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Human-Robot Interface using Face Detection and Recognition, for the Service Robot, "Donaxi"

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Abstract. This paper is in the context of algorithms for detection and face recognition, as well as face tracking, integrating them into service robots at home, this paper was made for service robot "Donaxi", to the contest in RoboCup. The proposal was to set up a hybrid algorithm with different functional algorithms for the detection, recognition and face tracking, even after losing face. For detection we used the Haar algorithm, for tracking Kalman filter was used, and recognition strategy was used to segment the image into regions weighted, and discriminate against them through a decision tree for possible recognition. The experimental results show that the system is stable when saturated its field of view with many faces or persons, in this case only discriminate which is closer to the robot. It is noteworthy that followed the rules of test "Who's Who" of the category of the RoboCup at Home, this test is still an open problem for the robotics community in the area of Human-Robot Interface.

Keywords. Hybrid algorithm, face detection, face tracking, face recognition, Kalman filter, Decision trees, Phase correlation, Histogram comparison.

Introduction

One of the great challenges in computer vision is to improve the automated systems for objects detection and tracking or regions of a set of images. Nowadays, detecting human-face is a discussed problem using different types of features. Face tracking is a difficult problem because faces are deformable objects with areas of little texture. Most of the algorithms for detecting face using binary pattern-classification. This means that the content of an image is transformed into features for a face classifier previously trained, decides if the image is a face or not. The process of face detection consists of two steps. The first is building models. The second step is to find a particular region in the image, called area of interest.

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Some other tracking algorithms use the advantage of correlations between image frames to accelerate tracking process. Fundamentally, the features of the object itself are local information, and the features of an image sequence belong to global information.

There have been many works for object detection and tracking for object detection and tracking. Most of these algorithms have the main idea on estimating the movements of area of interest using probabilistic theories like some popular models and approaches, like Kalman filter.

Baek proposes a face tracking algorithm, this consider the corresponding face vector status, including the central position, the size of the containing rectangle, the average colored area and their first derivatives [1]. For the evaluation of new face candidates we employ a Kalman's estimator. In the tracking phase the algorithm detect if the face is new or not, using the face's previous frame like a template, with this data calculates the new face position.

In parallel, another point of attention has been the faces recognition. In this context is presented problems in the variability of the head rotation, the intensity and angle of light, facial expression to take a picture and others which have complicated the recognition systems [2] [9].

Face recognition methods and algorithms commonly assume [10] that face images are aligned and have an equal posture, but in many practical applications it is impossible that these conditions will be present. One solution that has been presented to reduce these factors is to obtain sub-features of a face, which enables a better approximation to say whether a face is known or not based on the analysis results and related features.

Some work on face recognition [10,11] have shown that an adequate solution to measure the characteristics is the use of decision trees, a probabilistic technique that through certain events and probability weights can make a decision in context.

This paper is organized as follow. In section 1, related algorithms that will be used to built a hybrid system for detecting human-face detection, recognition and tracking. Section 2 describes the detailed information of hybrid system that we propose. The results are presented in section 3 and the conclusions in section 4.

1. Related Algorithms to build a hybrid system

To build a hybrid system for detecting human-face and tracking unrestricted is necessary to use different algorithms. In This paper we propose an algorithm for recognizing and tracking a person.

The goal to this algorithm is to search a face in an image using a recognition process based on the detection of features that encode some information about the face to be detected, once face image detected is cropped, the segmentation is to determine if a face is already known, continues to track the face, so it will trace the journey that the faces will be making and storing a image is taken from the coordinates in which the face is detected, it is able to continue to monitor if the face is not fully facing the camera.

When the face is back facing the camera turns to make the recognition to ensure that the face is the same as it began to follow, Figure 1.

