THE APPLICATION OF MOTION PATTERN RECOGNITION IN THE BEHAVIOMETRICS OF HUMAN KINEMATICS

Andar Bagus Sriwarno
Research Group of Human and Industrial Product, Industrial Design Section
Faculty of Art and Design, Institute of Technology Bandung
Jalan Ganesha 10, Bandung, Indonesia 40132
E-mail: andarbugs@fsrd.itb.ac.id

ABSTRACT
Current trends seem to accredit motion as a sensible biometric feature for human identification in spite of physiological parameter which related to the shape of the body. As in many image processing system, the recognition is running under the circumstances of the lighting condition that may moving object acquitioned by the computer. Through this principes, this paper presents the application of video inter-frame analysis system for determining human motion from the sagittal view video sequences. By using this method, the behavior of person can be recognized and determined the type of motion. Some researches have coined the term behaviometrics for this class of biometrics. The experiment was conducted by asking subjects to conduct the simple motion. Eight healthy male subjects participated in the experiment to raise from the deep squatting (STS) at the three different foot elevations: full squatting (FS) which the plantar feet were fully contact to the floor (0 degree), slope squatting (SS) which a 15 degrees of wedge was applied underneath the feet, and tiptoe squatting (TS) which subjects rose the heel by extending the metatarsal joint at their preferred height. The result showed that raising the heel significantly affected the postural adjustment that at TS condition was significantly smaller in forward displacement on the knee and the hip during ankle dorsiflexion and influenced to short the time taken at the forward movement to conduct STS movement than shown at FS and SS. Significant differences were also appeared in the parameter of task period and segmental body angle. These findings suggest that the differences way to achieve STS movement in some ways can contribute to decrease task period and to differ the pattern of motion that furthermore supports the identification in behaviometrics.

Keywords: behaviometrics, motion pattern, video acquitition.

1. INTRODUCTION

1.1 Behaviometrics system

Human can be identified through many biometrics such as face, iris, fingerprints etc. These physiological paramaters represented the attibutes of body shape. As the method to recognize human, biometrics focus on the attribute of intrinsic physical or behavioral traits. In information technology, in particular, biometrics is used as a form of acces control and management. However, the method to identify motion character of person is less in consideration due to differ the type of activity (Nixon, 2008). The term of biometrics which consider to analyze motion is behaviometrics (Zhang et al, 2007). Essentially, computer vision technique was used to deploy motion of the appeared object in the video screen. The sequences of images derived from frames represent to a set number which are unique to individual or similar tasks (Yang et al, 2008). The method to recognize human motion has showed the advantages which not shown in physiological parameters assesment that require data entry directly from the part of the body. In general, to derive the set numbers, human limbs have to defined at first. Video motion analysis then calculating the algorithm of visual tracking into the plot of motion.

1.2 Video Motion Capture

Behavioral features such as gait or body motion are more difficult to be disguised than facial or fingerprint features but understanding person's motion gives us the pattern of human movement clearly. Therefor, the difference in kinematics of the human limbs movement need to be detected for identification purposes. In addition, these features should be invariant to other factors such as tracked moving object and the background. Zhang (2007) showed that gait was unique behavioral characterisitc if all gait movements were considered. However, in general movement recognition settings, the input signals are image sequences taken by cameras (video motion capture). Observing that most human motion is influenced by anterior – posterior direction, in this study, the camera was set from the sagittal pane of the subject (Sriwarno et al, 2006). In the laboratory experiments, subjects were asked to conduct a simple movement from squatting to standing (STS). The proposed algorithm of behaviometrics assesment is outlined in Figure 1.

Through this simple research, the possibility to recognise people by the way of their motion giving us an alternative approach to determine human gait in general. Based on tracking result obtained from the model from the computer, sequences data can be used to apply the related field not only biometrics but more in the field of human factors, ergonomics, physiology and product design development.

