Dynamic Measurement of Body Inclination in Walking by Body Area Network Sensing System

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Abstract. *This paper shows the dynamic measurement system and result of body inclination in walking by monitoring acceleration at waist. To monitor the acceleration in walking, the sensing system had been constructed as a wearable and small scale wireless network system (body area network sensing system [BANSS]) put on body. BANSS is constructed with a host system and plural sensing nodes. Sensing node has sensors, microprocessor and near field communication device (NFCD). In this study, the sensing node measures the acceleration at waist of user in walking, and sends them to the host system regularly. By analysing the acceleration data at host system, the situation of body inclination in walking was estimated dynamically. It has been confirmed that the body inclination generates for everybody regardless their consciousness.*

Keywords: sensing system, body inclination, dynamic measurement

1. Introduction

In daily life, quality of life (QOL) is the highest concern for all of people. They hope to keep it well and enhance it. Parameters of QOL are many kinds and different to each person. The parameters are concerning to the situations of living, health, family, friends, job, money, meal, hobby, social activity and so on. Especially, physical condition like health is the most basic and indispensable parameter. The physical condition depends on physical activity in daily life and changes dynamically. Then, to know the state of physical condition in detail, it is necessary to measure that continuously in daily life. Wearable and wireless body area network sensing system (BANSS) is the most suitable system to measure the dynamical physical condition continuously. Concerning the measurement system of body motion in walking, there are several kinds[1-5]. In this study, to detect body inclination in walking, BANSS collects the acceleration at waist dynamically, analyses the data and sends the information to host system. The body inclination in motion becomes the cause of heavy load and strong pain at a hip joint and a knee. Most of people do not feel their body inclination in daily life. The detection of body inclination in walking is to discover the sign of them.

2. Body Area Network Sensing System (BANSS)

To measure physical conditions in motion like walking, running and various kinds of physical activities in daily life, there are several parameters which are heart rate(HR), SPO2(Oxygen density in blood), body temperature, skin temperature, accelerations at many points of body (shoulders, waist, knees and foots [ankles]), impact transmitting in bones and so on. The measuring points of these parameters are distributed on body area. And users should be not limited their behaviours in motion by devices and wires of the monitoring system. Then, the formation of sensing system should be light and easy to use, wearable and near field wireless network to communicate measuring data and commands on and around body area. In this paper, that system is called as the wearable and wireless Body Area Network Sensing System (BANSS). Fig.1 shows the conceptual construction of the wearable and wireless BANSS.

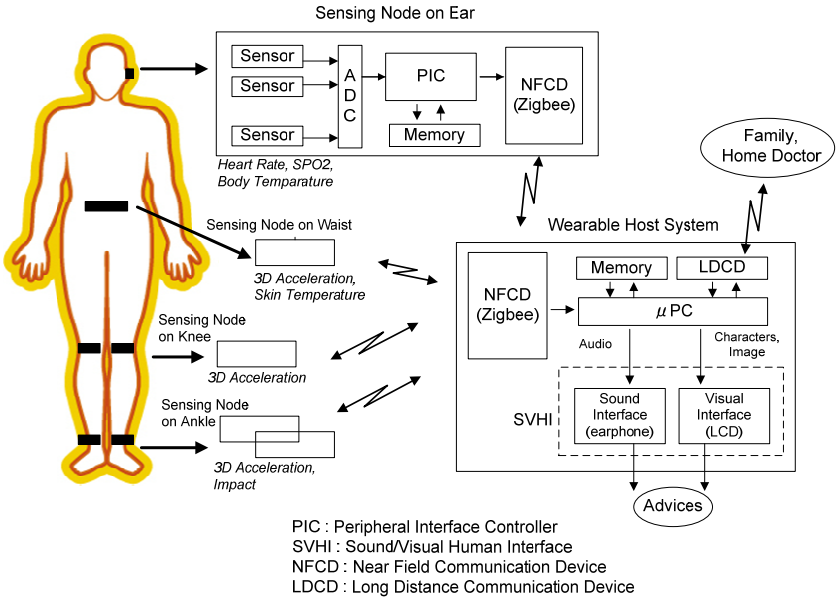


Fig.3. Concept of body area network sensing system (BANSS)

3. Measurement of body inclination in walking

Using a function of BANSS, body inclination in walking has been measured dynamically. Fig.2 shows the concept of the detection of body inclination by acceleration sensor. User puts 3D acceleration sensor on waits. The data of X axis of the sensor output expresses the movement of up-down direction of user. The data of Z axis expresses the movement of front-back direction. And the output signal of Y axis of the sensor expresses the movement of right-left direction. Fig.3 shows the detection of body inclination by analysing the signal of Y axis of acceleration sensor in walking. Fig.3(a) shows the output signal of Y axis of 3D acceleration sensor. It is seen that the signal is fluctuating around zero. The movement of right-left direction in walking is not so high speed. Blue line in Fig.3(b) shows the signal filtered by LPF (less than 0.1 Hz). The filtered signal has the bias changing slowly. To detect the bias locally, the average of the filtered signal in a constant time interval is calculated. The series of green squares in Fig.3(b) shows the fluctuation of local average each 30 sec..

