Hand Recognition Using Implicit Polynomials and Geometric Features

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Abstract. Person identification and verification using biometric methods is getting more and more important in today's information society; resulting in increased utilization of systems that combine high security and ease of use. Hand recognition is a promising biometric that is being used in low-level security applications for several years. In this work, implicit polynomials, which have proven to be very successful in object modeling and recognition, have been proposed for recognizing hand shapes and the results are compared with existing methods.

1. Introduction

As the personal and institutional security requirements increase, a person has to remember lots of passwords, pin numbers, account numbers, voice mail access numbers and other security codes. In the future, biometric systems will take the place of this concept since it is more convenient and reliable. Trying to come up with a all-purpose, or at least multi-purpose, personal identifier is what the art and science of biometrics is all about. A broad variety of physical characteristics are now being tested to determine the potential accuracy and ultimate consumer acceptance of their biometric measurement as personal identification standards. Up to now, biometric properties like fingerprint, face, voice, handwriting and iris were the subjects of many research efforts and used in different types of identification & verification systems. But the main reason of increased interest in this research area is that as the technology develops, these kinds of systems are more likely to run on the personal devices such as mobile phones and laptops [3].

In many access control systems like border control, personnel follow-up**,** important point is verification rather than identification. To protect the individual, verification systems are more suitable than highly distinctive biometric systems (iris, fingerprint) [3,7]. Hand recognition systems are very appropriate for these purposes, because they do not cause anxiety like fingerprint and iris systems. People's ease of acceptance due to their convenience, and their easy and cheap setup are the major superiorities of hand geometry based recognition systems to other systems.

There are many hand recognition systems available, and new algorithms were proposed recently giving better performance. Most of these methods rely mainly on geometric features and use the same logic for feature extraction. In this paper, we propose a new method for recognizing hand shape using implicit polynomials. The performance of the proposed system will be compared with existing methods and a way to combining geometric features with the invariants calculated from implicit polynomial fits of the hand will be studied.

2. Implicit Polynomials

Implicit polynomial 2D curves and 3D surfaces are potentially among the most useful object and data representations for use in computer vision and image analysis because of their interpolation property, Euclidean and affine invariants, as well as their ability to represent complicated objects. There have been great improvements concerning implicit polynomials with its increased use during the late 80's and early 90's [2, 5, 10]. Recently, new robust and consistent fitting methods like 3L fitting, gradient-one fitting, Fourier fitting have been introduced [6,11], making them feasible for real-time applications for object recognition tasks.

The implicit polynomial model is given as:

$$f_n(x,y) = \sum_{0 \le i,j;i+j \le n} a_{ij} x^i y^j = a_{00} + a_{10}x + a_{01}y + a_{20}x^2 + a_{11}xy + a_{02}y^2 + \ldots + \quad \textbf{(1)}$$

An implicit polynomial can be completely characterized by its coefficient vector:

$$\left[a_{n0}, a_{n-1,1}, a_{n-2,2}, \ldots a_{0n}, a_{n-1,0}, a_{n-2,1}, \ldots a_{0,n-1}, a_{n-2,0}, \ldots a_{0,n-2}, \ldots a_{10}, a_{01}, a_{00}\right] \Leftrightarrow f_n(x,y) \quad \textbf{(2)}$$

An implicit polynomial curve is said to represent an object

$$\Gamma_0 = \left\{(x_i, y_i) \mid i = 1, \ldots, K\right\} \quad \textbf{(3)}$$

if every point of the shape Γ_0 is in the zero set of the implicit polynomial

$$Z(f) = \left\{(x,y) \mid f(x,y) = 0\right\} \quad \textbf{(4)}$$

The zero set of an implicit polynomial fitted to the data will usually be close to the points of Γ_0 but cannot contain all of them.

The most important and the fundamental problem in implicit polynomials is the fitting problem, namely to find the implicit polynomial function f(x,y), or the corresponding coefficient vector that best represents the object. The fitting procedure has to be robust, which means a small amount of change in the data should not cause a relatively huge amount of change in the coefficients of the fitted implicit polynomial. Traditional fitting methods such as least squares fitting lacked this property, and the slightest change in data set caused dramatic differences in resulting coefficients. New algorithms such as 3L fitting [6], gradient-one fitting [9] and Fourier fitting [9] have this desirable character, enabling us to use implicit polynomials for object recognition tasks in a reliable manner.

The main advantage of implicit polynomials for recognition is the existence of algebraic invariants, which are functions of the polynomial coefficients that do not change after a coordinate transformation. The algebraic invariants that are found by Civi [2] and Keren [4] are global invariants and are expressed as simple explicit functions of the coefficients. Their performance have been tested with different complicated objects and they were found to be very successful in object recognition tasks even in the presence of noise, and missing data [12].

3. Methodology

Despite the fact that commercial systems for hand recognition exist in the market, there aren’t many and detailed studies on this field in the literature. However due to the reasons explained above, new methods have been proposed recently [1,3,8]. All of the methods proposed use various geometric features of hand (width height and length of the fingers, hand size, height profile, etc.). In our study, we tried to improve the success of the former methods by using implicit polynomials to model the fingers.