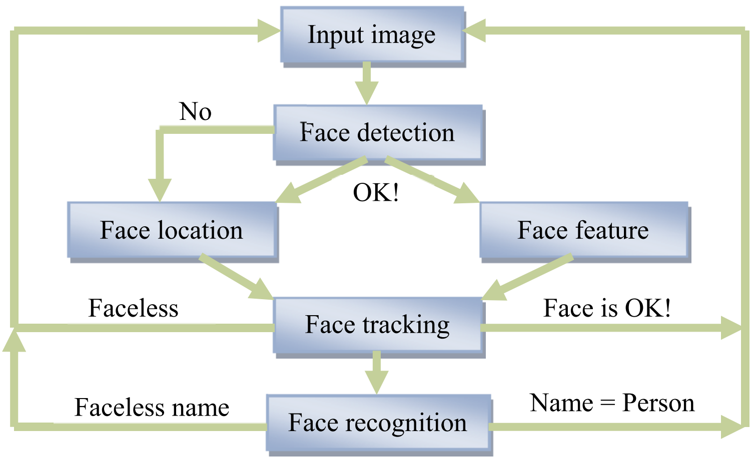

Figure 1: Hybrid system to Detection, Recognition and Tracking Unrestricted.

Importantly, firstly the algorithm must find a face to follow. We should also mention that this algorithm was tested on the service robot "Donaxi@HOME".

1.1. Face Detection

Face detection is the first stage of an automated face recognition system, since a face has to be located before it is recognized. In this case, we use the object detector of OpenCV. This object detector has been initially proposed by Paul Viola and improved by Rainer Lienhart. The algorithm's first step is the creation of a training file. The generation involves an analysis of various images and face views (positive examples), and arbitrary images (negative examples).

This training can be applied to a region of interest in an image this region must be to the same size as used during the training. The working of the training produces a "1" (if the región shows a face) and "0" (not face in image). To search for the object in the whole image one can move the search window across the image and check every location using the classifier.

1.2. Face location

Once a face is detected within the image, the center coordinates of the face to know are stored so the system can map the exact location of the face within the image when the face changes its position; the new coordinates are also stores in order to know the person trajectory.

With the obtained data is generated a line graph as this type of graphic is used to compare values over time.

After we are going to analyze the behavior of the graph and discard those values that are far away from others to ensure that the plotted points show the person trajectory.

To find the direction and extent to which the person moved draw a line from the point where the face was detected for the first time to the last point where the face was detected. The information that we obtain after to detect a face is used in the Kalman filter configuration to face tracking.

1.3. Kalman Filter

In order to keep the person even when the face isn't fully in front of the camera we use the Kalman filter. Kalman filter estimates the state variables of a process with feedback. Calculate the process state at some point and then get information (fed back) of the measure.

If you want to apply the Kalman filter to face tracking, you must provide a characteristic representative thereof, to be taken as the observation of the object. In this case an image is stored each time a face is detected or a picture of where the face was detected last. To calculate this point we will call the center of mass and determines the position of the stored image is necessary to perform a series of operations on the image.

To identify movement of the face within the image is necessary to apply motion detection techniques. This way we continue to face that hovers over the image.

The study of movement of the face within the image is essential to introduce the time variable. A sequence of images is given by the function f (x, y, t), where x, y are the coordinates of the center of the head at a particular time instant, t. Therefore the value of f (x, y, t) represents the intensity of pixel (x, y) within the image t.

In face tracking measures are necessary observation corresponds with the position of center of mass of the face. In this case it is used to determine the position based on projections which use the center of mass, which, as mentioned above is obtained from the center point of the head. Previously eliminates potential noise given only to those parts of the image over a fixed number of pixels above the threshold. In this way we make sure not to consider some isolated pixel face.

1.4. Probabilistic Decision Trees

Decision trees [4] are a widely known formalism for expressing classification knowledge. The traditional approach to constructing a decision tree from a training set of cases described in terms of a collection of attributes is based on successive refinement. In a general context, the decision trees are particularly useful when one or more decisions in sequence should be taken and they are affected by one or more uncertain events to which they are assigned a certain probability weighting which directly affect the value (usually expressed in earnings) for final decision.

