

A FUZZY SYSTEM FOR INTEREST VISUAL DETECTION BASED ON SUPPORT VECTOR MACHINE

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Abstract: Despite of the advances achieved in the past years in order to design more natural interfaces between intelligent systems and humans, there is still a great effort to be done. Considering a robot as an intelligent system, determining the interest of the surrounding people in interacting with it is an interesting ability to achieve. That information can be used to establish a more natural communication with humans as well as to design more sophisticated policies for resource assignment. This paper proposes a fuzzy system that establishes a level of possibility about the degree of interest that people around the robot have in interacting with it. First, a method to detect and track persons using stereo vision is briefly explained. Once the visible people is spotted, their interest in interacting with the robot is computed by analyzing its position and its level of attention towards the robot. These pieces of information are combined using fuzzy logic. The level of attention of a person is calculated by analyzing the pose of his head that is estimated in real-time by a view based approach using Support Vector Machines (SVM). Although the proposed system is based only on visual information, its modularity and the use of fuzzy logic make it easier to incorporate in the future other sources of information to estimate with higher precision the interest of people. At the end of the paper, some experiments are shown that validate the proposal and future work is addressed.

1 INTRODUCTION

The interaction between Intelligent Systems and human beings is a topic that is focusing a great research effort nowadays. The development of natural and multimodal interfaces is needed to enhance the interaction abilities of current Intelligent Systems. In particular, within the area of Robotics, the development of successful robotic systems applied to service tasks in home and office environments implies the generation of natural human-robot interfaces. In that sense, important issues that must be taken into account are how robots can detect the presence of persons around them and how do they recognize when and how long a person is interested in establishing an interaction. In order to achieve this goal, it is necessary to solve several problems. First, a robot must be able to detect persons in its vicinity and track their movements

over time. People tracking is not an easy task since several persons could be moving at the same time, crossing their trajectories and occluding each others. We can find many works in the literature on this topic (Fritsch et al., 2003; Snidaro et al., 2005). The techniques to perform the detection and tracking are frequently based on the integration of different information sources such as: skin color, face detectors, visual analysis of the motion or laser range finder.

Once a robot is able to recognize and track the persons in its vicinity, it should be able to detect their interest in establishing an interaction with it. In that task, several types of signals from the human can be taken into account (both verbal and non-verbal). Some authors (Bennewitz et al., 2005) use sound source localization or speech recognition besides visual perception to detect which persons are the most interested. In other cases, facial expressions (Song

et al., 2001) or hand gestures (Ghidary et al., 2002) are analyzed. Finally, other authors (Kulic and Croft, 2003) propose the use of non-verbal signals present in physiological monitoring systems that include skin conductance, heart rate, pupil dilation and brain and muscle neural activity.

In regards to the role of the fuzzy logic in robotics, an extensive catalogue of the uses of fuzzy logic in autonomous robots can be found in (Saffiotti, 1997). Fuzzy logic has been successfully applied to a multitude of problems such as: design of controlling behaviors for navigation, behavior coordination, map building, integration of deliberative and reactive layers, etc (Aguirre and González, 2000). Lately, fuzzy logic has also been applied to the area of human-robot interaction. In (Bien and Song, 2003) several soft computing techniques are applied to service robotic systems for comfortable interaction and safe operation. Fuzzy logic is used for recognizing facial emotional expression and for coordinating bio-signals with robotic motions. In (Kulic and Croft, 2003) several sets of fuzzy rules are used for estimating intent based on physiological signals.

In this work we are interested in computing a value of possibility of the interest of a person to interact with the robot. This value is computed using only visual information, but the modularity of the system makes easy the posterior incorporation of other types of input data as sound or laser range finder. The interest is computed according to the position of the person and its degree of attention. In a first step, people detection and tracking problems are solved by a stereoscopic system. The use of stereo vision brings several advantages when developing human-robot applications. On the one hand, the information regarding disparities becomes more invariable to illumination changes than the images provided by a single camera, being a very advantageous factor for the background estimation (Darrell et al., 2001). Furthermore, the possibility to know the distance to the person could be of great assistance for the tracking as well as for a better analysis of their gestures.

