PERSON FOLLOWING BEHAVIOR GENERATED WITH JDE SCHEMA HIERARCHY*

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Abstract: One useful capability for service robots is person following. Service robots, like other autonomous robots, are demanded to exhibit a full range of different behaviors. A control architecture is required to integrate them. This paper describes the design and implementation of the person following behavior within JDE architecture, as two groups of concurrent schemas. The robot follows a person wearing a coloured shirt, actively searches for her when lost in the image, and safely avoids obstacles. Successful experiments with a real robot are also described, that validate JDE for this vision-based real-time behavior.

1 INTRODUCTION

Robots are entering at homes. The Aibo robot from Sony, sold as a pet, and the Roomba autonomous vacuum cleaner from i-Robot are two real samples, both best sellers. For service robots it is desirable to exhibit a whole set of different behaviors and to unfold them accordingly to situation and goals. Their control architectures are responsible of such ability.

Follow person behavior is part of a natural human-robot interface for service robots. This paper faces the generation of a such behavior with a hierarchical control architecture based in schemas. This application has been already solved (Kleinehagenbrock et al., 2002; Fritsch et al., 2004; Schlegel et al., 1998; Sidenbladh et al., 1999) with real robots. The added value of this paper is its implemention within a perception-control architecture, named JDE (Cañas and Matellán, 2002), which is designed to ease the integration of other behaviors into the same system. Such vision-based, soft real time behavior poses a challenge and is a good test for JDE architecture.

Our solution uses shirt color as the person main feature. It does not perform any face recognition because when the robot is following a person, it mainly sees her shoulder. The robot must follow the tracked person while avoiding bumping with her or with other obstacles.

Second section of this paper briefly details the design and implentation of the behavior. Experiments with a real robot are shown in third section. Finally, conclusions of the work are presented.

2 PERSON FOLLOWING DESIGN WITH JDE-SCHEMAS

The behavior is oriented to a robot endowed with monocular vision over a pantilt unit, which can guide the camera at will in any orientation. The general design of this behavior includes two groups of schemas that run concurrently, as can be seen in figure 1. The first group reactively controls the movement of the pantilt unit that guide the camera to visually follow the person, keeping her at the center of the image by means of fast saccadic movements. The second group reactively controls the robot's base to align it with the pantilt unit.

Visual tracking schemas

The visual tracking is performed with three schemas: `color-filter`, `center` and `search`. The camera data are processed by the `color-filter` schema, which determines the presence and position of the person in the images. If the target person ap-

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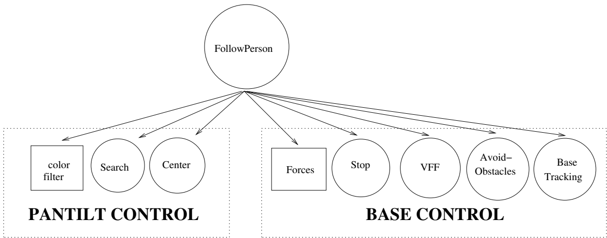

Figure 1: JDE-schemas for person following behavior

pears inside the frames then the `center` schema will move the pantilt to keep the person centered. If she does not appear, then the `search` schema will move the pantilt around to look for the lost target.

The perceptive schema `color-filter` detects the presence of the person in the camera images using a HSI color filter. It is always in ACTIVE state. Its input are such camera images. As output it builds three dynamic stimuli which will be used by `center` and `search` in their control decisions, and in the Action Selection between `center` and `search`. First, a boolean variable (`presence`) indicates the presence or absence of the person in the frame. If the number of pixels complying the color filter exceeds a threshold then the `presence` variable is set to true. Second, the location of such person in the image (`position` variable) is computed as the center of masses of all the pixels complying the color filter. And third, it stores in the `side` variable whether the target appears in the left or right side of the frame.

