A REVIEW OF HUMAN BODY SHAPE DETECTION TECHNIQUES AND THEIR APPLICATION TO THE PREDICTION OF HEALTH RISKS

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ABSTRACT

Human body shape detection techniques have applications across fields such as surveillance for security purposes and design and clothes fitting estimations in the fashion industry. We here propose the use of body shape detection for the classification and estimation of health risks since body shapes are directly related to fat distribution. With the phenomenal increase in prevalence of obesity worldwide and the ensuring epidemic of diabetes and other weight related sequelae, the monitoring of body shapes has assumed great relevance. This is especially so among children where earlier identification and timely interventions may impact future health outcomes. Body shape assessment by traditional manual methods can be tedious, time consuming and may exaggerate psychological effects on obese students. Therefore non-invasive approaches employing images has potential to both screen larger numbers as well as avoid direct contact. Although such techniques are available, the equipment necessary can be expensive thereby limiting access to those from poorer countries whose populations are most vulnerable to epidemiologic transition to obesity. In this paper we provide a review of body shape classification techniques and discuss possible low-cost alternatives that can be used to monitor body shapes of school-aged children using camera photographs.

KEYWORDS

Body shape, feature detection, image processing

1. INTRODUCTION

Human detection in images has been explored for many years but the interest and development of the field continues to grow due to the vast range of areas to which it can be applied such as medical analysis, video games and surveillance (Kart et al. 2011, Shotton et al. 2013, Lee & Nevatia 2007). However, studying humans from images and extracting body features are not straightforward. Challenges arise due to the wide variations in appearances (height, weight, shape), clothing and pose (Brandao et al. 2014).

The analysis of a person's body shape can be used to determine current and even potential health risks. Wang et al. (2015) pointed out that body health is not only determined by body fat percentage but also by how that fat is distributed throughout the body. They also explained that studies have shown that persons with more fat around their abdominal region have a higher chance of developing cardiovascular diseases and other associated diseases, such as diabetes and hypertension, than those who store fat around their hips. The distribution of fat around different areas of a person's body leads to different body shapes such as apple, pear, triangle, hourglass and rectangle. Identifying high-risk body shapes in a timely manner allows for timely intervention.

This paper gives a review of techniques that have been used to determine a person's body shape from images. The paper is organized as follows. Section 2 presents some applications which have been created to categorize a person's body shape. Section 3 discusses the findings from the reviewed work and proposes a method for determining the body shape of school children. Finally, the paper concludes in Section 4 with a summary of the findings.

2. APPLICATIONS TO CATEGORIZE BODY SHAPES

Most systems that have been developed to categorize body shape have been built for the specific purpose of virtual clothing fitting applications. One of these applications is presented by Simmons et al. (2004). They selected some basic female body shapes and used both visual and recorded data (3D body scan measurement data of the abdomen, stomach, hip and waist) to derive mathematical formulas which can categorize persons into the various shapes such as hourglass, rectangle, oval, triangle and diamond. Subsequently, Neophytou et al. (2013) built an online fashion application that uses the classification formulas developed by Simmons et al. However, instead of using data from 3D body scan data, measurement details were extracted from images uploaded by the user. Their system applied a GrabCut method (Rother et al. 2004), in order to subtract the background. The models' shapes were learnt by applying principal component analysis to vertex coordinates from the scans. Energy functions were used to match a user's silhouette to a model. The methods used by Simmons et al. were then applied to determine the user's body shape. A similar system built by Kart et al. (2011) required the user to enter personal information, such as weight, height and age, and also a 2D photograph of themselves taken in front of a plain, light color background and dressed in dark colored clothing. The user's information was processed using functions from MATLAB's Image Processing Toolbox. The RGB (red, green and blue) image was first converted to an HSV (hue, saturation, value) image, then noise reduction algorithms were applied. The negative of the image was taken and, finally, the pixels were counted in order to determine measurements for different parts of the body, such as the bust, waist and hip. The measurements, as well as calculated body mass index (BMI), were then passed to a decision algorithm which determined the body shape of the person. Sekine et al. (2014) presented a virtual clothes fitting application which overlaid images of clothing, worn by a model with a similar body shape, onto the user's image. They used depth images in order to easily obtain the locations of a person's joints and trained their system by matching depth images to 3D human body models of varying body shapes and poses. At run-time, the system matched the user's depth image with one of the pre-trained depth images. Characteristic measurements, such as height and waist width, were used to select the shape model whose shape best matched that of the user. After the body shape model was selected, the image of the clothing was scaled and overlaid onto the user's image. Likewise, Chang and Wang (2015) implemented a technique for estimating body shape in order to improve the experience of shopping for clothing online. Part-based feature extraction was first used on training images of persons in skin-tight clothing. Descriptive features of the person's body shape, such as height and leg length, were extracted from the semantic parts. Principal component analysis was performed on the features in order to reconstruct the person's shape and also to aid with modelling variation in shapes. Multiple camera views were used to improve the accuracy of the estimated shape. The previously selected features were used as constants across the various views. Linear regression was applied to match measurements across the different views of the person. Finally, optimal coefficients were calculated for each view in order to reconstruct the body shape of the person. The reconstruction coefficients were allowed to be different across multiple views. In order to evaluate the proposed technique, the DC Suite, a 'try-on' software, was applied on the SHREC' 14 dataset.