Once the surrounding people is spotted, we propose a new method for estimating the interest of the detected people in interacting with the robot by means of computer vision and fuzzy logic. The person's attention is detected by the analysis of the pose of his head. To detect the head pose we have employed a view based approach using Support Vector Machines (SVM) (Cristianini and Shawe-Taylor, 2000) that let us classify the head pose in real time.

The approach presented in this work is not only valid for robotic applications. It can also be employed in intelligent systems that use stereoscopic devices.

For example, it can be applied in intelligent spaces where one or several intelligent devices wish to interact with people according the interest shown by each person.

The remainder of this paper is structured as follows. Section 2 gives an general overview of the hardware and software system, describing the method employed for the detection and tracking of people in the surroundings of the robot. In Section 3 it is explained the SVM based approach to estimate the head pose and the fuzzy system for estimating the interest of people. In Section 4 it is shown the experimentation carried out, and finally, Section 5 outlines some conclusions and future works.

2 PEOPLE DETECTION AND TRACKING

The hardware system is comprised by a laptop to process the information, a stereoscopic system with a binocular camera (PtGrey, 2005) and a Nomad 200 mobile robot (see Fig. 1).



Figure 1: Robot with stereo vision system.

The ability of detecting and tracking people is fundamental in robotic systems when it is desirable to achieve a natural human-robot interaction. They are achieved in our architecture by combining stereo vision and color using plan-view maps. Following, the process for people detection and tracking is explained in a summarized way. The readers more interested in this process are referred to (Muñoz-Salinas et al., 2006).

Our robot has a stereo camera that is mounted on a pan-tilt unit (PTU). The stereo camera captures two images from slightly different positions (calibrated stereo pair) that are transferred to the computer to calculate a *disparity image* containing the

points matched in both images. Knowing the intrinsic parameters of the stereo camera it is possible to reconstruct the three-dimensional position p_{cam} of a matched pixel (u, v) . Then, the points captured are translated to a “robot” reference system, placed at the center of the robot at ground level in the direction of the heading of the robot. Generally, the number of points captured by our stereo system is very high. In order to perform a reduction of the amount of information, the points captured by the camera are orthogonally projected into a 2D plan-view map O named *occupancy map* (Harville, 2004; Haritaoglu et al., 2002; Hayashi et al., 2004).

The next step in our processing, is to identify the different objects present in O that could correspond to human beings (*human-like objects*). For that purpose, O is processed with a closing operator in order to link possible discontinuities in the objects caused by the errors in the stereo calculation. Then, objects are detected as groups of connected cells. Those objects whose area are similar to the area of a human being and whose sum of cells (occupancy level of the object) is above a threshold θ_{occ} are considered human-like objects. This test is performed in a flexible way so that it is possible to deal with the stereo errors and partial occlusions. However, the human-like objects detected might not belong to real people but to elements of the environment. The approach employed in this work to detect a person consists in detecting if any of the human-like objects found in O show a face in the camera image.

Face detection is a process that can be time consuming if applied on the entire image, thus, it is only applied on regions of the camera image where the head of each object should be (head region). As the human head has a typical average width and height, the system analyzes first if the upper part of a human-like object has similar dimensions. If the object does not pass this test, the face detector is not applied to it. This test is performed in a flexible manner so that it can handle stereo errors and people with different morphological characteristics can pass it. If the human-like object passes this test, the corresponding region in the image is analyzed to detect if it contains a face. The face detector employed is based on the face detector of Viola and Jones (Viola and Jones, 2001) which was later improved by Lienhart (Lienhart and Maydt, 2002). We have employed the OpenCv’s Library (Intel, 2005) implementation that is trained to detect frontal human faces and works on gray level images.