Initially preliminary work was performed on the sample database that has been downloaded from [1], (including eight images from nine persons) and tried our algorithm on these images, which gave a 98% of success in identification, encouraging us for future work. We then formed our own hand database by taking 30 images from 28 people. We used backlighting in order to take robust images independent of lighting conditions. We did not use fixation pegs as the methods we referenced employ; and did not constrain users; the only requirements were to place hands in the backlighted area and not to combine fingers. Our main motivation in doing so was the high performance of algebraic invariants independent of scaling and rotation. For preprocessing, a LoG edge detector was applied to the acquired images and then images were enhanced to obtain a single-pixel-width boundary of the hand. 20 of these 30 images were used for training and the rest for test purposes. The image acquired from the prototype system and its processed output is seen Fig. 1 and Fig. 2.

Fig. 1. Original image taken with the setup

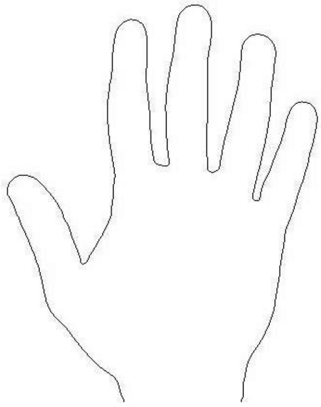

Fig. 2. Processed boundary image

Geometric features are calculated as seen in Fig. 3 [1,3]. Using the boundary data, a signature analysis was performed to find appropriate points and reliably extract the fingers. A fourth degree implicit polynomial was fitted to each of the fingers both using gradient-one fitting and 3L fitting; resulting coefficient vectors were used to calculate Keren's and Civi's invariants. As previously stated, one of the most useful properties of implicit polynomials is their interpolation property for locally missing data; and we employed this fact during our application as the extracted boundary data for fingers were not connected. Fig. 4 shows how implicit polynomials handle this situation. We observed that Keren's invariants gave better results for all cases, and also gradient-one fitting slightly over performed 3L fitting. Experiment results are summarized in Table 1. Numbers in the parenthesis show the number of features used. For classification purposes, Mahalanobis distance was used.

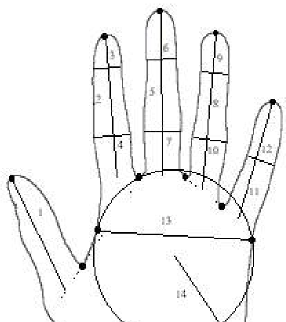

Fig. 3. Geometric features used to construct the feature vector illustrated.

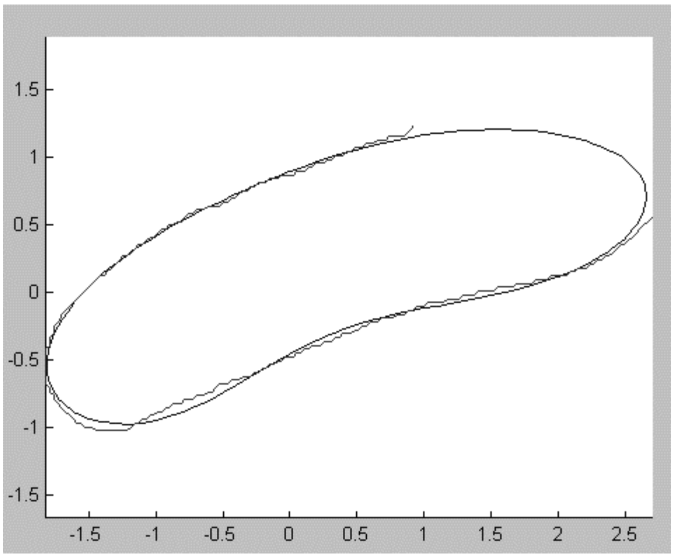

Fig. 4. A 4^{th} degree fit to one of the fingers extracted from boundary data *(closed curve shows the fitted polynomial*).

The first column in the table shows the results of using 16 features. However the second column uses 12 features since it is observed that some features are misleading (e.g. some features for thumb since its geometry is not stable), as a consequence of the image taking policy where minimum constraints were imposed on the user. Third column gives the results obtained using implicit polynomials in all five fingers. Fourth column gives the results by using implicit polynomials in four fingers excluding the thumb. Since 4th degree implicit polynomial fit does not give an accurate fit for the thumbs, identification performance of the invariants is not as good as the geometric features. An alternative approach may be to use 6th degree fits which is more accurate and geometric invariants. This method is expected to increase the success of implicits.

The last column in Table 1 shows the results obtained by combining the features of both methods. As it is clearly seen, while the fusion of the methods increased the identification success above to 95%, the verification rate increased above to 99% and the false acceptance rate decreased down to 1%.

	Geometric (16)	*Geometric (12)*	*IP(15)*	*IP (12)*	*Geom.+ IP (16)*
Identification	80%	88%	73%	85%	95%
Verification	89%	98%	84%	90%	99%

Table 1. Table shows the results obtained using different methods.

4. Conclusions

In this paper, implicit polynomials, have been proposed for recognizing hand shapes and the results are compared with existing methods while researching the best features for identification-verification tasks. The results show that the fusion of invariants from the implicit polynomials and geometric features improve the performance of identification and verification. More accurate 6th degree polynomial fits and geometric invariants have not been tested, but as previous works [12] show, they will most probably give better and more stable results, favoring use of implicit polynomials for hand recognition. A more successful hand recognition system will contribute to the other biometric methods' effectiveness and can widely be used in applications that require low-medium security.

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