A Topological derivative based image segmentation for sign language recognition system using isotropic filter

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Abstract-The need of sign language is increasing radically especially to hearing impaired community. Only few research groups try to automatically recognize sign language from video, colored gloves and etc. Their approach requires a valid segmentation of the data that is used for training and of the data that is used to be recognized. Recognition of a sign language image sequence is challenging because of the variety of hand shapes and hand motions. Here, this paper proposes to apply a combination of image segmentation with restoration using topological derivatives for achieving high recognition accuracy. Image quality measures are conceded here to differentiate the methods both subjectively as well as objectively. Experiments show that the additional use of the restoration before segmenting the postures significantly improves the correct rate of hand detection, and that the discrete derivatives yields a high rate of discrimination between different static hand postures as well as between hand postures and the scene background. Eventually, the research is to contribute to the implementation of automated sign language recognition system mainly established for the welfare purpose.

Key words: Sign Language, segmentation, restoration, topological Derivates, Quality measures.

I. INTRODUCTION

Currently, major research groups focus on the sign recognition problem. The recognition process includes segmentation as the chief step, but the segmentation results are not evaluated that good [18]. However, those recognition methods are based on several approaches that could also be used for sign segmentation [13]. The sign recognition methods can be classified into several categories according to the model of sign they refer to. The approaches are distinguished as one segment, multi segment and hidden model segment based. One-segment approach is used over this research work. In one-segment approach, each gesture is modeled as one single segment. This method has only been applied to gesture classification and was not employed to process real signs [2]. This kind of approach is mainly useful in sign language processing [14]. Here the research presents a segmentation approach to the automatic training and recognition of sign language. This work employs an enhancement method which uses filters with segmentation to locate the dominant hand. Both objective and subjective evaluation is measured by common parameters. The paper is organized as follows. In Section 2 we introduce the framework underlying the presented approach; Section 3 shortly introduces the restoration filters and Section 4 presents the segmentation method that is used in our approach. Section 5 presents the experimental results. Finally, the paper is summarized and concluded in section 7 with future work.

II SYSTEM OVERVIEW

An overview of the automatic sign language recognition system is given here. This allows the research work to adopt the image processing techniques according to the need of the system.

Figure 1: System Overview

There are many segmentation methods approved over sign language system. However these methods lacked precision due to the limited degree of freedom between the different hand signs [7]. This drawback resulted in common incorrect decisions since most hand signs are very similar thus not
allowing the system to differentiate between them [16]. This research work over here is towards the enhancement strength before segmenting the hand sign which henceforth gives better performance in classifiers [8]. When the system runs the language model, transition and emission probabilities can be weighted by exponentiation with exponents $\alpha$, $\beta$ and $\gamma$, respectively, the probability of the knowledge sources are estimated as in eqn (1):

$$
\Pr(w^*_1 \mid \theta_1^*) \propto p^\alpha (w^*_1), \quad \Pr(s^*_t \mid S^*_{t-1}, w^*_1) \propto p^\beta (S^*_t \mid S^*_{t-1}, w^*_1), \quad \Pr(x^*_t \mid S^*_t, w^*_1) \propto p^\gamma (x^*_t \mid S^*_t, W^*_1).$$

The exponents used for scaling $\alpha$, $\beta$ and $\gamma$ are named language model scale, time distortion penalty, and word penalty, respectively. The system overview is shown in Figure 1. The system overview is explained in such a way that the image is prescreened for hand tracking and from that the geometric features is extracted [9]. Linear discriminant analysis will be used for selecting combination of features that are to be trained through classifiers[10]. This paper will describe the intermediate part of how to segment the hand postures through topological derivatives combined with image restoration (filters).

### III. IMAGE RESTORATION TECHNIQUES

Noise occurs in all coherent imaging systems. To reduce the noise over the images two filters are used under continuum and discrete derivatives: isotropic and anisotropic filters. Here in this paper image restoration is handled with two filters which are shown in figure2. This approach before segmentation achieves the objective of detecting the number of open fingers using the concept of boundary tracing combined with finger tip detection [11]. It handles breaks, if any, during boundary tracing by rejoining the trace at an appropriate position. Here the restoration of the sign image is done using continuum and discrete topological derivative algorithm. The main idea behind this algorithm is to compute the topological derivative for an appropriate functional and a perturbation given by the introduction of cracks between pixels. This derivative is used as an indicator function to find the best pixels to introduce the cracks that, in the presence of diffusion, will most remove noise preserving relevant image characteristics[15]. Here, this paper shows the possibility to solve the image restoration problem using topological optimization. The basic idea is to adapt the topological gradient approach.

#### A. Isotropic filtering

Isotropic filtering is a method of enhancing the image quality of textures[6] on surfaces that are at oblique viewing angles with respect to the camera where the projection of the texture (not the polygon or other primitive on which it is rendered) appears to be non-orthogonal[3]. Like bilinear and trilinear filtering it eliminates aliasing effects, but improves on these other techniques by reducing blur and preserving detail at extreme viewing angles.

A vector filter is isotropic eqn (3), if its kernel $F(x) = F(x_1, \ldots, x_d) : \mathbb{R}^d \to \mathbb{R}^d$ invariant by rotation and symmetries:

$$R.F(R^Tx).R^t = F(x) \forall R \in O(d)$$

An Isotropic scalar filter $f$ depends only on radial distance : $f(x) = g(x^T x)$. This is not true anymore for isotropic vector filters.