Once a face has been detected on a human-like object, a color model of the person torso is created (Comaniciu et al., 2000). The idea is to assist the

tracking process by capturing information about the color of the clothes of the user so that the robot can distinguish him/her from other people in the environment. Therefore, pixels around what it should be the chest of the person are used. The position of the chest in the camera image is estimated as 40 cm below the top of the head region. The size of the region used to create the color model depends on the distance of the person from the camera. When the object is far from the camera the region used is smaller to avoid including pixels from the background and it becomes bigger when the object is near to the camera.

Tracking consists in detecting in subsequent frames the human-like object that corresponds to the person being tracked. The Kuhn’s well-known Hungarian Method for solving optimal assignment problems (Kuhn, 1955) is employed for that purpose. Two pieces of information are combined (position and color) to assign a value to each human-like object indicating its likelihood to be the person being tracked. On one hand, a prediction of the future position of the person being tracked is calculated using the Kalman filter. The nearer a human-like object is from the position estimated for the person being tracked, the higher likelihood it will have to be him/her. On the other hand, color information is employed to achieve a more robust tracking. The more similar the color of a human-like object is to the clothes’ color of the person being tracked, the higher likelihood it will have to be him/her. Both likelihood are combined so that when the person being tracked is near others, color information can help to distinguish him/her. The human-like object with highest likelihood is considered to be the person being tracked if its likelihood value exceeds a certain threshold. In that case, the Kalman filter is updated with the new observations and also the color model of the person is updated so that it can adapt to the illumination changes that take place.

When the position of the person being tracked is located, the system determines the location of his head in the camera image. In this work, the head is modeled as an ellipse whose size in the camera image is determined according to the distance of the person to the camera. Firstly, the system calculates an initial estimation of the head position in the camera image based on stereo information. Then, the initial position is refined by a local search process. For that purpose, the gradient around the ellipse perimeter is examined in order to determine the likelihood of a position using the Birchfield’s method (Birchfield, 1998). The position with higher likelihood is considered the person’s head position.

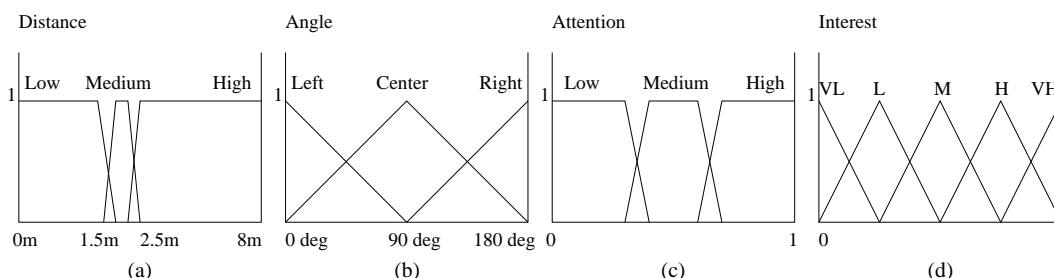


Figure 2: Fuzzy sets of the linguistic variables: (a) Distance (b) Angle (c) Attention (d) Interest.

3 INTEREST DETECTION

In the previous section, we have described as the robot is able to detect and track them the persons in its vicinity by using the stereo system. This section explains our approach for estimating the interest of the detected people in interacting with the robot by means of fuzzy logic. The approach presented in this work is based on stereo vision but the system can be easily expanded to merge other sources of information. The advantages of using fuzzy logic are mainly three. Firstly, the robot has to deal with information from the stereo system that is affected by uncertainty and vagueness. Fuzzy logic is a good tool to manage these factors using linguistic variables. Secondly, the human knowledge can be usually expressed as rules. Fuzzy logic allows to establish relationships among the variables of a problem through fuzzy rules providing an inference mechanism. Finally, there are methods in fuzzy logic to fuse the results from several fuzzy rules in order to achieve a final overall result. Therefore, the system designed in this work, based exclusively in stereo information, can be integrated with other fuzzy systems using other types of information as source sound localization, gesture analysis or speech recognition systems.

