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Detection and Tracking of Human Legs by a Mobile Robot

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Abstract:*The autonomous navigation capabilities of mobile robots is a social and technological issue.Many potential applications add to the importance of human following technology.Some of the applications include museum guide robots and service robots at shopping center.In this paper,we propose the detection and tracking schemes for human legs by the use of a camera.The robust tracking of humans is achieved by exploiting a human walking model.The leg detection and tracking schemes are realized by the combined application of support vector data description algorithm and a wheeled mobile robot.The proposed scheme is successfully verified in real time environments.*
Index term: *Human following, Human-robot interaction,Leg detection,Mobile robot navigation,SVDD algorithm.*

I. Introduction

The development of service robots that are able to assist humans during their everyday tasks has become a popular research area over the last few years.Possible application scenarios include assistance for elderly people and general service robots for shopping centres or public areas[1]-[3].A key requirement for service robots is the ability to detect humans and to interact them in non-technical and natural fashion.The goal of our work is to move toward a more reliable and robust system, where human detection is viewed as an fundamental stepping stone.

There are many different types of sensors, which are employed by robots and intelligent vehicles for the detection and tracking, such as vision (or camera), ultrasound, infrared, and laser range sensors.In [7],the use of radio frequency identification(RFID) technology is presented. Since the RFID tags provide unique ID information upon detection, they are very useful for differentiating detections among multiple tags and are very suitable to make associations in consecutive detections.On the other end, passive RFID tags are verysmall and compact as they do not have their own power source which in turn reduces detection range.

The Kinect sensor is also exploited for human following applications as in [10]. The Kinect sensor measures the depth information bythe use of infrared structured light.The field of view of Kinect sensor is narrower than that of other sensors which makes it less applicable for detection and tracking applications.Laser based approaches use scanning laser range finders to detect and track humans [6], [8],[15]. This technique is simpleto implement, requires little processing power, and allowsfor fast tracking. However, detection is limited to a singleplane. Numerous objects such as trees and poles can be falselydetected, and tracking multiple people who cross paths isdifficult.

Significant work has used motion analysis to detect humans [4],[5],[11],[12]. These approaches are heavilyreliant on custom models, and work with fixed cameras. Acamera mounted on a mobile robot will encounter difficultiesseparating human motion from robot motion.Model based methods use the structure of the human body to detect people in images [9], [14]. These approaches find partsof the human body, such as the head, hands, feet, and legs ina scene and construct a relationship between each component.Positive detections occur when the parts and their relationshipsmatch a model. This method is prone to error with clutteredenvironments, partially obscured people, and unexpected typesof clothing such has hats, gloves, long coats, and dresses.

Many studies have emphasized human detection for tracking movements.In [13],[16],[18]multiple hypothesis tracking(MHT) is successfully applied to the problem of human leg tracking.Another interesting target tracking scheme is sample-based joint probabilistic data association filter (SJPDAF) in [19]–[21]. Although these methods showgood results, the computational cost for tracking people is high because the probabilities of all range data should be computed.

In this paper, we focus at the detection and tracking of human legs by the use of a camera. The present work attempted modification of the above works.The major contribution of the present work can be summarized in three respects. The first contribution is the detection of human legs based on the data received from the camera. Some feature points are extracted automatically based on large number of sample data.Geometric attributes are defined and classifications are done by the application of support vector data description algorithm. The second contribution is the accurate tracking of leg positions based on the data from the SVDD algorithm. The third contribution is the experimental verification of the proposed scheme in a real environment.

The rest of the paper is organized as follows. In section II, we explain the proposed model. This is comprised of system analysis and communication block diagrams we used. In the next section III, we give a brief detail of the SVDD algorithm. This is followed by the section IV, which is the major part, which describes the experimental results. In section V, some concluding remarks are illustrated.

II. The Proposed Model

The proposed model of the system is shown in Fig 1 and Fig 2.The control section consists of a camera, a micro-controller, a voltage level converter and a zigbee module.

Cameras are relatively cheap sensors and provide a lot of data.The field of tracking and surveillance was well established when the rise of mobile robotics began. Therefore, a lot of results from that field could be applied on the problem of people tracking with a camera with minor modifications. Human detection has been implemented by combining the positional information and visual features from camera.

Once the human legs are detected,the SVDD algorithm performs classification of the obtained data.The methodology by which classification is performed is explained here. Firstly, the feature points are extracted automatically from the input image. The system then sets the feature points on the extracted edges or corner points. Then, the velocity of each feature point is calculated from the history of its motion.After that, the distance from the robot to each feature point is measured by the stereo vision system. The most suitable feature parameter for the person region detection is selected by the distribution of the feature points' distance and velocity parameters. The feature parameter that has the largest degree of separation is selected as the most suitable one for the person region detection.The person's area is extracted using the most suitable feature parameter selected.

After performing classification by SVDD scheme,the target person is recognized and the area of the target person is identified by combining the information of the pre-registered color and texture of the clothes the target person wears.

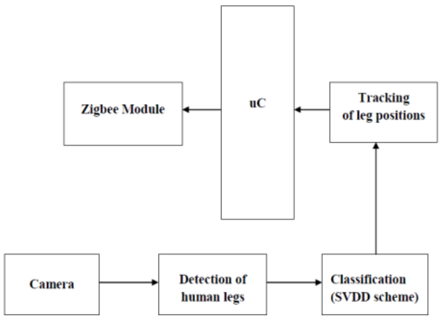

Fig 1: Control Section

After recognition of the target person, the distance and direction data to the target person is sent to the Motion control module.