In the context of this work, we take the principles of decision trees for use in face recognition, using as a key decision if the face is known or not, and as uncertain events similarities and differences in the detected face real time, against the face stored in the database of known persons. Similarity values and differences were obtained using phase correlation algorithms and comparing histograms.

In order to achieve this aim with better efficiency, face division by subsections was used, based on the aesthetic theories [5] where each subsection is analyzed in an independent way with the similarity and difference algorithms

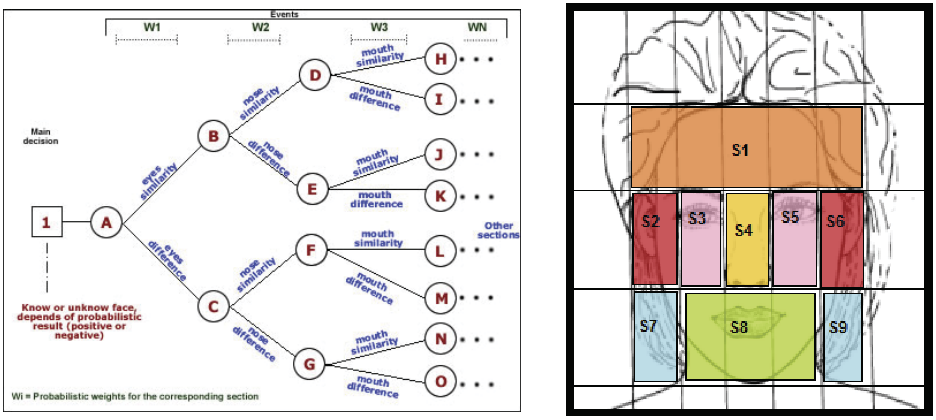

Figure 2. Decision tree and Face division in 9 characteristic subsections.

Each one of these subsections received a probabilistic weight based on how characteristic for the face recognition is, for finally integrate them in a probabilistic decision tree.

1.5. Phase Correlation

It is a method for determinate the displacement of one picture respect to other similar [7]. However phase correlation utilizes a direct way comparison, results are too ambiguous because it's required that the compared face images accomplish the same characteristics when it is used in a direct way. When this technique is combined with the face subdivisions technique, efficiency is incremented and results are more trustable for faces equality comparison.

1.6. Histogram Comparison

An image histogram [8] is a graphical representation of the intensity distribution of an image that quantifies the number of pixels for each intensity value considered. For the face recognition purpose we use the histogram equalization like a way to improve the contrast in an image in order to stretch out the intensity range.

With this first treatment, an image with a more generic tonality was achieved in order to make the recognition process based on the accumulative distribution equation.

$$H^{\wedge\prime}(i) = \sum_{0\le j<i} H(J)$$

Figure 3. Histogram equalization

The second histogram utilization is a comparison with the saved histograms of known subsections faces in order to be utilized as concept of comparison in the decision tree algorithm for face recognition. To compare two histograms (H1 and H2), first we have to choose a metric (d (H1, H2)) to express how well both histograms match.

For the algorithm, correlation and intersection histograms comparison metrics [8] are utilized.

2. Hybrid Algorithm

2.1. Tracking Face

The hybrid algorithm to track a person works as follows:

1 Detection and face cutting: At the beginning of the process, the system detects the person's face using the haar classifier, once is defined a face is there, it is cut out from the picture and becomes the new interest region.

2 The mass center of the interest region is obtained and stored in a database which will store all coming up mass centers.

3 The stored mass centers are plotted and the Kalman filter is applied to them in order to exclude those items which are far apart.

