Identification of human activity modes with wearable sensors for autonomous human positioning system

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ABSTRACT: Recently, mobile information devices and environment of mobile communication have progressed quickly. Under the situation, the technology which can monitor human activity and position has been needed in many fields and many developments and researches about it have been performed. Actually, a lot of systems using GPS and PHS have been proposed and put to practical use, though, there are still serious problems in the time-resolution and the limit of its usable area. For that reason, an autonomous positioning system not to depend on infrastructures has been developed, which can estimate walking human's position continuously and high time-resolution by combinations of same sensors with walking human and Map-matching to modify errors occurred by the sensors. But these positioning systems can be used only when users walk on smooth or flat surface, not applicable to the other various human's motion modes such as walking up and down the stairs, taking bicycle, car, train, bus etc. This paper, after investigating the characteristics of each motion mode pattern, try to estimate the various human's motion modes using the time-series motion data measured from a human body.

1. INTRODUCTION

Recently, with the rapid development of mobile information devices and environment of mobile communication, the position information of goods and human has come to attract attention. There are huge fields that need the positioning technology that human's position and action are gained and monitored more precisely, such as the service which distributes information according to the situation that a user searches for and the life or medical activity for children, elderly people and the physically handicapped. And such needs will continue increasing from now on.

Actually, a lot of systems using GPS and PHS have been proposed and put to practical use, though, in such infrastructure-dependent positioning technology, there are still serious problems such as the coarse time-resolution and the limited availability of the service. Among those problems, the most serious one is that the positioning service cannot cover all the area.

To cope with these problems, an autonomous positioning system not dependent on infrastructures has been developed, which can estimate walking human's position continuously with high time-resolution by combining several sensors attached to walking human and map-matching algorithm to modify errors occurred by the sensors. For example, Sagawa and Ina (1997) succeeded in estimating motion mode such as stillness state, up and down of stairs, taking elevator with high precision in addition to a walking mode using acceleration sensor and manometer sensor. In addition Takahashi et.al (1995) successfully discriminated an indoor walking from by comparing the measured acceleration waveform and a known standard waveform of that walk form.

But the focus of these researches was mainly directed only to the discrimination of human's walk forms, although the other motion modes may be important in daily lives such as the movement by car, train, bus and bicycle. The future development of positioning technology which can distinguish these motion mode with higher precision will help the improvement of location-based information service and medical services because service providers can grasp finer needs of users.

This paper, after investigation the characteristics of each motion mode pattern, try to discriminate the various daily motion mode (i.e. walking, running, up and down of stairs, riding of car, train, bus and bicycle) using the time-series sensor data from the acceleration sensor attached to human body.

2 . EXPERIMENT

2.1 Hardware

Experimental equipment used in this paper, consists of gyro sensor (Japan Aviation Electronics, JIMS-30C), note-PC and RS-232C serial interfaces to connect them. We fixed the gyro sensor by the belt on a subject's waist and measured vertical acceleration with 30Hz frequency. The measured data is sent to a note-PC by serial interface, and is processed.

2.2 Method of Analysis

In order to develop motion-classification algorithm, it is necessary to measure the characteristics of acceleration data from human motion. While test subjects performed a walk, a run and rise and fall of stairs inside the five story building and rode in vehicles, such as a car, bicycle, a train and a bus in the outdoor environment time series data of acceleration was measured. The power spectrum was computed from about 2 second sample data (the value of 64 pieces) using FFT.
Each experimental situation is as follows.

Walking: measured at a fixed speed in the passage inside a building.

Running: measured by the jogging grade in the passage inside a building.

Stairs up and down: measured without stopping from the first floor to the fifth floor of the stairs in a building.

Stillness state: measured by erection for a minute.

Bus: measured on a seat of central part of the bus.

Train: measured standing near a door on a each station train.

Car: measured taking a seat to a passenger.

Bicycle: measured on the paved road.

