An application for gait recognition using persistent homology

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Abstract This Demo presents an application for gait recognition using persistent homology. Using a background subtraction approach, a silhouette sequence is obtained from a camera in a controlled environment. A border simplicial complex is built stacking silhouettes aligned by their gravity center. A multifiltration is applied on the border simplicial complex which captures relations among the parts of the human body when walking. Finally, the topological gait signature is extracted from the persistence barcode according to each filtration. The measure cosine is used to give a similarity value between topological signatures. The input of this Demo are videos with resolution $320x240$ to $25fps$. The videos in CASIA-B database are used to prove the efficacy and efficiency. A computer with 2Gb of RAM memory and a DualCore processor was used to test the implementation of the propossed algorithm. In this Demo all related tasks have been programmed by the authors in the C++ programming language. OpenCV library has been used for the image processing part.

Keywords: Gait recognition, Persistent homology, persistence barcode, simplicial complex

1 Introduction

Gait recognition is a challenging problem that gives the possibility to identify people at a distance, without any interaction with the subjects, which is very important in real surveillance scenario [5, 6]. In this work, a platform made in C++ programming language to identify people at a distance via their way of walking, is presented. From a camera or video file and using a background subtraction approach we obtain a normalized silhouette sequence of people when walking. A 3D digital image I is obtained by gluing silhouettes through their gravity centers. A border simplicial complex $\partial K(I)$ is built from I. We order the triangles obtaining a sequence of subcomplexes of $\partial K(I)$, i.e., a filtration F which captures relations among the parts of the human body when walking. According to F, we use the incremental algorithm [2, 3] to get topological gait signature extracted from the persistence barcode [1]. The geometry of $\partial K(I)$ is encoded through F which has implicit a history of birth and death of the homological classes. Besides, $\partial K(I)$ is encoded using several filtration (multi-filtration) for getting a more robust representation. The angle between topological signature vectors given by the correlation cosine measure is used as similarity value.

According to experimentation protocol in [4] we built 50 topological signatures that represent to fifty person from CASIA-B database, i.e, four samples by people are used to train. When this Demo is running, it receives a video sample of a walking person. We extract a sequence of silhouettes using a background subtraction. From a 3D image I made by stacking silhouettes glued by its gravity center, $\partial K(I)$ is built. Finally, the topological signature extracted from the persistence barcode provided by incremental algorithm is obtained. We use correlation cosine measure and a boundary threshold, to obtain the most likely people according to the fifty persons mentioned above or unknown person.

The rest of the work is organized as follow. In Section 2 we explain how to obtain the simplicial complex $K(I)$. Section 2.1 is devoted to describe how we obtain the topological signature. The description of some functions of the graphical interface and an example that evaluates the efficiency of the method is presented in Section 2.2.

2 The simplicial complex $\partial K(I)$

First, the moving object (person) is segmented for each frame applying background modeling and subtraction. The sequence of silhouettes is analyzed to extract one subsequence of representation, which include at least a gait cycle [5]. One subsequence of representation is selected for each sequence.

The 3D binary digital picture $I = (\mathbb{Z}^3, 26, 6, B)$ where $B \subset \mathbb{Z}^3$ is the *foreground*, $B^c = \mathbb{Z}^3 \backslash B$ the *background*, and $(26, 6)$ is the adjacency relation for the foreground and background, respectively of a subsequence of representation is built stacking silhouettes aligned by their gravity centers (gc) (see Fig. 1.a).

The border simplicial complex $\partial K(I)$ associated with I is constructed as follows. First, we compute the 3D cubical complex $Q(I)$ (whose geometric building blocks are vertices, edges, squares and cubes). Second, we visit all the point of B, from down to up and from left to right. Let $v = (i, j, k) \in B$. If the following 7 neighbors of v,

$$\{(i+1, j, k), (i, j+1, k), (i, j, k+1), (i+1, j+1, k), (i+1, j, k+1), (i, j+1, k+1), (i+1, j+1, k+1)\},$$

are also in B then, the point v and its 7 neighbors form a unit cube which is added to $Q(I)$ together with all its faces (vertices, edges and squares). This way, we do not consider the small artifacts of I. Then, the cells of the 2D cubical complex $\partial Q(I)$ are all the squares of $Q(I)$ which are shared by a voxel of B and a voxel of B^c, together with all their faces (vertices and edges). The simplicial representation $\partial K(I)$ of I is obtained from $\partial Q(I)$ by subdividing each square of $\partial Q(I)$ in 2 triangles together with all their faces. Finally, coordinates of the vertices of $\partial K(I)$ are normalized to coordinates (x, y, t), where $0 \leq x, y \leq 1$ and t is the number of silhouette of the subsequence of representation.

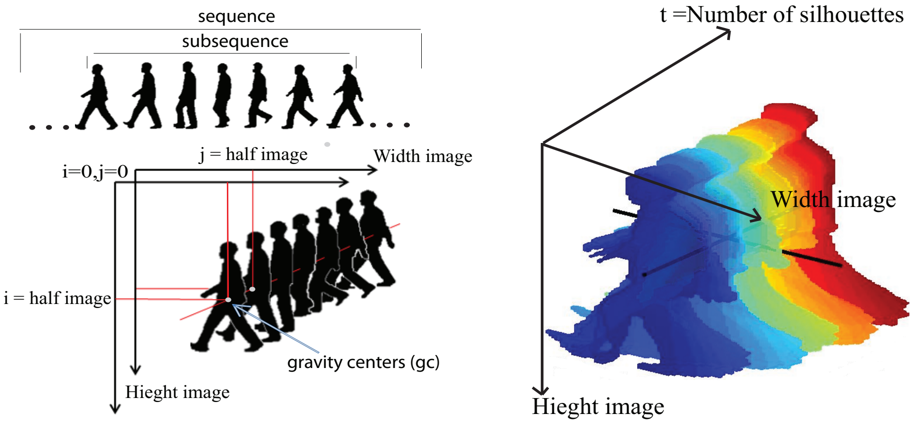

Figure 1: (a) Silhouettes aligned by their gravity centers (gc). (b) The 3D binary digital picture I obtained from the silhouettes.