The `center` schema is an actuation one which moves the pantilt in order to keep the target person close to the center of the camera images. It accepts `position` as input, and its output are the pantilt commands. The preconditions of this schema will hold whenever the `presence` variable is true. It follows the feedback control shown at figure 2, proportional for pan axis, constant in tilt axis, and with a dead band to avoid jitter. For instance, if the target appears in the right side of the image, the pantilt will rotate to the right.

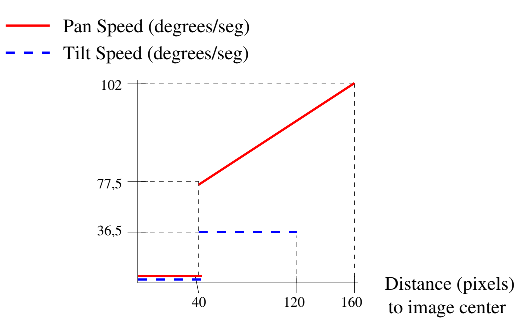

Figure 2: Proportional control in `center` schema

The `search` schema is an actuation one which moves the pantilt horizontally to look around, searching for the lost target person. Its output are the pantilt movement commands and its preconditions will hold whenever the `presence` variable is false, so the robot has lost its target person. This search begins turning the pantilt towards the last side (`side`) of the image where the person target was seen. If the person appeared in the right side before she was lost, the pan will rotate to the right. When it reaches the maximum angle, it rotates in the opposite direction.

Base tracking schemas

When moving the robot body both the target person and the obstacles must be taken into account. The behavior design with JDE-schemas is displayed in figure 3: Without objects around, the `base-tracking` will be activated; Otherwise `stop`, `avoid-obstacle` or `vff` will be activated depending on the distance to obstacles.

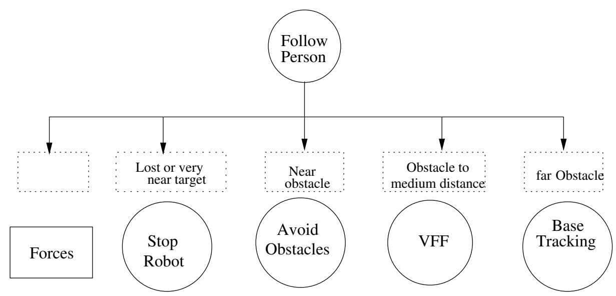

Figure 3: Schemas for robot base movement

The robot navegation is based on repulsive forces from the obstacles and attractive forces towards the target. The `forces` schema builds and keeps updated such forces, which are the input stimuli for the actuation schemas. It is always in ACTIVE state. The obstacles are detected reading the measurements of sonar sensors. The relative angle between the target person and the robot's heading is indirectly measured in the current position of pan motors.

The `stop-robot` schema stops the robot when the target has been lost or it is too close to the robot. Its output are speed commands to the motors of the robot base. The presence of the person in the image is read from the aforementioned `presence`. To detect that the target is near, we count the rows in the image with pixels similar to the color of the target person. If such count exceeds a given threshold, then the target person is already very close to the camera. This tecnique is robust to different person orientations.

When there is an obstacle too close to the robot, then the `avoid-obstacles` schema stops the robot and it rotates until it finds an free space in front.

Figure 4: Security region for `VFF` and `avoid-obstacles` schemas

Its input are the sonar readings and its output are the speed commands to base motors. Its precondition is the presence of close obstacles, those inside the security region in figure 4.

When the closest obstacle around the robot is at medium distance, then the `vff` schema will lead the robot avoiding such obstacle and advancing towards the target person. This actuation schema use Virtual Forces Field algorithm (Borenstein and Koren, 1991), to choose a compromise solution among both trends. Its precondition is the presence of objects inside the security region in figure 4, which is wider than that of `avoid-obstacle` schema.

When the target person is detected in the images and there is no obstacle in such direction, then the `base-tracking` schema will lead the robot towards the target person. The position of pantilt is the basic input of this schema, and is read from the pantilt encoders. The angular deviation of pantilt, read from pantilt encoders, indicates the direction to follow the target. A proportional control is implemented by this schema, similar to that of `center` schema, but with the base motors, which are slower than the pantilt ones. It also has a dead band, of 20 degrees.

