

Vision based behaviors for a legged robot

Juan V. Ruiz, Pablo Montero, Francisco Martín, Vicente Matellán

Robotics Lab (GSyC)

Universidad Rey Juan Carlos, Móstoles, España

{jvicente, pmontero, fmartin, vmo}@gsyc.escet.urjc.es

Abstract

This article describes two vision-based behaviors designed for an autonomous legged robot. These behaviors have been designed in a modular way in order to be able to integrate them in an architecture named DSH (Dynamic Schema Hierarchies), which is also briefly described. These behaviors have been tested in office indoor environments and experiments carried out are also described in this paper. The platform used in these experiments has been the Sony AIBO robot. The developed behaviors provide the robot with the *follow wall* and *follow person* capabilities, using as main sensor the robot on-board camera.

1 Introduction

Office environments represent a complex scenario where a robot can perform a lot of useful tasks for humans. This type of environment represents a big challenge for these robots due its complexity incremented and the possibility of human interaction. The robots must be able to perform task as, for example, getting the mail form the mailbox to the addressee's office, guiding across the office to blindly persons, security, etc. Our main research interest focuses on developing architectures which get fully autonomous behaviors in robots. In such a way, the robot could carry out these tasks without human guidance.

Two basic vision-based behaviors are presented in this work for their integration within the DSH architecture[?]. These

behaviors are based in active vision and they have been built and tested in the Sony AIBO robot ERS-210A, shown in figure 1. This robot is equipped with a 352x288 pixel camera located in its head, giving color images at 25 fps. This robot incorporates a 400MHz MIPS processor with 64 MB of main memory. It is also equipped with a wide variety of sensors, such as an infrared sensor located in its head, an acceleration sensor, a vibration sensor, two headphones in both ears, contact sensor in each leg, in its back and in its head. The actuators are 20 servos (3 in each 4 legs, 3 in the ears, 2 in its tail and one in its mouth) and one speaker located in its mouth. The robot is also equipped with a 802.11b wireless card.



Figure 1: Sony AIBO ERS-210A

Both behaviors have been designed using the DSH architecture. DSH is a ethological

inspired, behavior based architecture for robot control which uses dynamic hierarchies of small schemas to generate autonomous behavior. DSH architecture is based on the “schema” idea from Arbib[?] and ideas from ethology for attention and action selection, taking into account engineering and programming issues. Each schema in DSH can be described as an independent module that runs concurrently with another ones. Each schema has several parameters which tune it. It can also be turned on and off. The schemas can be independently designed and they can be reused by another higher level schemas.

This architecture distinguishes between two kinds of schemas: perceptual and motor. The first ones process information the environment. The information obtained is used by motor schemas to generate control commands for locomotion modules, or activation signal for other low level schemas (perceptual or motor) as well as their modulation parameters.

The hierarchies are dynamically built. If a high level motor schema needs use another lower level schema, it activates and setup the lower schema. This low level schema can be motor or perceptual one, and it can activate another lower level schemas and so on.

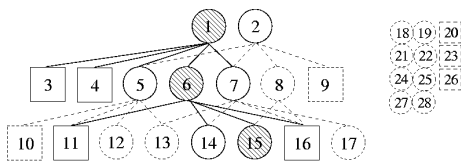


Figure 2: Schema hierarchy and pool of SLEPT schemas

Figure 2 represents a DSH architecture. Circles represents motor schemas and squares perception ones. Only one motor schema can be active in each level. More information about DSH can be found in [?].

In this work we will use the term *behavior* as a collection of schemas that collaborates to obtain a well defined goal. The two behaviors we have implemented are *follow wall* and *follow person*. The *follow wall* [?] behavior can

be used to navigate between rooms following a path, or to patrol the environment. *Follow person*[?] behavior is activated and modulated in order to follow a person.

The main characteristic of the behaviors presented in this work is that they use a camera as the main sensor.

In order to obtain the information required to implement the control schema we have used an HSV segmentation mechanism. We use this color space to avoid the noise produced by the illumination variations[?] and to obtain a robust method for detecting relevant information from an image.

The application has been developed using Sony Open-R framework¹[?] for the AIBO robot. This framework allows us to develop applications divided into several concurrent mono-thread objects with message-passing based communication. This framework also provides abstractions for robot sensors and actuators access. It also let us manage the wireless communication.

Using this framework, DSH schemas can be implemented as Open-R objects in a natural way. Each object can be seen as a concurrent perceptual schema (if it gets information from the environment) or a motion schema (if it produces output for the motion module or it activates and modules another schemas). The activation and modulation is implemented by the message passing communication.

