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Towards Optimized Placement of Cameras for Gait Pattern Recognition

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Abstract

Locomotion of an individual i.e., gait is proven to be unique. Recent past has seen a paradigm shift while considering gait as a trusted biometric trait even though it is a behavioral biometric. The study of gait includes body mechanics, changes in muscular action, and uniqueness in body movements. For extraction of features from gait, its proper acquisition becomes an important issue. This makes placement of cameras and their localization as an important domain of research for gait pattern analysis. When gait biometric is used for identification in surveillance purpose, it works in unconstrained manner since there is no predefined path or ramp for recording the motion of a subject. The model proposed in this article approaches for determining best possible placement of optimal number of cameras in a given coverage area. The model also updates/modifies the placement of cameras as the active walking region (path-band) in that area changes temporally. Moreover the model also provides the camera system to work in master-slave mode efficiently utilize the cameras to minimize the computational complexity.

Keywords: Gait biometric; Camera placement; Video surveillance; Height estimation

1. Introduction

Locomotion of an individual which is repetitive with same frequency and carries a temporal pattern is termed as gait [1]. Walk, trot, run, and to climb stairs are among such locomotion in which an individual has a temporal pattern that repeats with same frequency. This makes these activities candidates for being gait. The earlier progress towards establishing gait as a biometric trait is successor to the research of Johansson et al. [2] where experiments has been done to differentiate among different human postures by examining 10-12 nodal points over human body based on different sequence of biological motions done by the body and hence by the points. In recent past, gait biometric has been very commonly used in sport biomechanics to study and rectify the posture and movement of an athlete. Gait has been used in the medical field over the patients for rectification of ill-movement of a part of the body. In both the above cases there are predefined ramp and individuals are restricted to walk over that. Recently gait is used for identification of an individual and is therefore employed as a part of surveillance system. In such situation gait recognition is done in unconstraint scenarios. Since there is no predefined path of movement, therefore there are no perfect camera positions and there remains scope for minimizing the number of cameras, improving the position of cameras, and to optimize their usage.

A few works have been done towards identification through gait where computer vision techniques are not used. Mantyjarvi et al. [3] have used accelerometer and does not rely on computer vision. However, majority of the works include camera-view for analysis and feature extraction of gait pattern. In [4], Teixeira et al. have proposed a PEM-ID system using cameras and accelerometer to identify and localize people through their gait pattern. Goffredo et al. [5] have proposed gait identification through single camera to avoid the complexity of calibration of multiple cameras. Bouchrika et al. [6] have presented a new approach for tracking and identification between different non-intersecting uncalibrated cameras based on gait pattern analysis. Jeges et al. [7] have worked towards estimating human height in calibrated cameras that can be used as a supportive feature for identification. This justifies why camera placement plays a crucial role for gait analysis in unconstraint scenario.

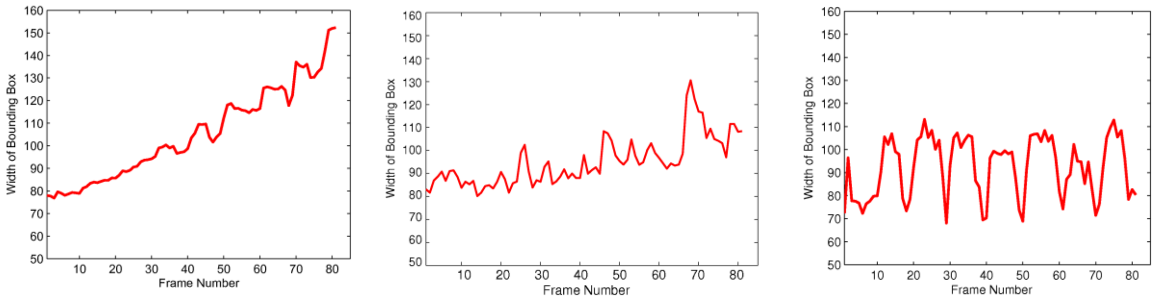
A camera can best capture the gait features when it is placed orthogonal with respect to the motion of the subject. Such positions of camera also make tracking easier and best placed for height measurement. The proposed model in this paper has an overhead-camera that prepares a path-band, based on the locus of various subjects traversed over a span of time. Other field-cameras are PTZ cameras placed at such positions where they can get maximum orthogonal views. These positions are estimated by overhead-camera using the proposed algorithm and path-band information. Further camera setup works in master-slave mode so that overhead-camera guides field-cameras to track the target efficiently. Section 2 of this paper states the problem under consideration in detail. The subsequent steps of proposed model towards the solution of the problem are illustrated in Section 3. Finally, Section 4 concludes the paper along with stating the scope for future works towards the proposed model.