Combination into global behavior

The concurrent execution of the described schemas provides the pursuit behavior of the robot. They are grouped together as children of the `follow-person` behavior, which encapsulates the desired functionality in a schema interface. This schema is the ultimate responsible for the whole pursuit behavior. In our experiments its activation comes from the human operator through the graphical interface of the application.

Following the design in figure 1, it will awake eight children at the begining, separated in two independent groups of schemas. All the schemas run concurrently, some of them in CHECKING state, some on READY state and one per group in ACTIVE state. There will be continuous competitions inside each group to control the pantilt and base motors respectively. Only one winner is allowed per group. In the visual tracking group, the `search` and `center` schemas will alternatively win, depending on the presence of the target person in the image. In the base tracking group, hopefully there will be no obstacle around and the `base-tracking` schema will be ACTIVE most of the time. There may be control overlaps, as the preconditions of `vff` and `avoid-obstacles` schemas may be fulfilled simultaneously. Cautiously, the last one has priority over `vff`.

Regarding the perception side of the behavior, the color filtering and force computations are performed *only* when `follow-person` is ACTIVE. This is a simple example of an attention mechanism.

3 EXPERIMENTS

The presented hierarchy of schemas for person following has been programmed and tested under different conditions on a pioneer robot[2]. The target person weared a green T-shirt during the tests, and so the target color was dark green.

Figure 5: Obstacle avoidance while pursuing target

In the experiments the robot successfully followed the target along our university corridors and halls. The target person constinuously moved from left to the right while the robot followed her smoothly. Along the typical pursuit in the corridors, the robot properly followed the target, alternating `vff` and `base-tracking` schemas in ACTIVE state. The target was continuously tracked by the pantilt unit.

The designed avoidance strategy depends on the obstacle proximity. When possible, robot avoids the obstacle without stopping, as can be observed in figure 5 when robot avoids a non-target person on the corridor. If obstacle is very close, robot stops and turns. When clearance is achieved robot starts moving towards the target again. Tracking the target during the avoidance maneuver is possible because the pantilt movement is decoupled from robot base movement.

[2] Some videos of the experiments are available at the web, http://gsyc.escet.urjc.es/jmplaza/research-vision.html

Figure 6: Target lost, searched and recovered

Due to occlusions that may be caused by corners at the end of corridors or obstacles, robot can lose the target. An example of the robustness of target recovering strategies can be seen in figure 6, when the target person disappeared from the camera images. Then the visual tracking schemas switched from `center` to `search`, rotating the pantilt unit to the right, looking for the lost green T-shirt. Robot stopped the motors (`stop-robot`) and initiated the search with the pantilt, rotated in the horizontal axis looking in the last known target position. This searching method have proved to quickly recover the target.

Figure 7: Robot keeps the distance using only vision

Maintaining a safe distance between robot and target is a key question in person following as we don't want the robot to bump into the human. As can be seen in figure 7, the designed behavior detects the size of the person in the image, and brakes the robot when such size surpasses a safety threshold. There is no explicit distance measurement. The `stop-robot` is then activated, and it continuously checks its precondition. When target moves away from the robot, the schema hierarchy reconfigures itself, activating the `base-tracking` and it starts to pursuing her again.

4 CONCLUSIONS

Person following behavior has been designed and implemented inside JDE as two concurrent groups of schemas. JDE combines several habilities in a small hierarchy: target tracking using a color filter, navigation behavior pursuing the tracked person, avoiding obstacles and mantaining a safe distance.

The robot exhibits good performance in the experiments: it follows the moving target with smooth movements avoiding obstacles and mantaining a safe distance with the tracked person. In addition, when target is lost the robot is able to recover the tracked person quickly.

We are working to introduce new behaviors to test JDE abilities to integrate a larger number of them.

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