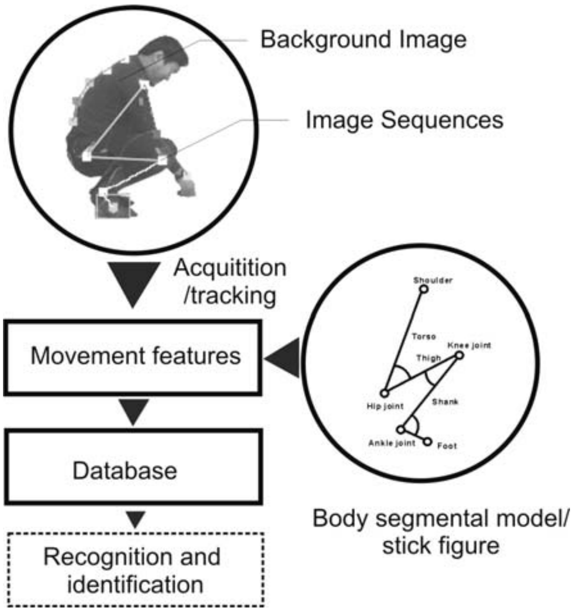

Figure 1. Outline of the proposed alghorithm

2. METHODS

2.1 Subjects

Eight healthy Indonesian males were participated in this study and reported to often performing deep squatting in their daily life. The data of average age (32.5±3.64 yrs), average height (168±3.68 cm), average weight (69.5±14.57 kg), average BMI (24.5 ±4.68), and average metatarsal joint angle (the angle between the heel to the metatarsal head to the floor level) about (24.3±11.63 deg) during tiptoe squatting were collected in the beginning of experiment. All subjects received an explanation prior to the experiment and gave written consent before participating in the study.

2.2 Protocol of experiment and task procedures

The STS movement were divided into three condition tasks on the basis of the different foot elevation. Subjects were asked to perform STS movement with eyes open and bare foot from the position of fully squatting (FS) which the foot elevation was 0 degree (entire foot fully contacted to the ground level) (Sriwarno, 2007), slope squatting (SS) which a 15 degrees of wedge was employed underneath the feet, and tiptoe squatting (ST) which subjects adopted tiptoe on the head of metatarsal joint therefore the foot elevation became higher than 15 degrees. Each trial was conducted in three times randomly with the rest of 1 min between the trials. All subjects practiced the trials before commencing collection data until the smooth movement sequences appeared in the data recording at the preferred or natural speed.

2.3 Kinematics measurement

The active markers (light emitting diode) were attached into the subject's anatomical location at the sagittal plane view. These included the acromion, the great trochanter (hip), the lateral epicondylus (knee), the lateral malleolus (ankle), and the fifth of metatarsal head as a representation of body landmark joints (Fig. 1) which similar to the study conducted by Fukuda (1999). The movements of all markers were recorded by the digital video camera at the sampling rate of 30 Hz. The video data were transformed and acquisitioned off line using the motion capture analysis software. The developed kinematics analysis (WINAnalize 1.3 Mikromak GmbH) was used to calculate the angles, the joint displacement, and the duration time of the forward and upward movement of each body joint from the marker's position. In the Figure 1 (right), three body joint angles were defined from the following: (1) hip joint (the angle between the line from the acromion to the hip to the knee), (2) knee joint (the angle between the line from the hip to the knee to the ankle) and (3) ankle joint (the angle from the line between the knee to the ankle to the fifth metatarsal head).

2.4 Data analysis

The parameters of kinematics measurement which was the change of the hip, the knee, and the ankle joint in the initial (average angle during preparation), maximum flexion and extension (average angle during STS movement), and maximum anterior and posterior of each joint during STS movement were calculated. The one-way ANOVA was employed to evaluate the difference between three condition tests by using StatView software. Tukey's test was used as a follow-up test for pair-wise comparison of means. Appeared significance is marked with (*).

3. RESULTS

Figure 2 shows a stick diagram of the representative subject reconstructed by the motion analysis program from the five markers placed on the body. As foot elevation increased, the hip and the knee movement pattern tend to move anteriorly during flexion phase. The STS movement in each squatting strategy showed the different postural adjustment that corresponded to the total time of the STS achievement. The mean of over all duration time remained less than 3 sec which FS, SS, and TS were 2.82 sec, 2.49 sec, and 2.36 sec. There was no significant difference between the squatting strategies of the rising to standing during upward movement in the extension phase. Differences existed among the squatting strategies during forward movement with at TS condition (0.021 sec) took significantly shorter ($p<0.05$) than at FS condition (0.53 sec).

