Communicating with the Deaf and Hard of Hearing through Automatic Arabic Sign Language Translator

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Abstract. The needs of persons with disabilities are still being undermined even though persons with disabilities have proven to be productive members of the community when given the right education, support, and tools. Assistive devices are being designed, developed, and sold to provide persons with disabilities the tools to be able to become productive members. With the advent of new technologies, software development has also concentrated on the needs of persons with disabilities. With the widespread of software’s especially on mobile devices, researchers can now develop tools for the community to communicate, work, collaborate and deal normally with persons with disabilities. In this paper, an automatic Artificial Intelligence (AI) based Arabic Sign Language Translator is proposed. The system is able to capture the picture of the sign language performed by a person who is deaf or hard of hearing and provide real-time translation of the hand gestures. Novel features are proposed to be extracted from the images to be input to the four different classifiers namely; Random Forest (RF), Bagging classifier, Regression, and Random Tree (RT). The result shows that the Random Forest classifier with proposed extract features performs better by achieving 92.15% accuracy as compared using input image directly with classifiers.

Keywords: Arabic Sign Language Recognition, Communicating with the Deaf, Random Forest; Geometric Features, Sign Language Translation.

1. Introduction

Assistive systems for persons with disabilities is a field of study that is evolving and with the advent of new technologies these assistive devices are becoming more sophisticated to ease the life of those who need them. The iPhone technologies for the blind and visually impaired is a great example how new technologies have been integrated to ease the life of persons with disabilities [1]. 15% of the world population are within the bracket of persons with disabilities according to United Nations statistics [2]. The large population of persons with disabilities makes it a must for all governments, researchers and organization to support the persons with disabilities so that they become contributing members in the
community. 360 million of those with disabilities are individual who suffer from deafness or hard of hearing problems [2]. With the advent of new technologies, a whole field of software development now concentrate on developing applications and programs that will serve as assistive systems for persons with disabilities. However, the with software, systems can also be developed to assist the community to communicate with, work with, collaborate with, and deal with persons with disabilities. For example, even though a person who is deaf and hard of hearing has a supporting community around him/her that have learned sign language, eventually the person will move out of their comfort zone to deal with people who do not know how to use sign language. In such cases, a system should be developed to assist those individuals to communicate with ease. This can be generalized not to software’s that will assist the community to deal with the deaf but to all persons with disabilities. The aim of this study is to design an Automatic AI-Based Arabic Sign Language translator that can be used by the community to communicate with persons who are deaf and hard of hearing. There have been systems proposed for the British Sign Language and American Sign Language, however, Arabic Sign language has not received the same attention. This provides a huge opportunity for researchers sign especially that Arabic is the native language for nearly 300 million people in 20 difference countries across the Middle East and North Africa (MENA) [3]. The vast population of Arabic Speakers with the population of those with disabilities and those who are deaf and hard of hearing entails that more attention should be given to the Arabic Sign Language. Devices acting as translators or interpreters in the communication process between the persons who are deaf and hard of hearing and the community is a target that can be eventually reached so that the device can translate both ways (read the sign language from the person who is deaf to translate it to the other person and translate oral words or written words into sign language so that it can be seen by the person who is deaf). The research falls in an area depicted Human Computer Interaction (HCI) and is thus implemented in one of two ways; image based or sensor based [4-6]. For ease of use and low overhead, image based systems can be achieved easily using pure software whereas sensor based will require hardware and software thus increasing cost and making the system not readily available for all. Even though sensor based is more reliable, yet new Artificial Intelligence based algorithms are increasing the accuracy and reliability of image based techniques as well. Both supervised and unsupervised machine learning algorithms have undergone recent developments that make the efforts in image recognition systems very accurate. The novelty of the proposed system is two folds; according to the authors knowledge the feature extracted from the Arabic Sign Language are novel and have not been applied to the Arabic Sign language before; and second the proposed translator is one few proposed devices that propose automatic image recognition of Arabic Sign Language alphabets.

The proposed translator however has several limitations; first it is only proposed for Arabic Sign Language alphabets and not for words, finger writing, and other gestures, second, the dataset used has a limited number of images, third, the process of translating oral and written words to sign language is still not integrated.