This paper is organized as follows: In section 2 we will describe the *follow wall* behavior. In section 3 will be described the *follow person* behavior for human following. In section 4 will be described the experiments carried out to validate these behaviors., Finally, the results and the future guidelines of this work are discussed in section 5.

2 Follow wall behavior

The environment where the robot must perform its task is made up by corridors and rooms. The robot must be able to navigate from one concrete room to another, or to patrol the environment.

¹<http://openr.aibo.com/>

This behavior has been implemented as two independent schemas: one perceptual schema and one control schema.

The perceptual schema takes images from the camera and extracts useful information (named stimulus), such as the border limit between the floor and the wall. This schema will also be in charge of getting the doors positions.

The control schema receives the stimulus from the perception schema and depending on the mode selected, it can perform two different types of movements:

Following a wall The border line between the floor and the wall is used to determine the distance to the wall. The robot corrects its angular velocity for don't collide with the wall. If there is two border lines, the robot knows it is in front to a corner and it turns to adjust its trajectory.

Following a path The robot uses the border line between the floor and the wall and the door information for following a given path. When the robot completes the path, it stops.

In the following sections we will detail the two schemas developed for this behavior. Perception schema will obtain the information needed from the environment. The control schema will use this information and it will actuate consistently.

2.1 Perception schema

This schema identifies two different stimulus: doors and the border limit between the floor and the wall. Doors are identified too. Border between the floor and the wall is used to determine the distance and angle with the wall. This information will be useful to avoid colliding with the wall.

The identification of the doors in the environment will be used in the path mode as a basic element.

Border detection is made through different consecutive steps. These steps will get the

stimulus from the raw image captured by the on-board camera(Figure 3). These steps are:

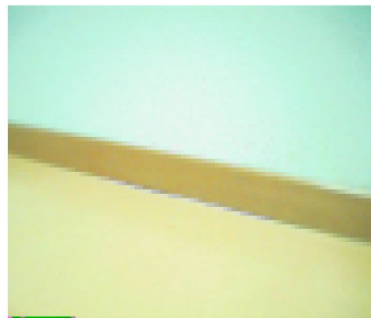


Figure 3: Original image

1. To convert the image from RGB (Red, Green, Blue) to HSV (Hue, saturation, Value) color space. The HSV color space is more convenient due to its robustness to illumination variations. This color space let us decompose the image in a more convenient way for segmentation. Figure 4 shows the HSV components (represented as three different curves) variation from a portion (bottom of the figure) of the original image shown in figure 3.

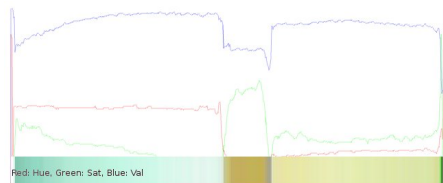


Figure 4: HSV color space

2. Then, the normalized image is filtered using a Sobel convolution filter for getting borders (Figure 5). Matrix M is used to obtain the horizontal borders.

$$M = \frac{1}{2} \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix}$$



Figure 5: Image filtered by the Sobel convolution filter

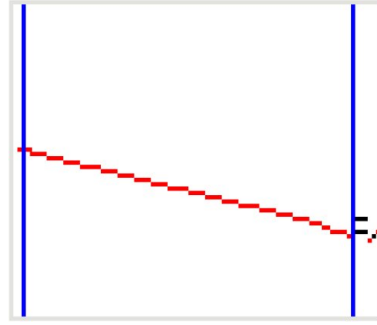


Figure 6: Stimulus extracted from the image

3. Then, the wall and floor pixels are selected from the image. These pixels are the ones whose H and S values are within a range. This range is calibrated off-line in order to classify the pixel right:

$$H_{min} \leq H_{pixel} \leq H_{max}$$

$$S_{min} \leq S_{pixel} \leq S_{max}$$

The V pixel components is not used because this components is the one related to the environment lighting conditions. These conditions are not controlled.

4. The continuous pixels with the same inclination are grouped getting small segments. These segments are grouped again depending on their inclination resemblance for getting just one segment. This segment represents the border limit between the floor and the wall (Figure 6)

The door detection is also performed in similar way as we do in the border line case. The door pixels are the ones whose H and S values, in HSV color space, are within a precalibrated range. Figure 7 shows an original door image. Figure 8 shows the door detection (blue pixels) by color segmentation.