ISSN: 1907-5022

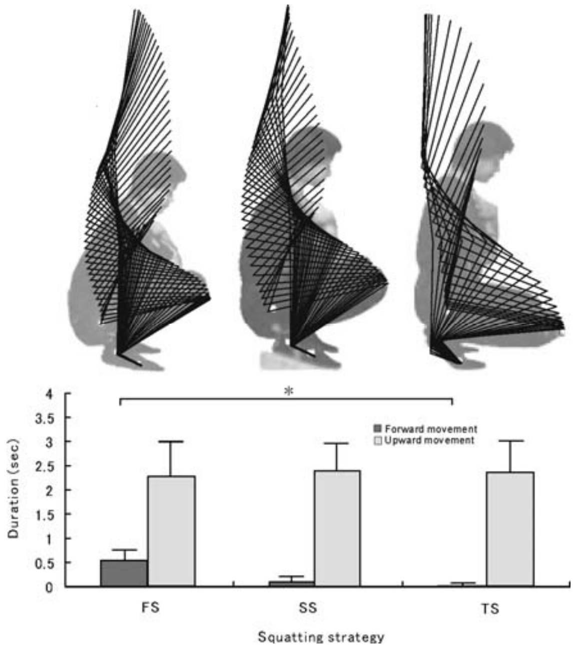

Figure 2. Stick figures of the three different STS movement (top) and the task period required in each movement

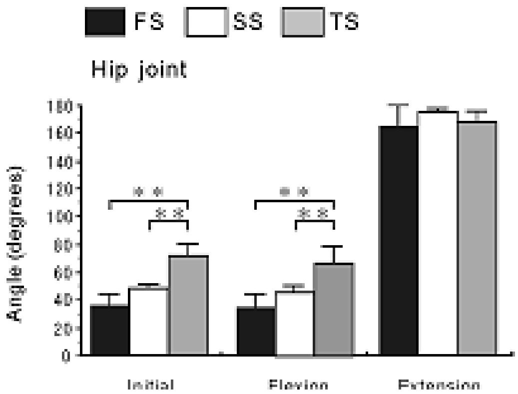

Figure 3. Hip joint flexion of three STS movements in three phases of motion

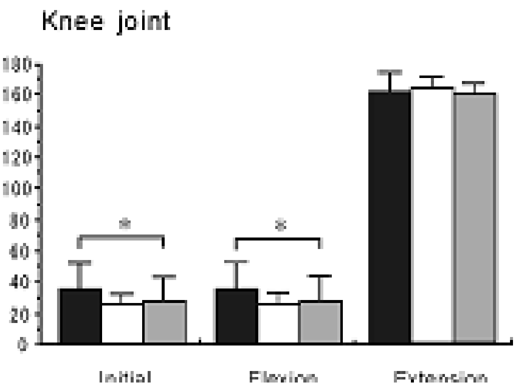

Figure 4. Knee joint flexion (degree) of three STS movements in three phases of motion

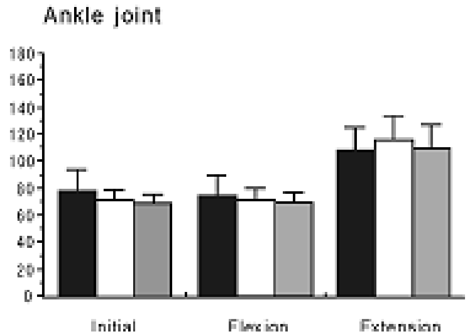

Figure 5. Ankle joint flexion (degree) of three STS movements in three phases of motion

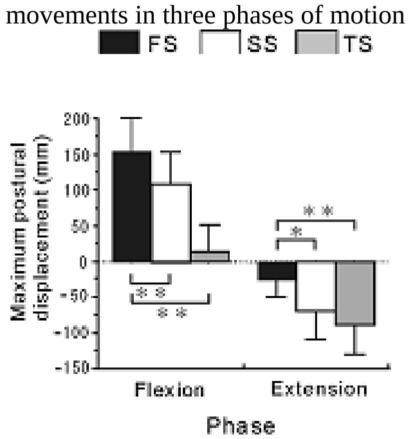

Figure 6. Displacement of hip joint in two phases of motion (flexion and extension)

