Poster: An Improved Approach to Gesture-Based Authentication for Mobile Devices

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ABSTRACT
We present a gesture-based authentication method for mobile devices using acceleration and angular rate data. Using data gathered from 17 test subjects we analyzed how the choice of gesture, classifier, extracted features and dimensionality reduction affects the authentication accuracy. The results enabled us to determine an optimal configuration of these variables for authentication with an accuracy of 99.94%. We show that gesture-based authentication is feasible on mobile devices, and can be improved by using a gyroscope in addition to the accelerometer presently found on many devices.

Categories and Subject Descriptors
H.5.2 Information interfaces and presentation: Miscellaneous.

General Terms
Algorithms, Experimentation, Languages, Measurement, Security

Keywords
Mobile Devices, Acceleration Sensor, Gyroscope, Authentication, Machine Learning

1. INTRODUCTION
Mobile phones are becoming a ubiquitous computing platform as their number increases throughout the world. Likewise, the amount of sensitive personal data stored on mobile devices is steadily rising. Furthermore, an increasing amount of people use mobile internet for applications which are in need of secure authentication. Currently, the most popular method for user authentication on mobile devices is the entry of a PIN. This method is not only potentially unsecure but also cumbersome as it requires remembering an abstract artefact.

Various schemes have been proposed to improve mobile authentication. In this paper, we focus on mobile user authentication through gesture input. Gestures for authentication are entered by the user by moving the mobile device in the air. The resulting acceleration forces and rates of rotation are measured by a sensor embedded in the mobile device. Authentication through gestures has the advantage that for most users remembering movements is easier than remembering abstract concepts like PINs. The ability to measure biometric characteristics has the potential to make gesture-based authentication more secure than PIN-only authentication due to the fact that knowledge of the gesture does not guarantee potential attackers to access the system. In contrast to previous work [2, 4] which relies solely on data from a 3-axis accelerometer, this work also uses data obtained by a gyroscope.

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2. DATA CAPTURE AND FEATURES
We used the SHAKE SK6 sensor package [1], which can record three-dimensional acceleration and angular rate signals in three axes. We collected data for eleven different gestures (see Fig. 1). The gestures we chose were partially inspired by previous work in the domain of gesture recognition [4, 5]. We collected a total of 5610 gesture inputs containing acceleration and angular rate data from 17 participants.

We extracted four features from the six components of the acceleration and angular rate data: mean, standard deviation, energy and pair wise correlation (15 attributes). Furthermore, we added the gesture duration as a feature. The usefulness of these features has been demonstrated in work by Ravi et al. [3]. Thus, our feature set contains 34 attributes in total. For each gesture entry, one feature vector was generated. Additionally, we used the principal component analysis (PCA) to transform the data from a high dimensional space into one with fewer dimensions.

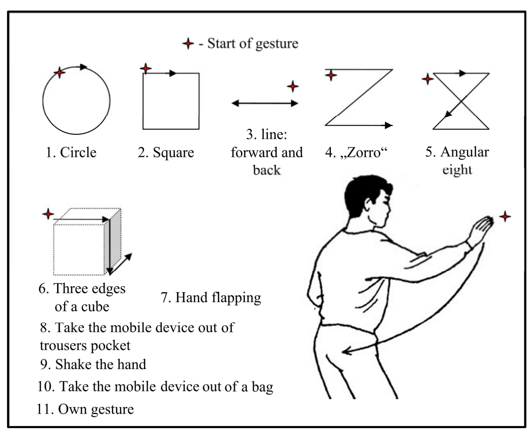

Figure 1: Gestures entered by users.

3. AUTHENTICATION RESULTS
We evaluated the performance of the following 5 classifiers using MatLab: quadratic Bayes classifier (QBC), decision tree, k-nearest neighbours (kNN), Parzen windows and support vector machines (SVM). To calculate the accuracy for configurations that are analyzed, we conducted a 5-fold cross-validation for each of the classifiers and for each participant as legitimate user.