3 . RESULT AND CONSIDERATION

We conducted the above experiment and will see the computed power spectrum to consider each motion mode.
The following Figure 1~ 10 show Power spectrum computed by each time-series data of vertical acceleration measured by the gyrocompass.

(1) Walking

The value of frequency read at the peak of the power spectrum illustrated in Figure 1, that is around 2Hz, shows frequency of periodicity caused by motion of walking. And around frequency of 4Hz and 6Hz shows high value of power spectrum, too.

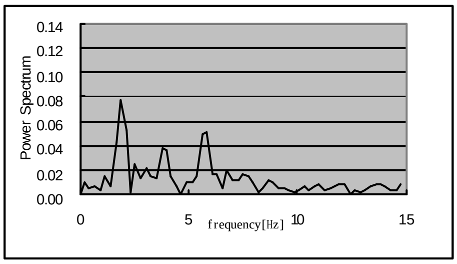

Fig.1: Vertical acceleration data in case of Walking

(2) Running

The frequency in which the value of power spectrum becomes large can be read near 3Hz. Other portions are small gently-sloping. That is the clear feature in Running.

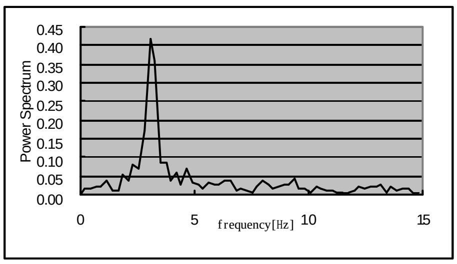

Fig.2: Vertical acceleration data in case of Running

3) Stairs going up

The value of power spectrum becomes large around 2Hz, 3Hz, 4Hz, 5Hz. From 6Hz to 15Hz, there is no especially marked peak. This case resembles Walking case in the frequency at the peak of the power spectrum. But the numeral value at peak of Stairs going up is smaller than that of Walking.

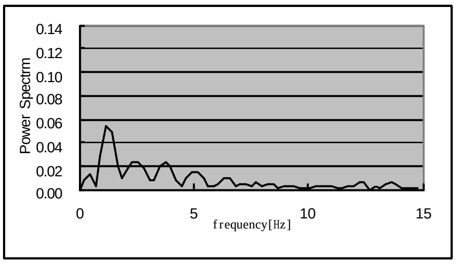

Fig.3: Vertical acceleration dat a in case of Stairs going up

(4) Stairs going down

The frequency that value of power spectrum becomes large can read at 2Hz, 4Hz, and 6Hz. This is quite alike to Stairs going up. But Stairs going up is larger at the peak of each frequency about 2 times. Moreover, this is alike to Walking, too, but there is a twice difference in the value of power spectrum at 2Hz between them.

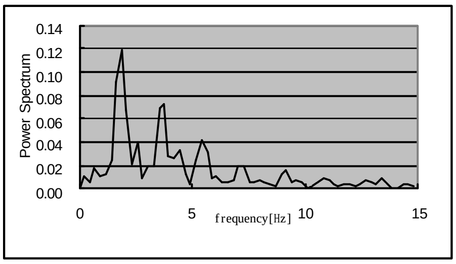

Fig.4: Vertical acceleration data in case of Stairs going down

(5) Stillness state

The value of power spectrum at most frequency shows around 0.This is distinguished from other above motions.

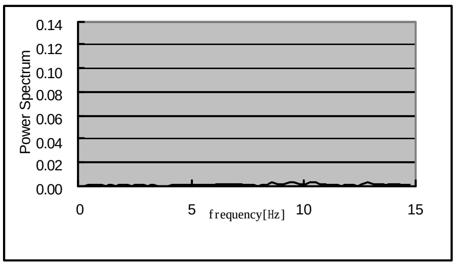

Fig.5: Vertical acceleration data in case of Stillness state

(6) Train

There is no marked peak at any values of frequency, but the power spectrum becomes large at around 1-3Hz, 5-7Hz 14-15Hz on the whole.