In this work, the determination of the degree of interest of a person is based on its position and its degree of attention. The position of a person is analyzed using both its distance to the center of the robot and its angle in respect to the heading direction of the robot. The first feature is measured by the linguistic variable *Distance* and the second one by the linguistic variable *Angle*. These linguistic variables have three possible values each of them, that are shown in Fig. 2. The meaning of these two variables is the following: if the person is detected near to the robot and more or less centered with respect to it, then we consider that the person is more interested in establishing interaction with the robot than when the person is far or at the left or right side of the robot. Nevertheless, the position of the person is not enough to determine his interest

in interacting with the robot. Thus, the third feature shown in this paper is the person’s attention detected by the analysis of the pose of his head. To detect the head pose we have employed a view based approach using SVM that is explained in the next section.

3.1 Estimating Face Attention using SVM

One of the most prominent cues to detect if a person is paying attention to the system is the orientation of his face, i.e., a higher degree of attention can be assumed when a person is looking at the system than when it is backwards. This section describes our approach for face attention estimation.

We have divided head poses in three main categories: “A” that comprehends all the frontal faces (faces looking directly at the camera), “B” that comprehends all the slightly sided faces (faces looking to some point slightly above, below or aside from the camera) and “C” that comprehends all the other faces (side faces, faces looking at some point in the ceiling or ground, backward heads). Figure 3 shows examples of each one of the categories employed.

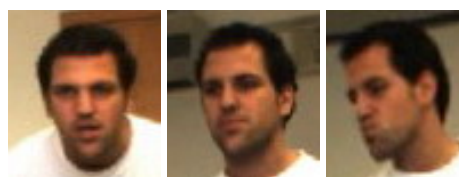


Figure 3: Head Pose Estimation: Classes A, B and C.

We have created a head pose database comprised by a total of 4000 samples equally distributed among the three classes. The database contain images of 21 different people (men and women), of different races, with different hair cuts and some of them wearing glasses. The database samples were manually classified into categories “A”, “B” or “C” according to where people were looking at. All the images are

gray-scale and 48x40 sized.

Since the information contained in the patterns is redundant, we have applied Principal Component Analysis (PCA) to reduce the data dimensionality. PCA (Henry and Dunteman, 1989) is a technique widely employed for dimensionality reduction able to retain those characteristics of the data set that contribute most to its variance, by keeping lower-order principal components and ignoring higher-order ones. Such low-order components often contain the “most important” aspects of the data. The more high-order characteristics we remove, the faster the process of training and estimation. However, it is important to use a number of characteristics that allow us to achieve good results without affecting our need to have real time results. We made some tests with different number of characteristics and we determined that 50 characteristics allowed a good trade-off between classification accuracy and computing time.

The training process has been carried out using SVM. For that purpose, we have employed the libsvm library (free software available in Internet (Chang and Lin, 2006)). For more information about SVM, the interest reader is referred to (Cristianini and Shawe-Taylor, 2000). To certificate that results were satisfactory before applying the model we trained the SVM with 85% of the data set and kept the remainder 15% to test the model generated. The result on the test set was of 93.14% of accuracy.

Our system estimates the attention of each detected person in real time despite of his/her movements. For that purpose, the head location in the camera image of each person is determined using the techniques described in Sect. 2. The head region of each person is resized to 48x40 pixels and then, the first 50 principal components are extracted and passed to the SVM classifier.

SVM estimates the head pose in one of the three categories previously indicated. However, the classifier output is an instantaneous value that does not take into account past observations. In order to consider past observations, we define the variable $HP_{(t)}$ as:

$$HP_{(t)} = \alpha HP_{(t-1)} + (1 - \alpha) SvmOut_t \quad (1)$$

where $SvmOut_t$ is defined on the basis of the classifier output as:

$$SVMOut_t = \begin{cases} 1 & \text{if current output of SVM = "A";} \\ 0.5 & \text{if current output of SVM = "B";} \\ 0 & \text{if current output of SVM = "C".} \end{cases}$$

In Eq. 1, α is a weighting factor that ponders the influence of past observations. In this work we set

$\alpha = 0.3$ that is sufficient to avoid abrupt variations and isolated pose estimation errors.