4 Estimate the position whre the person is located.

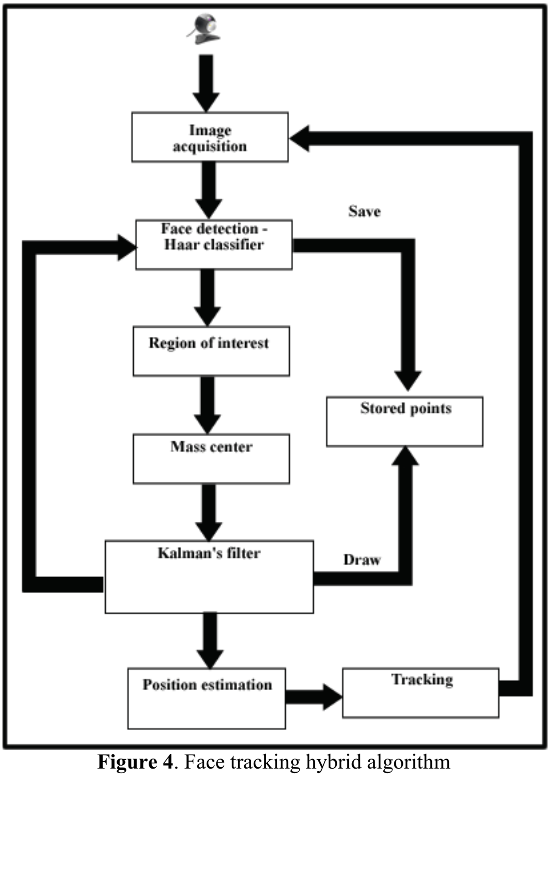

Figure 4. Face tracking hybrid algorithm

2.2. Face Recognition

The hybrid algorithm for face recognition works in three main phases:

1 Detection and cut face: In this first stage, we detect the face of the person using the haar classifier, once defined that there is a face, this is cut out of the picture.

2 Division of the face: Having defined the image available of the face, this is divided into 9 regions of space.

3 Calculation of similarity: Finally for the algorithm, correlation and intersection histograms comparison metrics [8] are Utilized For Each one of 9 Subsections. Both operations are performed with the detected face and the familiar faces and previously stored. The results of these operations are introduced to the decision tree, by which you get a percentage of similarity of the detected face against a familiar face before.

If the percentage of similarity exceeds a minimum value assigned to the face is considered as known, otherwise, the face belongs to a person not known to the algorithm.

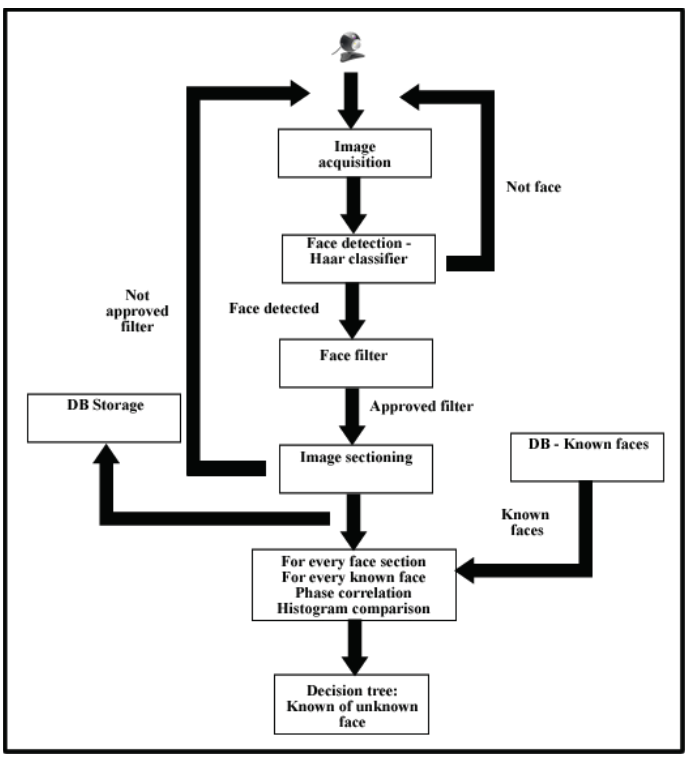

Figure 5. Face recognition hybrid algorithm

3. Results

3.1. Tracking Face

For the implementation of the experiment, we were the participation at least one person to track. When starting up, the person must be placed in front of the camera to detect possible face forward. Once the face is detected locked up his face in a circle and paint the center point of the face and the journey that makes the person as it moves.