Apart from the use in clothing fitting applications, there are a few methods developed solely to estimate a person's body shape. For example, Balan and Black (2008) proposed a method for estimating a 3D body shape of a person using multiple images of the person under varied poses. They applied a generalized notion of a visual hull where the body shape of the person lay within the visual hull and belonged to a family of parametric 3D body shapes. They also identified skin regions that allowed the deduction of certain constraints, such as the overall weight of the person. They also used gender-specific models to refine the shape estimation process. In addition, Hasler et al. (2010) proposed a multilinear method for estimating pose and body shape. The method was independent of the type of clothing worn by the subject and worked for both single and multiple camera views. They first derived bilinear, analytical and independent models for pose and body shape using a database of 3D scans of 114 undressed subjects each of which were scanned in various poses. In order to determine the pose and body shape of a silhouette in an image, an initial 3D shape was chosen and similarities between the shape and the silhouette were calculated.

Although our application differs from those discussed above (i.e. clothing fitting), the techniques involved are quite similar since our objective is to identify the outline of the person's body in order to determine if the person's dimensions and shape indicate potential health issues. Another difference with our work is that we require a low cost solution since the budget available in schools for such programs is typically quite small.

3. DISCUSSION

Human shape detection and feature extraction in images is still a challenging task. In addition, little work has been done on body shape classification. The body shape classification applications described in the previous section were mainly for virtual clothing fitting purposes but techniques used by these applications can be applied to body shape detection methods for health-risk detection purposes. The latter applications first extracted the user from the image, applied various techniques to extract measurements of different body parts, such as shoulders, bust, waist and hip, and then classify the user into a specific body shape. These applications employed a general set of procedures. These include background subtraction, segmentation of body in order to extract useful details such as shape features, training and use of a classifier to determine body shape and testing of the proposed system with a popular dataset or one which was self-obtained. The results are compared against manually acquired values or with the results of similar methods in order to assess the method's accuracy and efficiency. However, typically less information is required for body shape categorization since precise values of dimensions are not needed but rather ratios of these dimensions. These modified techniques may now be put to a novel use of stratifying the population into differential risk categories for the purposes of intervening to preserve health. Furthermore, our interest is to create low cost tools and applications that would find widespread use in low income and resource-constrained settings.

3.1 Preliminary Experiments

Initial experimentations were done in order to build a system that can easily and efficiently categorize the body shapes of secondary school students in their usual school uniforms, without the use of expensive equipment such as 3D scanners. Images of two students (1 male and 1 female), dressed in full uniforms, were captured with a color camera and also with a Seek Thermal Imaging Camera. It was initially hypothesized that infrared images will give a more accurate outline of a person's shape, rather than color images. However, as seen in Figure 1, thin materials absorb body heat, whilst thick materials prevented the IR camera from detecting heat in those regions. Hence we concluded that the analysis of color images would provide better accuracy than infra-red images in detecting body shapes of school students.

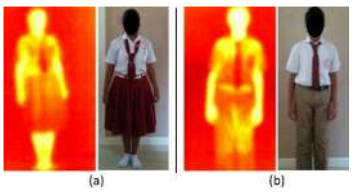

Figure 1. Infrared images of students along with their corresponding color images

3.2 Work in Progress

A 360 degree health application is being developed for secondary schools in Trinidad and Tobago. Heart disease is the leading cause of death in the country. It is well-established that pear-shaped individuals are at far less risk of heart attacks than those who are apple-shaped. Therefore, tracking the risks of developing heart disease at a young age and taking measures to prevent heart disease will be a useful public health intervention. The application collects data from students, processes it, derives a risk index and alerts the school's administration and parents/guardians of potential health risks. Once a month, students are asked to walk past a pair of cameras connected to a client application running on a tablet or laptop. One camera takes a frontal photo while the other takes a profile shot. These photos are automatically triggered since the system is meant to have minimal human intervention. Face recognition is used to identify the student. The frontal view of the person is captured when the user stands in front of a specially marked background. The marked background contains cues which can aid in automatically calculating a person's height. The students also stand on a weight scale that captures weight and body fat percentage via bioelectrical impedance analysis. The readings are sent to the client application via Wi-Fi or Bluetooth. Initial processing of the image is done on site before being transmitted via a Wi-Fi or cellular connection to a central database. This pre-processing includes edge detection in order to extract the important characteristics of the image. The resulting image is significantly smaller in size and hence can more easily (and cheaply) uploaded to the central server.

Further processing is done on the central server. Various dimensions of the image are measured and these are discounted to take into account clothing since school uniforms can alter the perception of a person's actual body size and shape. However, an advantage is that all students are similarly dressed thereby minimizing the effect of outerwear. These discount factors are being determined based on initial experiments whereby image dimensions and actual dimensions of children dressed in school uniforms are compared to determine the appropriate discount factor. Various ratios and measurements are calculated in order to aid in the categorization of a person's body shape. These include height, waist circumference, waist to hip ratio, waist to height ratio, torso length and the difference in volume between the top half of the torso and the lower half. Body Mass Index (BMI) is also calculated using a special chart for children between the ages of 5 and 17. Ethnicity detection is performed on the central server in order to incorporate an ethnic-specific criteria for BMI calculations. This is due to the fact that Caucasians are allowed the largest measures and Indians and Chinese have the least capacity and the lowest thresholds for decompensation as they grow fat. A combination of all of these dimensions and calculations are used as characteristics to determine which body shape category is most probable for the student. We also perform comparisons with historical data for that student to detect any trends. This information together with the body shape information and other data that may have been collected at the site (such as weight) or calculated by the central server (such as waist circumference) is then used to determine what action, if any, should be taken by the school.

4. CONCLUSION

The classification of human body shapes from images is a useful technique for predicting health risks. Most of the research in this area has been done in the fashion industry for virtual clothes fitting. However, we believe that we can identify children at high risk for adverse consequences of obesity using low cost equipment to non-invasively determine weight-related health issues of school-aged children. We are developing a low cost, automated framework for doing this and are presently running experiments.

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