To deal with the uncertainty and vagueness in this process we use a linguistic variable called “Attention” and divide it into “High”, “Medium” and “Low” values (see Fig. 2). This variable will take as input values the measures of face attention estimation considered by HP (Eq. 1). In figure 2 it is possible to see the labels for the variable “Attention”.

3.2 Fuzzy System for Interest Estimation

Once the three linguistic variables have been defined, the rules base that integrates them are explained in this section. The idea that governs the definition of the rules base is dominated by the value of the variable *Attention*. If the attention has an high value the possibility of interest is also high depending on the distance and the angle of the person to the robot. If the attention is medium then the possibility of interest has to be decrease but like in the former case depending on the distance and angle. Finally if the attention is low, it means that the person is not looking at all to the area where the robot is located and the possibility of interest is defined as low or very low depending on the other variables. The rules for the case in which *Attention* is High are shown by Table 1. The other cases are expressed in a similar way using the appropriate rules. The output linguistic variable is *Interest* that has the five possible values shown by Figure 2(d).

Table 1: Rules in the case of high Attention.

IF			THEN
Attention	Distance	Angle	Interest
High	Low	Left	High
High	Low	Center	Very High
High	Low	Right	High
High	Medium	Left	Medium
High	Medium	Center	High
High	Medium	Right	Medium
High	High	Left	Low
High	High	Center	Medium
High	High	Right	Low

Finally to compute the value of possible interest, a fuzzy inference process is carried out using the operator minimum as implication operator. Then the output fuzzy sets are aggregated and the overall output is obtained. The overall output fuzzy set can be understood as a possibility distribution of the interest of the person in the $[0, 1]$ interval. Therefore values near to 1 mean a high level of interest and vice versa.