2. Literature Review
Supervised and unsupervised learning algorithms are used for image based techniques. With image based techniques either feature extraction is used where features are hand-picked and engineered from images to be input into classifiers, or deep learning algorithms are used where features are automatically extracted to be used for classification. The feature extraction methods rely heavily on the extracted features for the classification accuracy. The feature extraction methods if carefully engineered can produce classification accuracy that are extremely high. The deep learning methods on the other hand, the features are automatically extracted in a hierarchical manner which reduces the problem complexity. Some research results indicate that deep learning achieves better accuracy while others show the feature based algorithms compete hand in hand with the deep learning algorithms. In all case, the research is continuous in to achieve the best classification accuracy according to the application under consideration [7-10]. Applications for persons with disabilities has been the target for many research projects worldwide. In [11], the authors propose a home monitoring rehabilitation system equipped with sensors and they propose the use of feature extraction techniques for motion and biophysical data. Their system also
monitors vitals for the person during the rehabilitation period. In [12-13], the authors propose an automatic medication and health monitoring systems for people with disabilities and the elderly that integrate Mobile applications, Internet of Things (IoT), and AI-based algorithms. In [14-15], the authors propose systems for hands free mouse control using head gestures for person with disabilities with motor skills disabilities. Both systems using sensors were proven to be effective in the control of the mouse and relative applications using head gestures along.

In [16], the authors propose the use of feature based extraction of speech signals to both identify mild to moderate disabilities and also the use of particle swarm optimization to select the most optimized features that will lead to better classification. In [17], the authors propose an IoT real time system for persons with disabilities that monitors their voice activity and alerts in case of any abnormalities. The authors extract speech features from the Discrete Cosine Transform (DCT) and employ the use of Support Vector Machine (SVM) classifier. Along with Raspberry Pi and Cloud computing they propose a real time system. They achieved an accuracy of 67.9% for real time analysis. In [18], the author proposed a system to assist the deaf and hard of hearing to recognize familiar sounds around them and convert them visuals that the deaf and hard of hearing can distinguish. For example, a doorbell sound or cautionary words are converted to visual signals. This requires a system that can recognize and classify these sound alerts using ANNs. They were able to achieve 90% accuracy. In [19], the authors provide a review of sign language recognition research and methodologies. They try to identify the best approaches developed by researchers to design sign language recognition systems. The review is comprehensive and provide a basis for new researchers to start where others ended. In [20], the authors propose a navigation system for deaf drivers. The system is able recognize voice from current available navigation system and translates the voice messages to vibrotactile stimulus that can be understood by deaf drivers. For their proposed system they extracted 13 element feature vectors from the voice stream and classified them into 6 categories for navigation instructions. They used K-nearest Neighbour Classifier (KNN) and achieved 99.05% accuracy. In [21], the authors propose a system for sign language recognition, Arabic Sign Language Recognition since the system is proposed for Quranic Recitation. The authors propose Eigen Values and Eigen Vectors for extracted features and the use of Back Propagation Neural Networks for Classification. In [22], the authors propose a system that converts hand gestures to voice by capturing the motion of the hand gestures. This will allow normal people to communicate with the deaf and mute people. The system was based on feature extraction and the authors extracted different features such as centroid, binary area, angle calculation, peak calculation, finger region, thumb detection, and others. They utilized NumPy environment for the feature extraction and fed the output as input to a 2-Dimensional Neural Network. They were able to achieve 86% accuracy.

In [23], the authors propose an automatic system for one-handed gesture of Russian Sign Language Recognition. Their proposed system works for online real time and offline to recognize 44 classes of gestures with 70% accuracy. Deep Learning approaches were used, and they integrated the Kinect for capturing the hand gestures. In [24], the authors propose full duplex communication system between person who are deaf and hard of hearing with normal indvuiual. The system is able to translate sign language to voice and text and to translate voice and text to sign language. Their proposed system goes through the phases of preprocessing, segmentation, feature extraction, and finally classification. In [25], the authors propose a Tamil sign language recognition system using fingers and palm gestures. Features extraction is done using adaptive thresholding techniques. With sequential model using as a classifier.

3. Proposed System
The proposed system follows similar steps as used in other feature extraction based methods and consist of the three main stages: Stage one is the preprocessing stage of the Arabic Sign Language Alphabet Hand Gesture Images. This preprocessing stage usually consists of segmentation, noise removal, size normalization, binarization and centering the image. The second stage is the most important stage and contains the novelty of the work in which feature extraction is done. In the second stage, hand selected and engineered features are chosen based on the application and in this case the recognition and classification of the Arabic Sign Language Alphabet hand gestures. In this paper, the novelty in extracting 40 local feature that provide the basis for the recognition of Arabic Sign Language Alphabet hand gestures are detailed. The finale stage consists of applying different classifiers to recognize the
Arabic Sign Language Alphabet hand gestures and to verify the accuracy of the proposed method. Within the third stage, some steps such as feature reduction, testing and training can be observed.

3.1. Experimental Data
The newly build dataset consists of 54000 RGB images representing 32 different Arabic Sign Language (ArSL) symbols [26]. The dataset was collected over 40 different persons of varying age, gender and ethnicity with a standard white background. The images were pre-processed to make them suitable for classification. RGB images are provided within the dataset with various dimensions which requires preprocessing before use. 80% of the data was used for training while 20% was used for testing. The 80% used for training was partitioned into 20% of the 80% for validation while the rest was used for training. 32 classes represent the Arabic sign Language alphabets and were labelled from 0-31 as shown in Fig. 1.