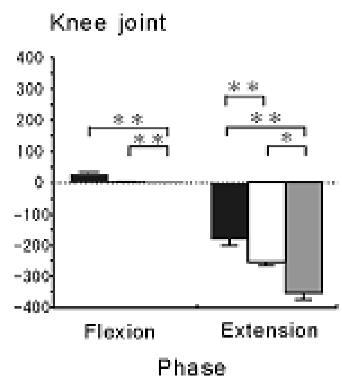

Figure 7. Displacement of knee joint (mm) in two phases of motion (flexion and extension)

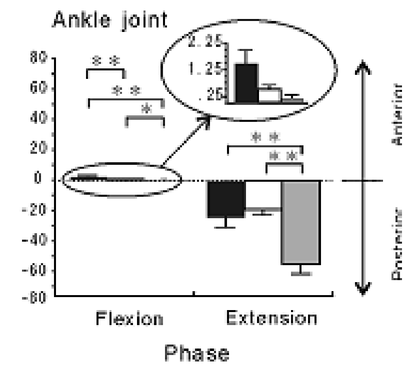

Figure 8. Displacement of ankle joint (mm) in two phases of motion (flexion and extension)

The average of the initial and the peak flexion angle of the hip joint (Fig. 3) significantly increased as the increase of the foot elevation at SS and ST ($p<0.01$). The significant decrease occurred when the condition shifted from FS to TS in the knee joint (Fig. 4) during initial and flexion ($p<0.05$). Although the ankle joint (Fig. 5) showed linearly decrease in the initial and the peak flexion when the foot elevation increased, the difference was not significant. No significant difference found when the hip, the knee, and the ankle joint positioned in the maximum extension although the small differences exhibited in the SS condition

As depicted in Figure 6, when the foot elevation increased, the mean displacement of the hip joint was detected smallest at the anterior movement that SS and ST condition were strongly significant to FS ($p<0.01$). The greatest displacement was observed in the knee (Fig. 7) and the ankle joint (Fig. 8) which the posterior displacement dominantly influenced the TS condition in comparison to FS ($p<0.01$). The anterior movement of the knee and the ankle joint during flexion phase at TS condition was observed significantly smaller than shown at FS and SS. The posterior displacement was showed inconsistent pattern that SS was the shortest distance (19.47 mm) whilst ST was significantly being the largest displacement (54.89 mm) to the other conditions ($p<0.01$).

4. DISCUSSION

In the present study, the assessment of kinematics based on video motion analysis and muscles activity during squatting to standing movement in the normal subjects has been clarified. The characteristics of STS movement found in this study was depend on the preparatory postural adjustment caused by the squatting strategy during initial which indicated that this condition is being critical during ascending. On the basis of resting position, it have found here a condition that buttocks were allowed to rest on the insufficient area of the upper calf region in deep squatting posture which can be compared to the sitting on the seat surface condition.

In my opinion, this condition was improvable by changing the squatting posture strategy regarding postural load reduction. As described in the subject's demographic data mentioned in the section 2.1, the mean of metatarsal joint angle at TS was 24.31 ± 11.63 degrees which meant higher than occurred at FS and SS therefore the increase of foot elevation primarily influenced the postural adjustment regarding stability equilibrium (Denchuan et al., 1998). It took shorter duration to achieve STS movement at TS condition than both FS and SS. However, the period to execute STS movement was strongly influenced by the time taken at the flexion phase which the subjects need to flex the hip, the knee, and the ankle joint therefore the body's centre of mass was transported forward within the feet. As foot elevation increased, anterior momentum of hip and knee joint was reduced and shortened the forward displacement therefore the total duration to standing from tiptoe squatting was minimum. This finding suggests that repositioning the foot elevation in preparatory STS movement could minimize the duration to meet the balance equilibrium before upward movement. Raising from the lower seat height, in this case the buttocks were lifted off from the some parts of the calf region, makes the movement phase more demanding due to propel power anterior shift (Fukuda et al, 1999; Galli et al, 2000).