Though the standard research proves that anisotropic filter is superior always, the scenario here states that the evaluation speaks positive only to isotropic filter, because

i) It works better for Gaussian noise.
ii) The image taken is two dimensional
iii) Defined only on unbounded domain.

#### B. Anisotropic filtering

Isotropic filtering is a method of enhancing the image quality of textures[6] on surfaces that are at oblique viewing angles with respect to the camera where the projection of the texture (not the polygon or other primitive on which it is rendered) appears to be non-orthogonal[3]. Like bilinear and trilinear filtering it eliminates aliasing effects, but improves on these other techniques by reducing blur and preserving detail at extreme viewing angles.

$$f(R^Tx) = f(x) \forall R \in O(d)$$

![Figure 2 Image restoration (a) Original Image (b) Noise (Gaussian) (c) isotropic filter (d) anisotropic filter](http://sites.google.com/site/ijcsis/)

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http://sites.google.com/site/ijcsis/

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The isotropic filter performs better than the anisotropic filter in sign images. The reason for the anisotropic filter performing less optimally at low SNR is because the filter kernel is derived from the data, which itself is very noisy. As the SNR was increased, the isotropic filters were more optimal and were less prone to blurring and other over filtering effects. The study also demonstrates that with data at moderately high SNR, filtering can easily introduce more errors than are removed. In conclusion, the results from this study demonstrate that isotropic filtering can effectively reduce errors in sign images as long as they are applied properly.

IV. IMAGE SEGMENTATION TECHNIQUES

There is no common solution to the segmentation problem in image processing domain. A priori knowledge about the objects present in the image, e.g., target, shadow, and background terrain, should be segmented in better way[14]. The visual relevance of the segmentation problems should be considered rather than simply their plurality; e.g. over-segmentation [5]. These techniques often have to be combined with preprocessing knowledge in order to effectively solve segmentation difficulties for a most needed application. One of the main purpose of proposed method is to precisely segment the image without the misuse of imperative information. Almost all image segmentation techniques are ad hoc in nature. Topological derivatives approach is used for image segmentation after best suited restoration process. Figure 3 demonstrates the experimental results of the segmentation work.

A. Topological derivative

Topological Derivative quantifies the sensitivity of a problem when the domain is perturbed by the introduction of heterogeneity (hole, inclusion, source term, etc.))[17][18]. Let the domain \( \Omega \) under consideration is perturbed by the introduction of small holes (topology changes) in \( \Omega \) as shown in fig4. Let us consider \( \Omega \) be a bounded open set in \( \mathbb{R}^N (N=2,3) \) and \( \gamma_\varepsilon \) be a crack of the \( \varepsilon \) centered at point \( x \in \Omega \)

\[
\psi_\varepsilon (\Omega) = \psi(\Omega) + f(\varepsilon)D^\varepsilon f(x) + 0 f((\varepsilon)) \ldots \ldots (4)
\]

Where \( f(\varepsilon) \) is known positive function going to zero with \( \varepsilon \) and \( D^\varepsilon f(x) \) is the topological derivative at point \( x \) given in eqn (4).

![Concept of Topological Derivative](image)

- **a. Discrete topological derivative**

The algorithm is based on discrete topological derivative concept proposed by larrabide in which the cost functional used for discrete approach is represented by the eqn (5)

\[
\Psi(\Omega^s) = \sum_s \sum_{pen} k^{s,p} \Delta \Omega^{s,p} \Delta \Omega^s \ldots \ldots (5)
\]

The Topological Derivative is given by the difference between perturbed cost function and original cost function.

- **b. Continuum topological derivative**

Continuum (set theory), is known as the real line or the corresponding cardinal number. Continuum (theory), is nothing but, anything that goes through a gradual transition from one condition, to a different condition, without any abrupt changes. A single point (in the unique topology on a single point set) is a continuum ("is trivially a continuum", meaning that it satisfies the properties is easy and that the result is uninteresting); a continuum that contains more than one point. It is same as discrete but the design vector is \( b = \{ \phi_1, \phi_2, \ldots, \phi_n \} \)[18]. These structure is modeled/analyzed as a continuum. Analysis models can therefore be large and expensive.
V. PROPOSED WORK

Conventional problems of segmentation are known to be complicated and always in need of research as it implies mainly for object fragmentation. This research work is the expansion of enhancement and the need for the restoration filter before actual segmentation. Every joint framework outcome seems to be more prospective. This effort is validated with both subjective and objective experiments. The special significance of it is, it obtains promising results for isotropic filter.

VI PERFORMANCE EVALUATION

It is always vital when evaluating the performance of an algorithm when it is addressing a specific application. The relative performance of restoration and proposed method were evaluated and compared using the MSE criterion, PSNR difference and iteration. This reinforces the evaluation effort more suitably. The performance has its own uniqueness over the images taken. Figure 7 and 8 explain the objective evaluation of topological segmentation before and after filtering. Figure 9 demonstrates the performance evaluation of isotropic filter over topological derivative segmentation of sign images. It estimates the concert of segmentation methods reviewed for this work through iteration.
VII. CONCLUSION

The approach over here is to prove the significance of isotropic filter with topological derivative segmentation. The evaluation of image segmentation techniques is a key field of this study. The evaluation is categorized as objective and subjective. The result over the combination of isotropic filter with segmentation has given hopeful outlook. The results indicate that the proposed approach is more robust and accurate than conventional segmentation methods mainly for foreground/background segmentation evaluation problem. The computational time and number of iteration can be comparatively condensed by using optimization technique in further research.

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