2. Problem statement

When a camera network is set up to identify a subject walking in a given area, the locus of the subject is not known in prior. Hence best positions for camera placement cannot be statically defined. If a most probable path can be estimated based on paths traversed earlier, then camera placement can be done optimally. Secondly, there can be an effort to find the minimal number of cameras along with their poses to cover the path. However, minimum required number of cameras depends on the nature of path traversed most frequently by the subjects. Number of cameras working together generates large volume of recorded data, which is difficult for storage and processing as well. Minimizing the number of cameras partially resolves the problem. Further reduction in computation is achieved as the camera network works in master-slave mode where awaking, sleeping, and panning of field-cameras is monitored by the overhead-camera.

3. Proposed model

The proposed model is governed by the fact that the best view of a moving subject for gait recognition, tracking, and height measurement can be done when the line of sight of camera is orthogonal to the movement of the subject. Experiments are conducted to support the above mentioned fact. The walking pattern of an individual is captured through different cameras, and background subtraction is applied on all the video thus obtained. Background subtraction method separates the moving subject from its stationary background and puts a rectangular boundary over the moving subject. Fig. 1 shows graphical plots representing the pattern of change in the width of bounding box around the moving subject for three different camera views of the motion of same subject. Fig. 1(a) represents the plot when camera is capturing the frontal view of the subject making an angle $\sigma = 0$ with the direction of motion, Fig. 1(b) represents the view captured at $\sigma = \pi / 4$, and Fig. 1(c) represents the view captured at $\sigma = \pi / 2$ i.e., camera placed orthogonal to the direction of motion. As σ changes from 0 to $\pi / 2$, gait cycles becomes gradually detectible. Two of the major gages for gait pattern, heel-strike (when the legs of the moving subject are maximally apart), and mid-swing instant (when the legs are crossing each other) are clearly visible as the peaks and troughs in Fig. 1(c) and are occurring with approximately same frequency. This justifies the necessity of orthogonal placement of camera for capturing gait pattern.



(a) $\sigma = 0$ (b) $\sigma = \pi / 4$ (c) $\sigma = \pi / 2$

Fig. 1 Change in width of bounding box of moving object with different camera placement angle

The proposed model of optimizing placement of cameras for gait recognition comprises of an overhead-camera of fixed type, and a set of field-cameras of PTZ type. The number of field-cameras depends on the curvature of obtained path-band, area under surveillance, and resolution of the cameras used. Proposed model towards solving the above mentioned problem is described in the following sections.

3.1. Locus tracking of subjects' movement

Movement of people in any area depends upon the type of area, obstacles around the area, entrance point, exit point, shortest distance from entry to exit etc. Hence there is no mechanism to predict the exact path to be travelled by a particular individual. This model proposes to place an overhead camera capturing the top view of the whole surveillance area, albeit of low resolution. It is so away from people that individuals cannot be recognized from the low-resolution images, but various locus of different individuals can be traced by background subtraction and frame-wise connectivity check. This operation takes place during a sufficient span of time to get enough data of traced paths.

Each frame captured from the surveillance area is divided into grids of size 8×8 pixels. The overhead-camera captures sufficient set of data of various paths, which makes a visible pattern of movement of individuals in the surveillance region. Fig. 2 shows the above mentioned scenario in an assumed area under surveillance.