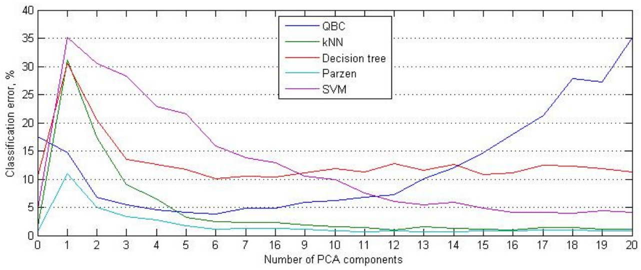

Figure 2: Effect of dimensionality reduction on the classification error.

We wanted to find features among the 34 selected ones that are less important than the others. Therefore, we ran the five classifiers on the data of gesture ‘line’ (1) with one feature removed at a time. The energy feature turned out to be most futile for all classifiers except for QBC.

We performed a series of tests to find out if feature reduction using PCA is meaningful for the classification performance and also to determine what number of PCA components should be chosen to obtain the best classification result. We compared the recognition errors for feature vectors reduced by PCA with dimensions from 1 to 20. For comparison we also calculated the recognition errors with non-reduced feature vectors. Again, we ran the five classifiers on gesture ’line’ (1). Figure 2 shows the results of this test. In this figure, 0 corresponds to the case without using PCA. It can be seen, that the classification errors decrease for all classifiers except the QBC and decision tree as the number of PCA components increases. In case of QBC the best results are achieved by using PCA with 6 components.

In order to find out how the choice of the gesture can affect the classification rate we ran the five classifiers for each gesture and used a 5-fold cross-validation. Figure 3 shows the classification rate averaged over the 17 participants for each gesture and all classifiers. The results indicate that for all classifiers, especially for Parzen, kNN and SVM the classification rate is relatively high using gestures (1), (2), (3), (4), (5), (6) and (11). We can interpret the results for gesture selection in the following way: gestures (1) - (6) are geometrical figures, which participants can easily remember and enter as identical as possible during each trial. Gestures of typical everyday behaviour (7)-(10) are harder to repeat. The last gesture (11) was freely chosen by the participants. Therefore, they are different over the participants which lead to problems evaluating them.

Furthermore, the results must be seen in the context of our population size (17 participants) and also that for every participant 16 (negative) datasets by the other participants were trained into the classifier’s model. The question how this result can be made to scale for larger population sizes remains to be answered.

4. CONCLUSION AND FUTURE WORK

We presented an approach to authenticate users of mobile devices based on three-dimensional gestures. To this, we used data from an accelerometer and a gyroscope. The data is pre-processed to extract features and create feature vectors for each gesture entry. To reduce the dimensionality of the feature vectors, we applied PCA.

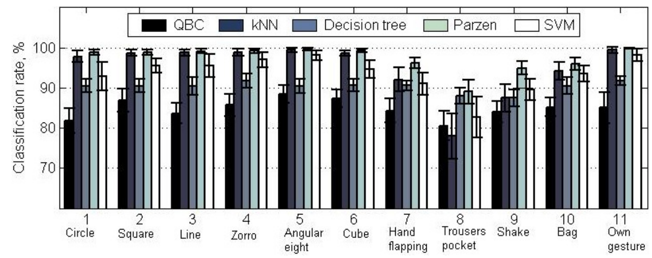

Figure 3: Correct classification rate by classifier and gesture.

We compared the results of five classifiers using different dimensionalities of PCA and also identified relevant features by analyzing the classification accuracy when features were selectively omitted. Furthermore, we evaluated how the choice of the gesture impacts the authentication’s error rate. The results show that the authentication based on three-dimensional gestures is feasible. We obtained the best results using the Parzen windows classifier with the gesture ‘angular eight’ (5). This combination yielded an accuracy of 99.94%. Additionally, we observed that all the geometric gestures (1)-(6) and also the user-selected gesture (11) performed better than gestures resembling everyday movements (7)-(10). The higher authentication accuracy which we obtained in contrast to previous work may be due to the addition of the gyroscope. This indicates that gyroscopes should be incorporated in future mobile devices that aim to make use of gesture-based authentication.

Based on these results, we plan to further evaluate the user authentication based on gesture (11) with more realistic test conditions. Furthermore, we want to evaluate the performance of more sophisticated classifiers such as Hidden Markov Models and Neural Networks. Even though the features we used provided promising results, there is still space for improvement and therefore, we will further explore feature extraction and try out different feature vectors. One possible idea is to use multiple feature vectors for a single gesture instance.

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