2.1 Topological Gait Signature

We define four directions $D_a = \{d^a_{xt}, d^a_{yt}, d^a_{ob1}, d^a_{ob2}\}$ and their opposite $D_b = \{d^b_{xt}, d^b_{yt}, d^b_{ob1}, d^b_{ob2}\}$ to obtain eight filtrated simplicial complex ∂K_d, for $d \in D_a \cup D_b$, i.e, eight ways of order of the triangles of $\partial K(I)$ (see Fig.2). According to each filtration persistence barcodes are computed. We reduce the barcodes by removing homology classes with low persistence which are associated to noise.

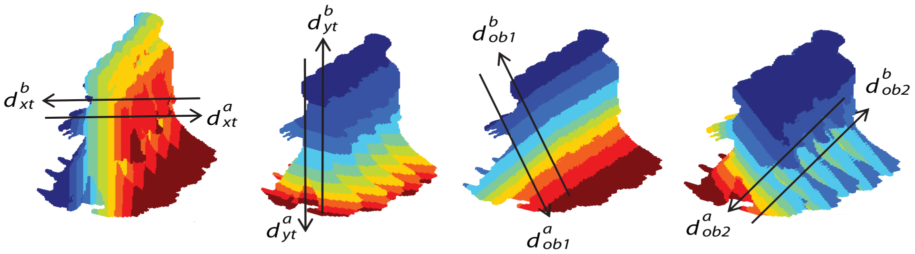

Figure 2: Ordering directions.

Now, n cuts are performed homogeneously in the sets ∂K_d, being n a given positive integer, as follows: Suppose $\partial K_d = \{\sigma_0, \dots, \sigma_m\}$. Construct the subsets $P_i^d = \{\sigma_{\lfloor \frac{(i-1)m}{n} \rfloor + 1}, \dots, \sigma_{\lfloor \frac{im}{n} \rfloor - 1}\}$, $1 \leq i \leq n$. Fixed i, the reduced persistence barcode shows:

- (a) Homology classes that were born or persist when the simplex $\sigma_{\lfloor \frac{(i-1)m}{n} \rfloor}$ is added, and, persist or die when the simplex $\sigma_{\lfloor \frac{im}{n} \rfloor}$ is added.
- (b) Homology classes that were born in P_i^d.

A vector of dimension $2n$ is then made by counting the number of homology classes classified as explained above. We only use homology classes of dimension 0 and 1, denoted by H_0 and H_1, respectively.

The *topological signature for a gait subsequence considering a fixed direction and its opposite* consists in four $2n$-dimensional vectors:

$$(V_{D_a}^{H_0}, V_{D_a}^{H_1}, V_{D_b}^{H_0}, V_{D_b}^{H_1})$$

constructed as explained above.

The similarity value for the topological signatures

$$(V_{D_a}^{H_0}, V_{D_a}^{H_1}, V_{D_b}^{H_0}, V_{D_b}^{H_1}) \text{ and } (W_{D_a}^{H_0}, W_{D_a}^{H_1}, W_{D_b}^{H_0}, W_{D_b}^{H_1})$$

for two gait subsequences considering a fixed direction of view is done by computing, first, the angle between the two vectors V_i and W_i, for $i = 1, 2, 3, 4$ using Eq. 1:

$$S_i = \cos^{-1}\left(\frac{V_i \cdot W_i}{||V_i|| \quad ||W_i||}\right) \tag{1}$$

Then, four angles (S_1, S_2, S_3, S_4) are obtained, since for each subsequence of representation, four vectors were computed. The total similarity value for two gait subsequences considering a fixed direction of view, O_1 and O_2, is the weighted sum of the four similarity measures (angles) computed before. In this demo $w_i = 1$:

$$S(O_1, O_2) = w_1 S_1 + w_2 S_2 + w_3 S_3 + w_4 S_4 \tag{2}$$

2.2 Description of the Demo

This Demo has a graphic interface and performs two main functions:

- (1) Build a database of topological signatures, via a video of gait samples of n people.
- (2) Load a video which can contain one or more samples of people walking.

While the Demo is running, silhouette sequence from the each person is extracted of the video in real time. The subsequence is put in a request queue, where the topological signature of each subsequence is obtained and compared with the signatures in the database. Finally, if there is a positive match in the database, a visual response of both people is given or, unknown person otherwise. Moreover, the video is show in a window. Other functions as loading a database of topological signatures are given.

In this Demo the more complex tasks that affect the efficiency are devoted to build the simplicial complex $K(I)$ and to compute its persistent homology. According to a video sample from the CASIA-B database, an example is given. A gait subsequence of 53 silhouettes is obtained. A simplicial complex of **139 504** triangles was built in **0.054** seconds and its persistent homology in approximately **8** second. A computer with 2Gb of RAM and a DualCore processor was used to test our developnent. In this Demo all topology related tasks have been programmed by the authors in the C++ programming language and OpenCV library has been used for the image processing part.

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