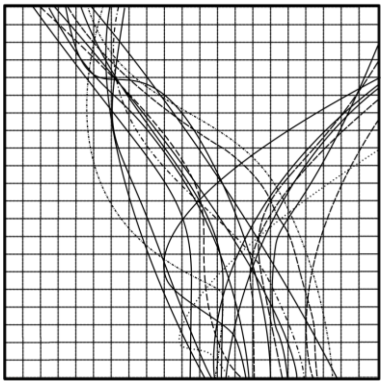


Fig. 2 Loci of different subjects tracked by the overhead-camera

3.2. Direction vector calculation

In the further sequence of processing, direction of movement of each individual in each grid is studied. The direction of movement is discretized into predefined angles based on the pattern of the pixels of individual motion in each grid. Fig. 3 shows the pixel patterns and the angle inferred from them. The angle of movement ranges in [0,π]. The movement is not considered in [0,2π] because the directions: x and $(x+\pi)$ produce same orthogonal. Histograms of the direction of angles of different traces are plotted with bin-width of π/8 for each grid blocks. If a single bin in the histogram contains no. of traces above a threshold, it signifies existence of prominent maxima indicating a unique direction of movement

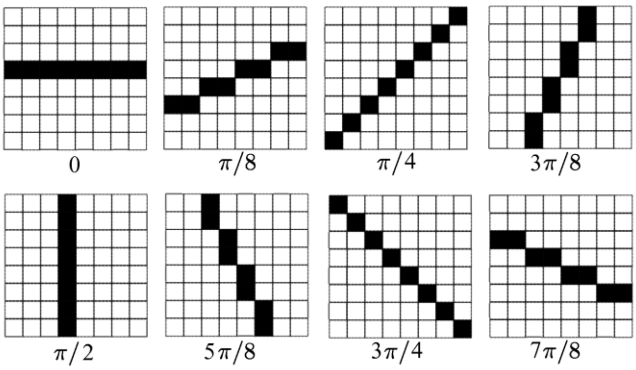


Fig. 3 Inference of angles from discrete pixel patterns in 8×8 grid

as sown in Fig. 4(a). If all the bins in the histogram are below a threshold, it implies approximate uniform distribution with no explicit maxima and the grid block is considered to be a chaos region with no specific direction of movement of subjects (an example is shown in Fig. 4(b)). Hence these kinds of grid blocks are rejected, and no direction vectors are assigned to them. Direction vectors assigned in such a way yields a collection of grid blocks with respective direction vectors. However, apart from chaos regions and grids with specific direction vectors, there may exist grids owing to such portions of surveillance area where no person traverses. These grids comprise no locus, and hence not considered for further processing (an example is sown in Fig. 4(c)).

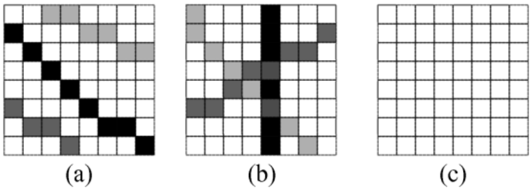


Fig.4 (a) Grid indicating unique direction of movement, (b) chaos region, (c) grid with no locus

3.3. Path-band estimation

All such grid blocks with explicit maxima will be considered for path-band estimation. Each such direction vector has its bin height (indicating the number of individuals traveled along the particular direction in the grid) as the magnitude of respective direction vectors. These magnitudes are compared and grid block with highest magnitude of its direction vector will get selected first. If more than one magnitude is found to be the maximum then anyone can be selected randomly for further processing. Generally such grid blocks are found at entry or exit points of the surveillance area.

Further, immediate 8-connected neighbors of the selected grid blocks are compared for contributing to the path band. A few blocks with low magnitude are rejected for further iteration, and rest goes to further processing. Again immediate neighbors of last iteration blocks are compared for rejection. As the iteration goes until the edges are arrived in the grid view of surveillance area, a path-band is formed as a collection of direction vectors. Fig. 5(a) depicts formation of a path band.