![Figure 1. Representation of the Arabic Sign Language for Arabic Alphabets](image)

3.2. Features Extraction Stage
The feature extraction stage consists of carefully extracting features from the images that would produce the best results. As mentioned above, the extraction of features is hand engineered to produce the best classification and recognition results. To start where others finished, a thorough review of literature was done in order to engineer the best features for the particular application of Arabic Sign Language Alphabet recognition. Thus, after careful review and due the complexity of this particular problem, it was decided to focus on local structural features rather than the global structural features.

Following is the list of the proposed geometric features extraction from each Arabic sign language images after converting them into binary images based on the automatic optimized threshold method.

- Feature 1: Area which based on the total white pixels.
- Feature 2-3: Vertically maximum and minimum number of continuous connected white pixels.
- Feature 4-5: Horizontally maximum and minimum number of continuous connected white pixels.
• Feature 6-9: Vertically and Horizontally maximum starting and ending location for x-axis and y-axis.
• Feature 10-13: Vertically and Horizontally minimum starting and ending location for x-axis and y-axis.
• Feature 14-15: Centroid x-axis and y-axis values of Arabic sign language image.
• Feature 16: Total circumference value of the binary image based on total white pixels.
• Feature 17-18: Vertically difference between maximum and minimum continuous connected white pixels based on the Feature 2-3.
• Feature 19-20: Horizontally difference between maximum and minimum continuous connected white pixels based on the Feature 4-5.
• Feature 21: Ratio between number of white pixels in the upper half and bottom of the image (Horizontally).
• Feature 22: Ratio between number of white pixels in the left half and right of the image (Vertically).
• Feature 23: Total number of edges in the binary image.
• Feature 24: Roundness of binary image based on the value in between 0 and 1.
• Feature 25-40: Total number of white pixels in each segment of the image by dividing the image in to 16 segments (4 × 4).

3.3. Classification Stage
Different classifiers are tested using the extracted features and based on the experimental methods, best performing four classifiers are chosen named Random Forest, Bagging Classifier, Classification through Regression, and Random Trees. This section briefly describes the classification methods used in this paper. For further details, readers may refer to [27, 28].
Model trees are basically binary decision trees that are produced in two steps; firstly, creating an ordinary decision tree and then pruning the subtrees and substituting them with linear regression functions where required. Classification and regression trees are a modest non-parametric regression method. Their main trait is that all predictor variables are recursively split into a different collection of groups. They gained popularity because of their simplicity and easy understanding of the obtained results. Random trees are an ensemble of tree predictors.
The main motivation for the ensemble approaches is to use a group of classification or regression trees for the final classification or prediction, instead of depending on a single tree. Bagging and random forests are two different methods to build these collections of trees.
Bagging classifier is a traditional ensemble approach that uses bootstrap sampling to replicate the training dataset. The bootstrapped samples are then used for forming many variants of a predictor. In classification problems, the outcome of the majority class predicted by the individual predictors. This method improves accuracy, especially if changing training data makes a significant shift in the outcome.
Random forest is an improvement of bagging that can enhance the variable determination process by randomly restricting the available set of predictor variables. Because of the random restrictions on decision variables, the trees may become even more distinct. The main parameters include the number of decision trees and the number of predictor variables used for the split decision. As evident random forest naturally supports multi-class classification. Similar to bagging and random forests allow the softening of firm decision boundaries.

4. Results
The data was divided into 80% for training & validation, and 20% for testing. Out of the 80% for training and validation, 20% was used for validation while the rest was used for training. Experiments are performed using the proposed extract 40 features as well as using the original image pixel values by considering it as features. Table 1 shows the average recognition accuracy of the various classifiers using the whole image as features. The whole image features include both local and global features with a total of 32×32=1024 different features.
Four different classifiers were used in the study with 6 metric measurement to show the performance of the classifiers. From Table 1, it can be observed that Random Forest (RF) achieved the best recognition accuracy of 89.65% and precision of 89.7%. Other metrics such as Recall 89.7%, F-measure 89.7%, ROC 89.3% and PRC 98.6% showed that RF is the classifier that achieved the best results in the recognition of the Arabic Sign Language Alphabets. Random Tree (RT) on the other hand achieved the worst recognition accuracy using the whole image as features. RT achieved an accuracy of 72.91%, precision of 73%, Recall of 72.9%, F-measure of 72.9%, ROC of 72.1%, and PRC of 86%. Table 1 shows the performance of the four classifiers in descending order.

