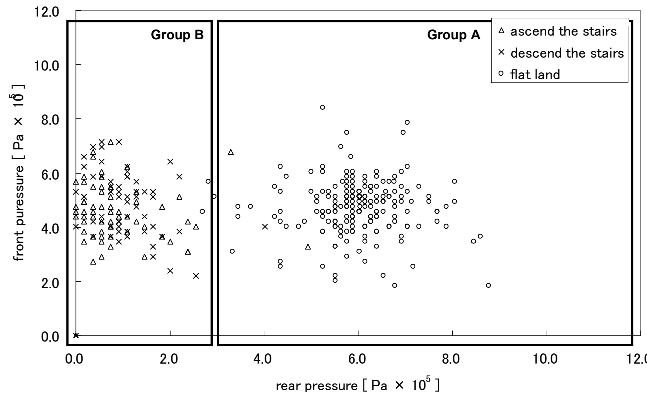


Figure 9: Front-rear diagram

V. RELATED WORKS

In the CodeBlue project[5] by V.Shnayder et al. they propose emergency medical service in healthcare management by using radio transmission sensor devices. The used sensor is a Mica2 Mote with a pulse type oxygen analyzer or an electrocardiogram sensor. It is attached to a person's finger or body and captured person state, is sent through radio transmission. The system requires explicit attachment of sensors to a body. Our system is characterized by unconsciousness.

Adidas 1[1] measures compression force, when a user's foot hits the ground. In addition, Adidas 1 adjusts cushion at the heel. Adidas 1 includes a microprocessor and sensors. A user of WINFO+ can analyze walking patterns. However, the Adidas 1 does not store data as a database.

Sung et al. [6] proposed a system that exchanges such information in the remote place. Real-time sharing system of disaster information [2] was proposed. In this system, a fire-person wears PC, CCD camera, and GPS to the body and acquires disaster information and the location information. This information is linked to the map and shared among users. It resembles this research in terms of sharing information. Although it resembles this paper from the viewpoint of sharing information, the amount of shared information is different.

With regard to massive collection of data generated by human, Riedel et al. [3] collects data of skate boards. This work is the most similar to ours, but ours has the advantage of assuming daily-used shoes.

VI. CONCLUSION

In this paper we have described the concept of aggregated personal information and the basic architecture of WINFO+. A WINFO+ client device obtains a person's walking condition together with the person's location. Thus, the information about easiness of walking is generated if the number of WINFO+ participants increases. Extensive experiments over a outdoor field remains for our future work.

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