Evaluation of Gait Authentication using a Large-scale Inertial Gait Database

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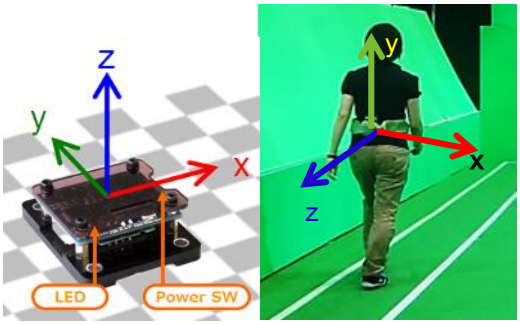
This report presents the very large inertial sensor-based gait database and its application to a statistically reliable performance evaluation for gait-based recognition problem. Whereas existing gait databases include at most a hundred subjects, we construct a much larger gait database for both accelerometer and gyroscope which includes 736 subjects (382 males and 354 females) with ages ranging from 2 to 78 years. Because a sufficiently large number of subjects for each gender and age group are included in this database, we can analyze the dependence of gait recognition performance on gender or age groups. The results with the latest existing recognition method provide several novel insights, such as the trade-off of gait recognition performance among age groups derived from the maturity of walking ability and physical strength. Moreover, the evaluation for the recognition performance improvement with a larger number of subjects was reliably confirmed in the experiments. As for sensor data type, acceleration is better than angular velocity for gait recognition performance. Compared to unnormalized distance, normalized distance works significantly better for angular velocity.



(a) IMU-Z (b) Sensor attachment

We collected the gait data of visitors in an exhibition during five days. We got the world largest database on inertial sensor-based gait. We captured 6D signal sequences from accelerometer and gyroscope in the IMU-Z sensor. After simple preprocessing to remove invalid data, we had a collection of 736 subjects (382 males and 354 females) with ages ranging from 2 to 78 years. Compared with the existing databases, the advantages of this database are as follows.

1) The number of subjects is approximately 7 times more than in the existing largest gait databases. This significantly improves the reliability of the gait recognition performance evaluation.
2) The male-to-female ratio is close to 1. This is a desirable property for more reliable performance evaluation of gait-based gender classification and for comparison of gait recognition performance between genders.
3) The subjects' ages are widely distributed from 2 to 78 years. In particular, the number of children is comparable to the number of adults. This provides more statistically reliable results on gait-based age group classification and difficulty level comparison of gait recognition among age groups.
4) 6D gait signal includes 3D acceleration and 3D angular velocity data captured at high frame rate is not only useful for gait recognition but also for understanding the walk motion.

To evaluate this large database, we apply recent four benchmark methods by Rong et al [1], Gafurov et al. [2], Derawi et al. [3], and Trung et al. [4]. Before evaluating, we carried out the experiment to select the best method for the proposed database and Trung et al. method was selected. Authentication performance was evaluated by Receiver Operating Characteristic (ROC) curve [5]. The ROC curve denotes a trade-off curve between a False Rejection Rate (FRR) and False Acceptance Rate (FAR) when the acceptance threshold is

changed by a receiver in personal authentication scenario. The Equal Error Rate (EER) where FRR and FAR are equal was also used to evaluate the performance. The lower the EER, the better the method performs.

The first evaluation result is the impact of the number of subjects. In this evaluation, we can see the advantage of a large number of subjects. We randomly selected 20 subsets of 100 subjects from the whole database and compute the standard deviation for each value of FRR. The result showed that the actual standard deviation range for a subset of 100 subjects was very close to the theoretical deviation presented by [6]. The theory also says that theoretical deviation of a large database is much smaller than that of a small database. For example at 4% FAR, the standard deviation is reduced from 1.9% to 0.7% if the whole proposed database is used instead of a subset of 100 subjects. This indicates that the accuracy of the performance evaluation increases approximately three fold.

The second evaluation result is impact of sensor type and distance function. In this section, we compared the accuracy for using accelerometer and gyroscope, and also explored a proper distance measure for each sensor. Normalized distances based on NCC and Tanimoto distance were compared with the unnormalized distances, L1 norm (Manhattan distance) and L2 norm (Euclidean distance). In the evaluation, accelerometer produces a better recognition performance than the gyroscope. Normalized distance measures (NCC and Tanimoto) work better than unnormalized distance measures (L1 and L2 norms) for the gyroscope's data. Meanwhile, we cannot see a significant difference among all these distance functions for the acceleration data.

The third evaluation result is impact of gender. In this evaluation, recognition performance among females is better than that among males. This evaluation is reliable since the ROCs curves with their deviation boundaries are separable with our database.

Finally, impact of age groups is evaluated. We compare the recognition performance of age groups: under 9, 10s, 20s, 30s, 40s, and over 50. The gait recognition performance for the child age groups is worse than that for the other age groups, and this gradually improves with older groups up to 40 years. This result is understandable because the intra-subject gait fluctuation for children is relatively larger due to the immaturity of their walking skills. On the other hand, fluctuation in gait for adults is quite small since adults have established their own walking style; in other words, they have a stable gait pattern. On the other hand, the gait recognition performance for groups over 50 years old declines as the subjects become older. This degradation in performance is inferred from the fact that physical strength generally declines as the subject grows older and hence, the gait tends to fluctuate more. Consequently, gait recognition performance of subjects in their forties is regarded as a trade-off between the maturity of walking ability and physical strength

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