The effect of a "lower seat height" shown at FS supported the previous investigation that hip joint was repositioned in the greatest flexion and caused the increase of velocity in order to stand raising. For those reasons, the squatting posture was improved from fully squatting to tiptoe squatting that allowed the heel to lift and the hip joint to extend. During vertical movement in the deep squatting, the event of upward movement was simply determined by the buttocks lift off as the initiation event when the knee joint onset to extend. Lifting the heel higher than FS position was known to bring the centre of mass shifted forward therefore the whole body were adjusted on the segmental linkage coordination. This postural adjustment contributed the critical balance movement stability which TS placed the centre of pressure within the narrow area of the base of support of metatarsal region during preparatory that increase the hip joint while knee joint decreased as a caused of the load increased in the thigh.

The small area of the base of support contributed to the imbalance of dynamic stabilization which influence the ability of STS movement. In the action of standing from squatting, short maximum forward shift and large displacement upward movement of the knee and the ankle joint as the postural adjustment at SS and TS condition suggested that the centre of mass has been already oriented within the base of support as the influence of the increasing foot elevation. Since forward movement was not appeared to generate upward propulsive force, the hip appeared to be more extended therefore the heel strike was sufficient to perform at TS and SS. The large displacement in the extension phase of the ankle joint posteriorly move to 54.89 mm which indicated that during balance stabilization the heel touched down the floor therefore the foot elevation was 0 degree at standing position. These findings suggest that the cycle of STS movement was found continue as a sequence of the ankle dorsiflexion followed by the extension of the knee and the hip joint. This mechanism seems to differ with the sit-to-stand movement from the chair showed discontinue from forward to upward movement as reported in the previous investigation due to the location of centre of body mass was for behind the feet base of support. Bringing the body forward cause the forward displacement longer than deep squatting and appeared as a horizontal sliding between the buttocks and the seat.

5. CONCLUSION

The experimental results demonstrated that the sagittal plane contains biometrics identification information. Other view point may also contains important movement features such as task period and the type of movement phase which may also be useful in recognition. The results of the present investigation suggest that by using the simple method to track the moving marks, the pattern of motion can be determined. In practical situation and clinical application for rehabilitation and therapy, the information from analysis of functional activities and the establishment of what is accepted baseline of ideal data of squat-to-stand is needed to provide the action to assist the disability of elderly (Flanagan et al, 2003), the task which required certain movement skills, impaired physical function patient (Fukae et al, 1998) or pregnant. Also raising to standing is an important functional task that may become difficult to execute in obese patient because the determinants factor of weight condition, muscle weakness, low back pain and the size of the abdominal circumference cause the disability to flex the hip joint deeply in deep squatting. The limitations of our study are noted. The small sample size may have influenced the outcome certainly studied with longer sample size are required to determine the clinical utility of the investigation here regarding behaviometrics database.

REFERENCES

Denchuan,. C, Manlai, Y. (1998). An ergonomics approach to public squatting-type toilet design. *Applied Ergonomics*, 29, 147-153.

Flanagan, S., Salem, G.J., Wang, M.Y., (2003) Squatting exercises in older adults: kinematic and kinetic comparisons. *Medical Science Sports Exercise*, 35, 635-643.

Fukae, A., Sato, H., Andrew, P.D. (1998). Pressure on the tibial plateau when standing from seated position. *Journal of Physical Therapy Science*, 10, 81-85.

Fukuda, K., Koto, A., Fukuchi, Y., (1999). Characteristic form of standing up from squatting in Miyoshi’s distal muscular dystrophy. *Clinical Neurology and Neurosurgery*, 101, 249-252.

Galli, M., Crivellini, M., Sibella, F., (2000). Sit-to-stand movement analysis in obese subjects. *International Journal of Obese*, 24, 1488-1492.

Nixon, M. (2008). Gait Biomterics. *Biometric Technology Today*.

Sriwarno, A.B., Shimomura, Y., Iwanaga, K., Katsuura, T. (2006). The evaluation of the effect of stool height alteration on workload of squatting postures performed by Indonesians with different body mass index (BMI). *Journal of Human Ergology*, 35, 238-246.

Yang, X., Zhou, Y., Zhang, T., Shu, G., Yang, J. (2008). Gait recognition based on dynamic region analysis. *Signal Processing*, 88, 2350-2356.

Zhang, R., Vogler, C., Metaxas, D. (2007). Human gait recognition at sagittal plane. *Image and Vision Computing*, 25, 321-330.