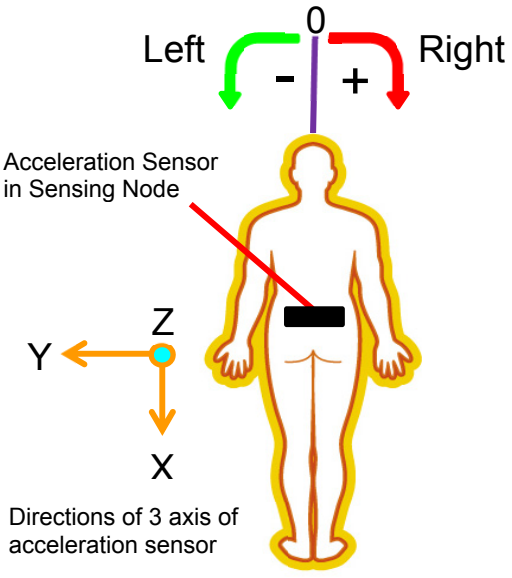
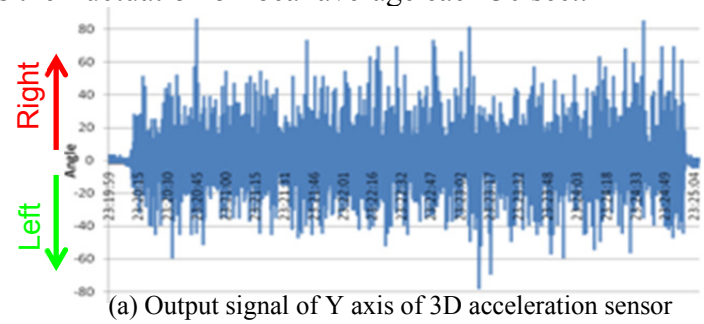
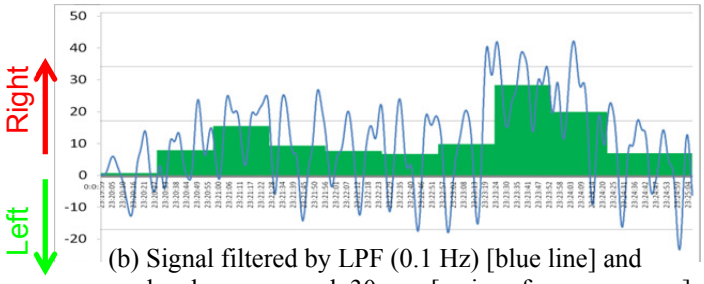


Fig.2. Concept of the detection of body inclination by acceleration sensor.



(a) Output signal of Y axis of 3D acceleration sensor



(b) Signal filtered by LPF (0.1 Hz) [blue line] and local average each 30 sec. [series of green squares]

Fig.3. Detection of body inclination by analysing the signal of Y axis of acceleration sensor.

In Fig.3(b), it is confirmed that the series of local average each 30 sec. has shifted to right side. By this observation, it has been estimated that the body inclination of user is right in walking.

To confirm the system operation obviously, the body inclination by unbalance sandals was estimated. Fig.4 shows unbalance sandals. Fig.5 shows walking path, the distance of which is 82m/round. Subject walked two times around the square path. He used with balance sandals in the 1st walking, with unbalance sandals in the 2nd walking. Fig.6 shows the estimated results. Using balance sandals, body inclination was zero mostly. On the other hand, using unbalance sandals, body inclination became right side. As the right heel is lower than left heel, the acceleration to right side became strong in walking.

Fig.4. Different heights of heels.