3.4. Finding efficient camera placement

Perpendicular can be drawn on each direction vector and at each point of the path band. There will be collection of points where more than a certain number of perpendiculars intersect. Voting is done for each pixel of the surveillance region to find how many perpendiculars are passing through a particular point. Number of perpendiculars passing through a point also depends on the number of traced paths considered while training of overhead camera. Collection of these points will form a few potential regions (depicted in Fig. 4(b)). There may be physical constraints as lack of place for installing cameras, which has to be considered to reject few points from the potential region. Further, out of available points in a region, the

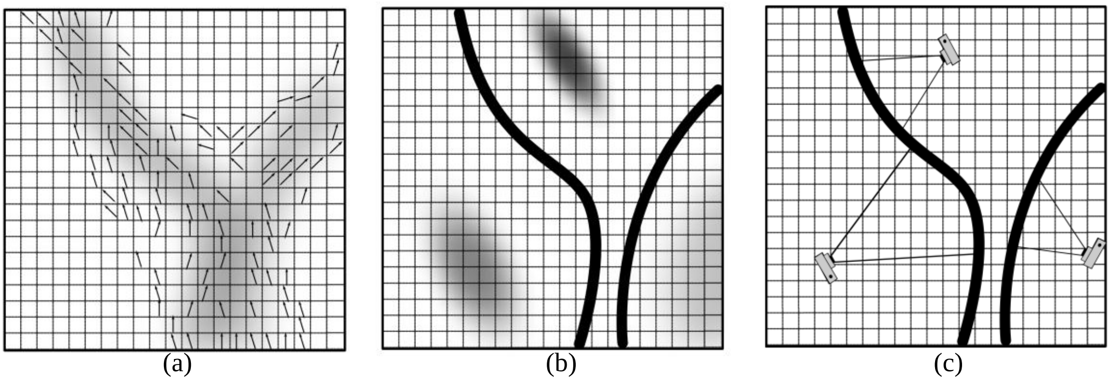


Fig. 5 (a) Estimated path-band, (b) voted regions for camera-placement along with thinned path-band, (c) sample placement of three field-cameras one with higher number of intersections may be chosen for camera placement. A sample placement of camera is illustrated in Fig. 4(c).

3.5. Localization and working of camera-network

An overhead-camera of fixed type is already placed that has fetched the best probable locations for placing PTZ cameras. PTZ cameras have the ability to pan, tilt and zoom according to the way they are programmed to. Placing PTZ cameras at such points can best utilize the location of its placement since it can pan with the movement of the subject to track, and to capture the gait pattern for longer duration. Since the camera remains approximately orthogonal to the subject with a high probability, it is best-positioned to estimate the height of the subject as well.

Further camera setup (overhead-camera of fixed type, and field-cameras of PTZ type) can be made to work in master-slave mode [8]. For this, camera setup should be calibrated and localized. Overhead camera works in master mode and PTZ cameras work in slave mode. Master camera analyses from its top-view that which field camera should remain active and what should be the panning speed to constantly track a subject. This lets the camera-network to be used proactively and also optimizes the computational cost. Field-cameras which are not active may go to sleep mode to reduce power consumption and to reduce complexity of calculation. Hence the master camera efficiently manages the mode of slave cameras for optimized use.

4. Conclusion and future work

As the number of subjects walk through the coverage area, there will be more number of locus and hence more data for overhead-camera to refine its calculation. Hence camera placement is refined over the time. At the time of path-band calculation, only those grid blocks are considered where a good number of loci are passing almost parallel, assuring that orthogonal to the direction vector of this block will be orthogonal to most of the locus at this grid block. On the contrary, chaos region would not contribute to path-band. This assures maximum orthogonal view of camera from the subject’s locus. If the path-band turns out to be a consisting very less curvature, then the region of camera placement is spread through both the sideways of the band, indicating that all the points on both sides of the band are equally potential for placing of field-cameras. Further each field-camera, when calibrated and localized with overhead-camera, optimizes the usage of the camera-network. The accuracy of finding the loci and hence performance of the proposed model severely depends on the resolution of the cameras. Although there are ample theoretic justifications of the model proposed, the proposed model still awaits experimental verification in some surveillance zones.

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