Figure 7: Original image

2.2 Control schema

The control schema will send its output to the AIBO actuators (its legs) in order to follow the wall without colliding with it.

The *follow wall* behavior can be activated in two different modes:

- Following a wall. The *follow wall* mode will make the robot patrol the environment following the walls. Figure 9 shows the trajectory of the robot in this room.
- Following a given path. When activated in this mode, the robot follows a predetermined path. This path has to be previously given by the schema that activates this schema. In the experiments we have used a GUI, that will be described in section 4 for path specification. We have developed a basic

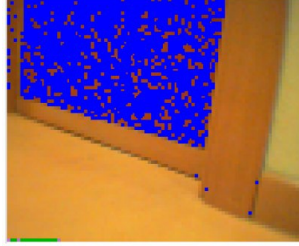


Figure 8: HSV door segmentation

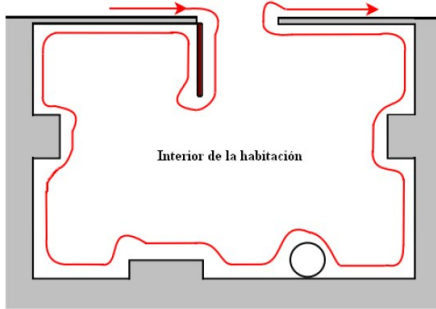


Figure 9: Follow-wall behavior for patrolling

way to specify the path. Paths are specified according to the elements that the robot can detect in the environment. For instance, as the robot is able to find doors, the path could be specified as a sequence of doors. Furthermore, If the robot is able to detect corners, the path will be specified as a doors and corners sequence. In figure 10 a path is specified as a door and corner sequence where the robot must detect two doors and a corner before entering in the third door.

3 Follow person behavior

The *follow person* behavior will be also implemented by two schemas. Obviously, the relevant stimulus in this case are the person and its relative position to the robot. The first schema is a perceptive one, that must detect the person and its position. The second

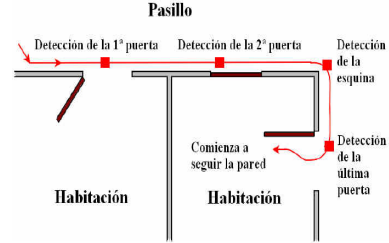


Figure 10: Path followed by the robot

schema is a control one, that sends its output to the robotic platform in order to follow the person at a predetermined distance.

Liveness is the essential requirement in this behavior. The perception schema must get images, analyze them and make the processed information available to the control schema. If the person moves quickly the robot must be able to follow him. If the robot cannot determine the person position, it will spin until it finds again the person.

3.1 Perception schema

The stimulus identified by this schema are the person and the distance to it. We have used the images from the on-board camera and the infrared sensor to implement it. The robot will detect the person using the color of her clothes. Infrared sensor is used to obtain the distance to the person. The robot will try to maintain this distance within a certain value.

Color segmentation of the clothes is made by the robot following these steps:

1. Converting images from RGB (Red, Green, Blue) to HSV (Hue, saturation, Value) color space.
2. The pixels selected in the original image p are the ones whose H and S values are within a range. This range is represent the color clothes we are selecting:

$$H_{min} \leq H_{pixel} \leq H_{max}$$

$$S_{min} \leq S_{pixel} \leq S_{max}$$

3. A new image p' is obtained. This image contains only the filtered pixels. The mass center C for image p' is calculated as follows:

$$C = (C_x, C_y)$$

where,

$$\left. \begin{aligned} C_x &= \frac{\sum_{i=0}^n x_i}{\sum_{i=0}^n 1} \\ C_y &= \frac{\sum_{i=0}^n y_i}{n} \end{aligned} \right\} \forall (x, y) \in p'$$

3.2 Control schema

This schema uses the stimulus developed by the perception schema and adjust the velocity of the robot motors. The robot is continuously tracking the person trying to keep the mass center C of the person in the center of the camera. The robot moves its neck for carrying out this tracking.