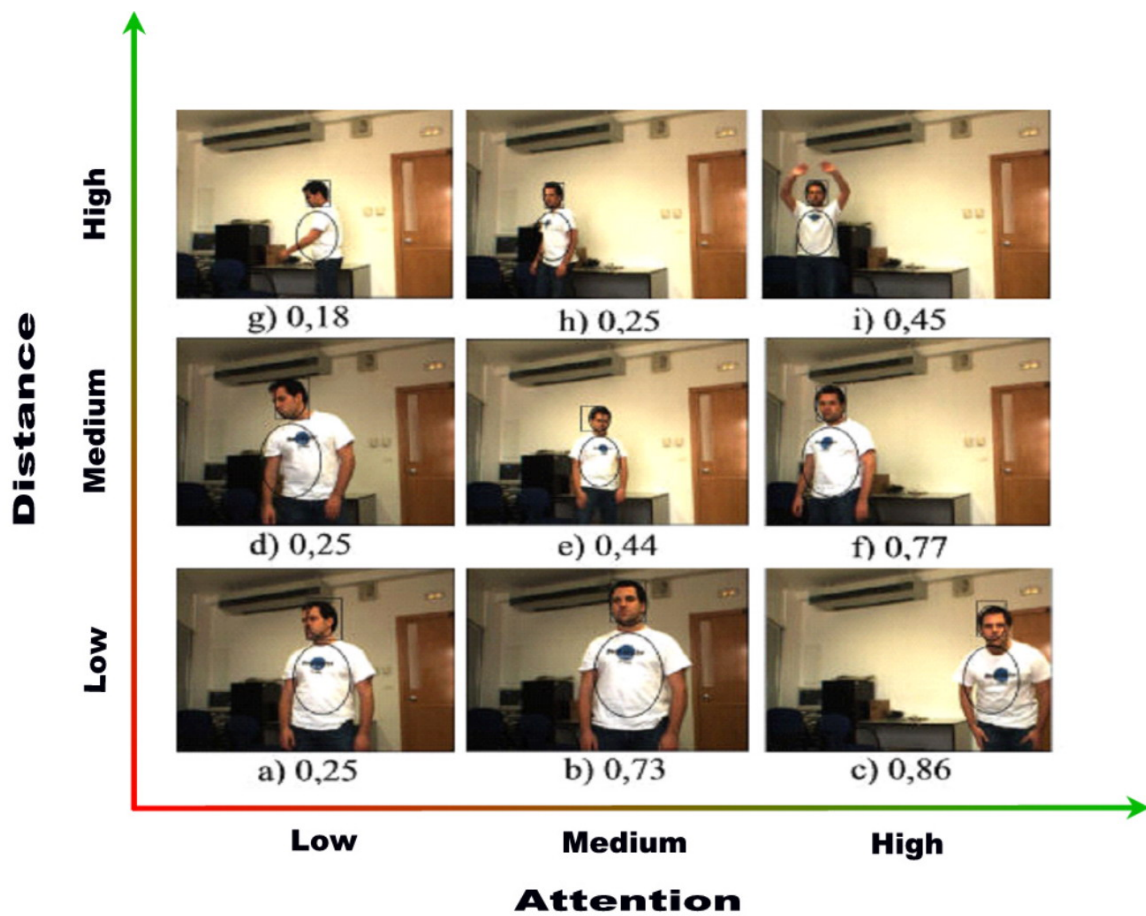


Figure 4: Interest according distance and attention. Frames in each row (*a, b* and *c*), (*d, e* and *f*) and (*g, h* and *i*) show the person at different distances while frames in each column (*a, d* and *g*), (*b, e* and *h*) and (*c, f* and *i*) show the person with different attention.

4 EXPERIMENTATION

A broader experimentation has been done to validate our system. All of these experimentations results were very satisfactory in respect to interest estimation using our system. Because of space reasons we opted to describe in detail only one of the experimentations. To perform the stereo process we have used images of size 320x240 and sub-pixel interpolation to enhance the precision in the stereo calculation. The operation frequency of our system is about 30 Hz without considering the time required for stereo computation.

Regarding the interest estimation, we have checked that the interest degree assigned to each tracked person increases and decreases dynamically accordingly to the behavior of the person in relation to the robot. To test it, one person has been recorded moving in front of the robot in a manner that it was possible to have frames of the person in all the situations regarding “Attention” and “Distance”. Frames

from this video can be seen in Fig. 4. In this figure, frames *a, b*, and *c* show the person close to the robot (“Low Distance”) and looking in different ways. Interest is higher when when person looks towards the robot. In frames *d, e* and *f* it is possible to observe the same situation but at a higher distance (“Medium Distance”). Therefore the final interest value computed is slightly lower. In frames *g, h* and *i* we have the same person in the same situations (in respect to where he is looking at) but at even a higher distance from the robot. Therefore the final interest value computed is even lower. It is also possible to observe that when the person is looking approximately the same way (in frames *a, d, g* person is showing low attention, in frames *b, e, h* person is showing medium attention and in frames *c, f, i* he is showing high attention) interest varies usually according distance. The closer to the robot the higher the interest.