Finally, the line graph which would indicate the direction and magnitude at which the person moves. To verify if the plotted course was right, it was proof that a person stands in front of the camera waiting for her face is detected and so get moving. If the program traces the route that matches the person that I do, it is considered that the test was successful.

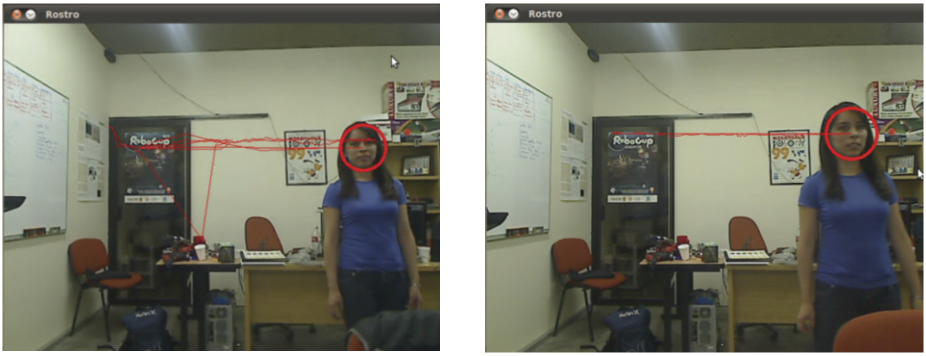

Figure 6. Face Tracking and Kalman filter application. The first image on the left is seen to have many disturbances generated by the same variation in the identification of the face, in the second image on the right is applied Kalman and observed substantially improving the correction of the estimated center position of the head.

3.2. Face Recognition

This face recognition algorithm was planned to solve the problem of vision test posed "Who is Who" for the RoboCup 2012, so for testing and obtaining the same results were a series of tests emulating this specific activity. The evidence that was submitted to the algorithm were to teach four previously (acquaintances) and then start the recognition phase where different people (both known and unknown) were located in front of the camera and then proceeded to run your algorithm procedure to determine whether they were known or unknown to him.

In tests, the system has been exposed to a total of 205 choices of action (situation where you have to decide if a face is known to him or not) of which were obtained the following results:

Face Recognition Tests		
	Quantity	Average (%)
Action decisions	205	100
Correct decisions	178	86.83
Uncorrect decisions	27	13.17

Table 1 Obtained results for face recognition.

These tests were performed by taking a static camera images, and showed positive results with a high percentage of correct recognition, as well as efficient processing speed.

Figure 7. Face recognition real time application.

4. Conclusions

The algorithm was tested in the service robot "Donaxi @ HOME", which participates in the RoboCup since 2009.

The model for face tracking and recognition is proposed in this paper seeks to exploit the ability to use the comparison of characteristics to define whether a face is known or not, based on a current face and the features of a face stored above so we can determine if the face that is always the same. This was determined by face recognition at the beginning and end of follow up.

The combination of different techniques shown here (haar classifier, face split into subregions, phase correlation, comparison of histograms, decision trees and Kalman filter) have unique capabilities and advantages that may develop in part a recognition and tracking faces, but in combination (to generate the proposed hybrid algorithm) can get a better focus and greater efficiency when performing this task.

The results have shown that one can obtain a high efficiency rate with this algorithm, although the results should be viewed with caution because this algorithm has not yet passed the phase of high-level tests (test the algorithm bases data and robust free faces that are available on the web) so what is the next phase of its growth.

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