Figure 11: The robot stops if the distance is less than 1 meter

Depending on the distance to the person and its angle with respect the robot, this schema sends different outputs to the robot actuators:

infrared sensor < 1 m The robot stops its legs, but it continues tracking the person using its neck (figure 11).

infrared sensor ≥ 1 m The robot moves depending on the neck angle with respect its body:

less than 10° In this case, the robot assumes the person is front of it and it keeps moving straight forward(figure 12),

$$v_{output_{lin}} = v_{lin_{max}}$$

$$v_{output_{rot}} = 0$$



Figure 12: The robot goes forward if the distance is more than 1 meter and the angle is less than 10°

between 10° and 50° The person is moving lightly with respect the robot and it moves and turn simultaneously (figure 13),

$$v_{output_{lin}} = v_{lin_{mid}}$$

$$v_{output_{rot}} = v_{rot_{mid}}$$

more than 50° The person is about to be lost from tracking and the robot must spin quickly (figure 14),

$$v_{output_{lin}} = 0$$

$$v_{output_{rot}} = v_{rot_{max}}$$



Figure 13: The robot spin and goes forward if the distance is more than 1 meter and the angle if between 10° and 50°



Figure 14: The robot spin if the distance is more than 1 meter and the angle if bigger than 50°

4 Experiments

The experiments were oriented to test the behaviors developed in this work. For an easy analysis we have developed a GUI for each of the behaviors. With these GUIs we can test each of the behaviors independently before integrating them in the DSH architecture. These GUIs let us also to activate and to tune these behaviors. GUIs are executed in a Linux based PC that communicates with the robot wireless using TCP. The user can send commands to the robot using these GUIs.

The *follow-wall* behavior GUI (Figure 15) must let the user select between the “following walls” or “following path” modes. If following

path is selected, the user can introduce the path. In this GUI we can also visualize the image from the camera and the information extraction results.



Figure 15: *follow-wall* GUI

The *follow-person* behavior GUI provides an easy method for selecting the colors to follow. The different colors to follow are defined as “channels”. The user can configure 1-8 channels. They define HSV ranges for colors. The channels are configured in the GUI by selecting a channel and clicking in a image pixel. Then, this pixel will be incorporated to that channel, modifying its HSV ranges.

In figure 16 the user has configured two channels. By selecting the first channel and clicking in the person t-shirt the user modifies the HSV filter range for the first channel. The filtered pixels are shown black in the real time image. If the user makes a mistake when clicking and deteriorate the HSV ranges for a channel, he can observe the results in the image and he can undo the last selection. This method let us obtain good results in segmentation, as well as a fast calibration mechanism.

The experimentation process are shown in some videos in our site². These behaviors are currently working in our office environments. The *follow-person* behavior has been tested with a big number of colors and under different lighting conditions. The *follow-wall* behavior has been tested patrolling our office

²<http://gsyc.escet.urjc.es/robotica/pfc/pfc-siguepersona-aibo.html>



Figure 16: *follow-person* GUI

environments and it has been setup with many different paths.

The paths were followed rightly under different lighting conditions as well as under different configurations of opened and closed doors.

5 Conclusions and further work

Two behaviors, *follow-wall* and *follow-person* for a legged robot have been described. They have been successfully implemented complying the schema distribution of DSH. Perception and control have been partitioned into different schemas has been validated. These two behaviors have been implemented using a perceptual schema, which extracted the relevant stimulus for the behavior, and control one, which use this information to decide the correct output to the locomotion module

The local behaviors developed have used an active on-board camera. The behaviors are liveness, responding quickly to changes in the stimulus perceived by the perceptual schemas.

HSV segmentation has been used in order to improve the robust against dramatic illumination changes.

Further works in this area will also focus on adding new behaviors to these robots and improving existing implementations. Once the navigation has been partially solved, we can focus on the development of others behaviors, like *mailman* or *security agent* behavior, could be implemented.

References

- [1] Michael A. Arbib and Jim-Shih Liaw. Sensorimotor transformations in the worlds of frogs and robots. *Artificial Intelligence*, 72(1-2):53-79, 1995.
- [2] Juan Vicente Ruiz Carrillo. Comportamiento de seguimiento de pared con el robot aibo, 2005.
- [3] J. Chamorro-Martínez, D. Sánchez, and B. Prados-Suarez. A fuzzy colour image segmentation applied to robot vision. In *VII Online World Conference on Soft Computing in Industrial Applications*, 2002.
- [4] Vicente Matellán and Jose M. Cañas. Dynamic schema hierarchies for an autonomous robot, September 25 2002.
- [5] Pablo Montero Nóvoa. Sistema de seguimiento basado en visión para el robot aibo, 2004.
- [6] José M. Cañas Plaza. *Jerarquía Dinámica de Esquemas para la generación de comportamiento autónomo*. PhD thesis, Universidad Politécnica de Madrid, december 2003.
- [7] Francisco Martín Rico. Open-r: un enfoque práctico. Technical report, Robotic Lab, GSyC, 2005.