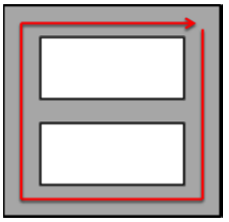


Fig.5. Walking path

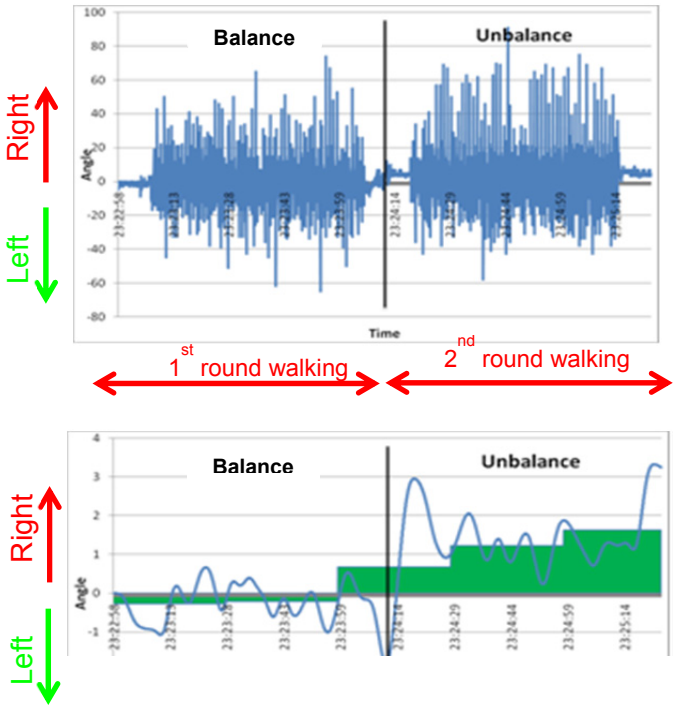


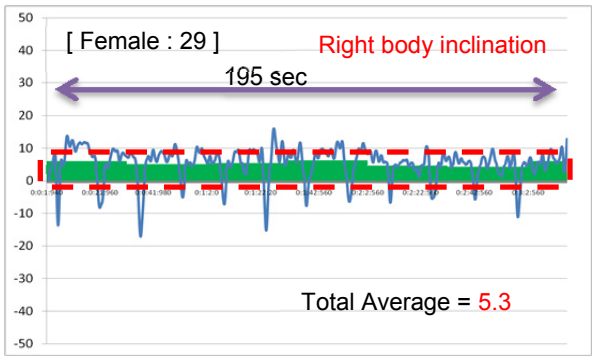
Fig.6 Different body inclinations by balance and unbalance heels.

By using this system, the body inclinations in walking of 5 Laboratory staffs were measured. They walked on same path 3 times continuously with their own shoes. As a remark, they have no consciousness concerning to body inclination at standing and in any motions in daily life. Fig. 7 shows the measurement results. In Fig. 7a, acceleration signal has 11 peaks to left side. These are caused by centrifugal force at right turns.

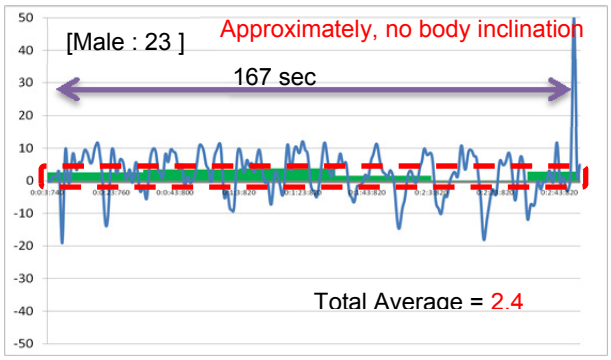
(a) in case of Male 32 years old

(b) in case of Male 24 years old

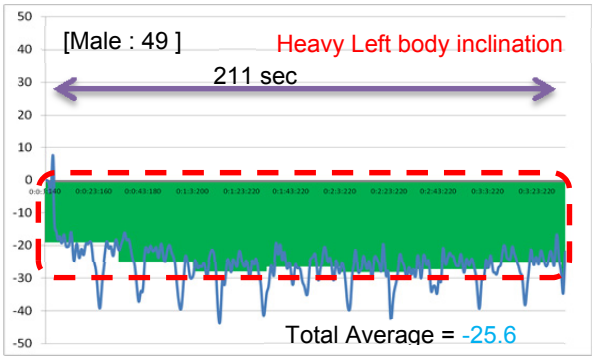
Fig.7 a, b. Estimation of body inclination in walking.



(c) in case of Female 29 years old



(d) in case of Male 23 years old



(e) in case of Male 49 years old

Fig.7 c, d, e. Estimation of body inclination in walking.

In Fig. 7d, the series of local average are around zero. Then, the body inclination was not observed approximately. In Fig. 7e, the body inclination is heavy to left side. It seems that his waist (hip joints) and left knee have got strong load in walking.

4. Conclusions

Body inclination in motion causes unbalance of physical activity and gives heavy load to waist (hip joints) and knees. Mostly, the body inclination occurs without consciousness at the beginning. By using wearable and wireless BANSS, it was confirmed that the body inclination in walking was estimated dynamically. As future works, the body inclination in running and walking for long time will be measured. BANSS is useful tool to measure the physical parameters at various parts on body and estimate physical condition dynamically in motion. That does not become obstacle to various motions. By reconstructing BANSS as small and robust system, the application fields will spread more and more.

References

[1] Hisao Oka and Tomonori Inoue, Monitoring of physical Activity by Accelerometer, *Technical Report of IEICE MBE98-50*, 1998.

[2] Kiyoshi Teramoto and Nagao Usui, Effect of Pelvis Adjusting Method on Leg Length Inequality and Centre of Gravity of Patients with Hip Joint Disorder, *Rigakuryoho Kagaku* 11(4): 201-206, 1996.

[3] Naofumi Tanaka, Shigeru Sonoda, Yoshihiro Muraoka, Yutaka Tomita, Naoichi Chino, Reproducibility and Validity of Gait Analysis Using Portable Accelerometer, *Jpn J Rehabil Med* 33: 549 – 553, 1996.

[4] Yosinori Nishijima, Tatuo Kato, Takahide Baba, Masatada, Yoshizawa, Effect of Stride Frequency on EMG during Level Walking and Stair Ascending, *Walking Research*, No.7, 2003.

[5] Masuo Hanawaka, Masaharu Sawamura, Naoyuki Fujimoto, Akira Satoh, Gait Measurement System and its Applications, *YOKOGAWA TECHNICAL Report* Vol.51, No.3, 2007.