As it was expected, the higher value of interest

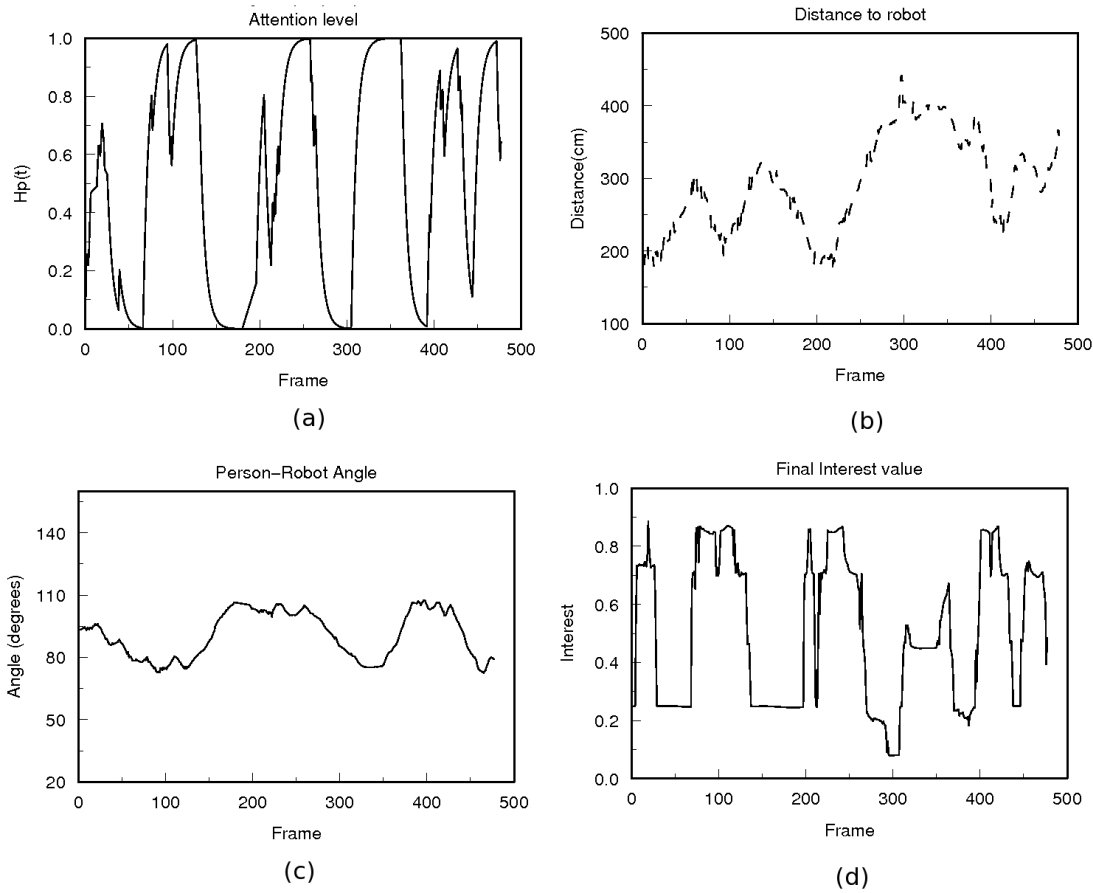


Figure 5: Graphs that show the variation of variables “Attention” (a), “Distance” (b), “Angle” (c) and “Interest” (d) during the video referred in Section 4.

is achieved in frame *c*, because the person is looking directly at the robot and it is very close to it. On the other hand, in frame *g* the person is not paying any attention to the robot, moving at a distance far-away from it. Therefore the lowest interest value is achieved in this frame.

It is also possible to observe in the graphs showed in Fig. 5 the variation of variables “Attention”, “Distance” and “Angle” in Fig. 5.a, Fig. 5.b and Fig. 5.c respectively during the whole video. The fourth graph Fig. 5.d is the interest computed also for the whole video. It is also possible to observe in these graphs the relationship among the interest computed and the other variables.

In order to better understand the performance of the system, several videos are available in the following web site <http://decsai.ugr.es/~ruipaul/interest.htm>.

5 CONCLUSIONS AND FUTURE WORK

In this paper we have shown a system for detecting, tracking and estimating the interest of the people in the surroundings of a mobile robot, using stereo vision, head pose estimation by SVM and fuzzy logic. As a first step, the method for people detection and tracking has been briefly shown. While a person is being tracked, the fuzzy system computes a level of possibility about the interest that this person has in interacting with the robot. This possibility value is based on the position of the person in relation with the robot, as well as on an estimation of the attention that the person pays to the robot. To examine the attention that a person pays to the robot we analyze in real time the head pose of the person. This analysis is solved by a view based approach using Support Vector Machines. Thanks to SVM head pose can be detected achieving a great percentage of success that

is no dependent of the morphological features of the heads. The experimentation shows that the system is able to detect the persons present in its vicinity, track their motions and give a value of possible interest on the interaction of the persons with the robot.

The proposed method can be easily updated in future works to analyze other types of input data as sounds or laser range finder. Also, the degree of interest will be useful to plan the actions of the robot towards the persons in order to allow a more natural human-robot interaction.

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