Table 1. Performance evolution using Sign language image as features with different classifiers

| Classification Method      | Accuracy | Precision | Recall | F-Measure | ROC   | PRC   |
|---------------------------|----------|-----------|--------|-----------|-------|-------|
| Random Forest             | 89.65%   | 89.70%    | 89.70% | 89.70%    | 89.30%| 98.60%|
| Bagging Classifier        | 81.16%   | 81.20%    | 81.20% | 81.10%    | 80.60%| 97.40%|
| Classification by Regression | 72.59%   | 72.70%    | 72.60% | 72.60%    | 71.70%| 94.90%|
| Random Tree               | 72.91%   | 73.00%    | 72.90% | 72.90%    | 72.10%| 86.00%|

Taking the 40-hand engineered extracted features proposed in this work and applying them to the four classifiers produced the results shown in Table 2. It also shows that Random Forest (RF) achieved the best recognition accuracy of 92.15% with precision of 96.24%. Other metrics were also higher for the RF with Recall of 96.92%, F-Measure 96.58%, ROC 99.92%, and PRC 99.06%. This is significantly higher than the accuracy achieved by using the whole image as features. In fact, using the 40 hand selected features, the accuracy was increased by 2.5%.

Table 2. Average Performance Evolution using Proposed 40 Features with Different Classifiers

|       | Accuracy | Precision | Recall | F-Measure | ROC   | PRC   |
|-------|----------|-----------|--------|-----------|-------|-------|
| RF    | 92.15%   | 96.24%    | 96.92% | 96.58%    | 99.92%| 99.06%|
| BC    | 87.63%   | 88.20%    | 87.60% | 87.80%    | 98.40%| 92.30%|
| CF    | 82.57%   | 83.20%    | 82.60% | 82.70%    | 97.30%| 86.90%|
| RT    | 80.87%   | 81.40%    | 80.90% | 81.00%    | 92.50%| 74.20%|

Table 2 also shows the Random Tree is still achieving the worst classification and recognition accuracy of 80.87% and precision of 81.4%. But still even with RT using the proposed 40 selected features, the accuracy was increased by 7.96% as compared with using the whole image as features. The rest of the metrics for RT are reported as Recall 80.9%, F-measure 81%, ROC 92.5%, and PRC 74.2%. Table 2 again list all the classifiers according to their performance in descending order.

Fig. 2 shows graphically the performance of the four classifiers; Random Forest, Bagging Classifier, Regression, and Random Tree. The figure clearly shows that Random Forest (RF) achieves the best precision results among the four classifiers and Random Tree is achieving the worst results. The results in Fig. 1 are based on the use of the proposed hand selected 40 features.
Fig. 2. Comparison of different classifiers results using proposed 40 features

Fig. 3 shows the confusion matrix of the RF classifier using the 40 proposed features. The confusion matrix shows what Arabic Sign Language signs are confused with others and the false classification rate of the various signs. It can be observed that the sign for “Dha” is confused with “Ta”. It can also be observed that the sign “Ya” is confused with most other signs and is somewhat problematic. Overall, the proposed method led to the reduction of confusion between the various Arabic Sign Language hand gestures which has led to greater precision and thus accuracy. All in all, the results presented in this work outperformed similar techniques from previous literature.

5. Discussions

The Arabic Sign Language image recognition has been given little attention compared with the American and British sign language hand gestures. In this work, a feature extraction based method is proposed in which 40 hand selected local features are used as input to the classification techniques used in the work. Four classifiers have been used namely, Random Forest (RF), Bagging Classifier,
Regression, and Random Tree. It was shown that using the 40 extracted features, the precision and accuracy were increased as compared to taking the complete image with all local and global features. Whole image produces a total 1024 features which increase the computational complexity and computation time, while 40 features reduce the computational complexity and computation time drastically. Computation time and complexity is not shown in this work because the aim of the work is to show that using the 40 selected extracted features produces better precision and accuracy. The results showed that Random Forest (RF) produced the best average precision and accuracy followed by Bagging then regression. Random Tree (RT) showed the least average performance in all metrics including precision and accuracy. However, all classifiers produced better results with the use of the 40 features as compared to the complete image as features. The Arabic Sign Language Translator even at this rate of accuracy and precision can prove very helpful as a communication means between the deaf & mute with individuals not suffering from any disability or individuals suffering from different disabilities.

6. Conclusion

Feature based techniques have been proven as an excellent tool in image recognition especially when features are selected carefully and scientifically to increase the accuracy and precision of the classification and recognition process. In this paper, it was shown that using 40 hand selected local features produces better accuracy and precision compared with using the whole image as features. In addition, the results obtained in this work outperform similar techniques published in previous literature. The goal of this research is to have an AI-based Automatic Arabic Sign Language Translator. To do so, the classification and recognition accuracy should keep improving until it is as close to 100% as possible. Thus, future work will include more detailed feature extraction methods that will increase the accuracy and precision. More classifiers will also be considered in future work. Work will also include the use of new deep learning techniques such as Deep Residual Networks to increase the accuracy and precision.

7. References

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