The Vehicle section consists of a micro-controller and a motor.An accurate tracking of the target person is performed by the mobile robot .The motor of the mobile robot is driven by the micro-controller.

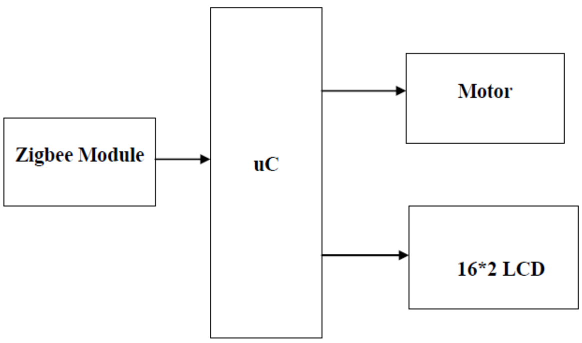

Fig 2: Vehicle Section

The explanation of the SVDD algorithm related with the proposed model is explained in III.

III. Svdd Algorithm

SVDD is one of the best known outlier detection and novelty detection methods.It obtains a spherically shaped boundary around the complete target dataset. This algorithm is a one-time classifier. It can be used for detection and rejection of unfounded confident classifications .It makes a description of a training set of objects and detects which objects resemble this training set.The boundaries extracted by SVDD are shown in Fig3.

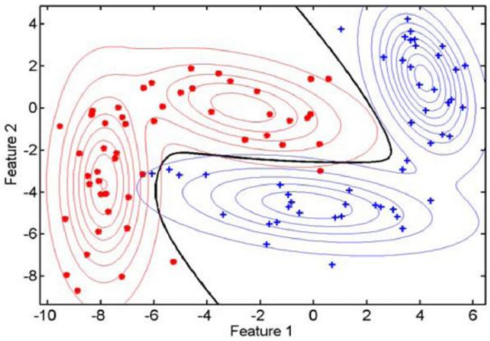

Fig 3: Boundaries extracted by SVDD

For the present work,we use support vector data description algorithm.The further details of SVDD can be found in[17].The feature extraction in SVDD algorithm is done by the following equation:

$$\min L\,(R^2, a, \quad \xi) = R^2 + C\sum_{i=1}^{n} \xi_i$$

subject to,

$\|x_i - a\|^2 \leq R^2 + \xi_i\,,\ \xi_i \geq 0\,,\ \forall\, i \qquad (1)$

In (1), n is the total number of data points in the attribute space.To classify n data points, we minimize the radius R of the sphere described by the center a through a Lagrangian. $\xi_i$refers to slack variables, and the parameter C>0 specifies the tradeoff between the volume of the sphere and number of errors.

IV. Experimental Results

In this paper, we mainly focus on leg detection and accurate tracking by human motion prediction. It is assumed that the target person makes smooth and slow motion. More efficient control schemes are desirable to improve the human-following performance. The proposed human detection and the algorithms are activated only when there are no collision risks. If the robot detects any collision, the navigation controller terminates navigation and makes a stop. The underlying autonomous navigation schemes were presented in [1],[2] and [24].

The experimental environment for detection and tracking of human legs is shown in Fig 4.The experiment is conducted in a real time environment.The environment consists of a flower pot,a trash can,a ladder and a fire extinguisher.

Fig 4:Experimental environment

After the points were clustered, SVDD algorithm extracted seven clusters, as shown in Fig 5.The trash can,flower pot, fire extinguisher and the ladder are being excluded since it doesn’t fall within the calculated feature values.

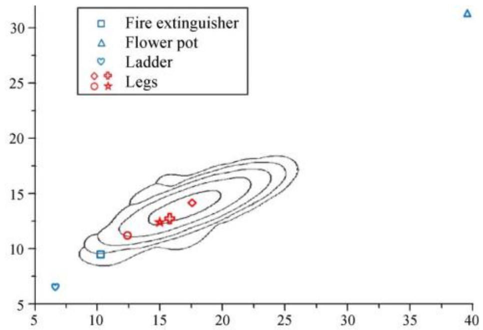

Fig 5:SVDD result for leg detection

Finally, fourlegs remained as leg candidates because they were not filteredout.The mobile robot detects the correct candidate based on the distance and direction data to the target from previous samples. As a result, the mobile robot could successfully follow thetarget person in the cluttered region.

We compared the performance of the proposed feature extraction approach with two schemes that are discussed in [22] and [23].Bounding box and Circle fitting are those conventional schemes that are used for feature extraction. Table 1 summarizes the performance of the feature extraction schemes.

True Label	Detected Label	Bounding Box	Circle Fitting	Proposed Approach
Person	Person	95.7 %	81.4 %	97.1 %
	No Person	4.3 %	18.6 %	2.9 %
No Person	Person	43.5 %	11.6 %	9.4 %
	No Person	56.5 %	88.4 %	90.6 %

Table 1: Comparison results of feature extraction

Comparison results show the probability at which the feature extraction schemes detect human legs. It is evident from the performance comparison that the proposed approach showed excellent classification compared to others.

V. Conclusion

In this paper,a method to detect and follow human subjects with a mobile robotic platform has been presented.The leg detection algorithm showed excellent classification performances.An efficient leg tracking scheme has been established to perform accurate tracking.The proposed schemes are successfully verified through experiments.Future works on this paper will encompass more accurate leg tracking schemes.The performance and reliability can be further improved by combining the proposed scheme with different types of sensors.

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