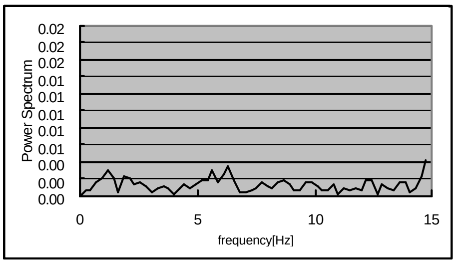

Fig.6: Vertical acceleration data in case of Train

(7) Bus

The value of power spectrum becomes obviously the largest from 1-2Hz. The frequency that the value of power spectrum becomes second largest are around 12Hz and 14Hz. On the whole, there are a lot of peak frequencies. This is characteristic in comparison with the others.

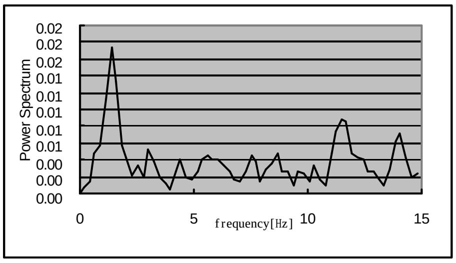

Fig.7: Vertical acceleration data in case of Bus

(8) Car

There is no marked peak at any value of frequency on the whole, but the power spectrum becomes a bit larger around 6-9Hz, 11-14Hz.

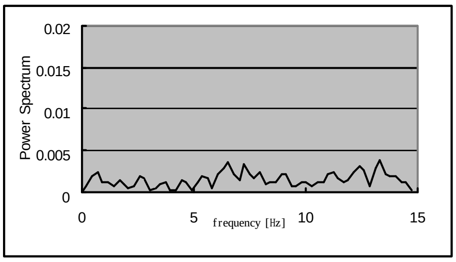

Fig.8: Vertical acceleration data in case of Car

(9) Bicycle

There are a lot of peak frequencies where the value of power spectrum becomes large, but around 2-4Hz and 6-8Hz have the collected peak.

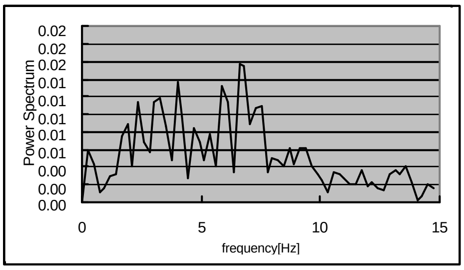

Fig.9: Vertical acceleration data in case of Bicycle

(10) Stillness state

Having the scale of the vertical axis of graph of this same with that of other vehicles for comparison, there is a very small peak around 8-11Hz.

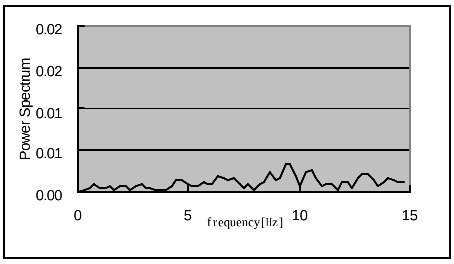

Fig.10: Vertical acceleration data in case of Stillness state

4 .CONCLUSIONS

From above experimental results and consideration, it became clear that there is respectively characteristic waveform in each motion modes. However, comparing the power spectrum of "walking" with that of "up and down of stairs", because both have peaks at the same frequency value and the whole waveform is alike, those differences can be estimated from the magnitude of power spectrum value. Although the waveform of train and car also seems to be alike apparently, there is a difference clearly to each wave pattern. Therefore, we could discriminate each motion mode by analyzing the data pattern of each motion mode in this experiment.

5 . FUTURE

In this paper, we measured human motion mode (walking, running, train, bus etc.) using only acceleration and succeeded in discriminating each motion mode from the characteristic waveform of these data. Human motion mode, however, has other vertical movement by escalator and elevator, not covered in this paper. Moreover, in order to distinguish stairs-rise and fall from others more clearly, it will be necessity to use a manometer in addition to acceleration so that more motion modes can be correctly distinguished.