ROBÓTICA INDUSTRIAL

Proyecto Webots

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Índice

- ***Objetivo***

- Aprender a usar Webots y programar el funcionamiento de un robot.
- Nosotros decidimos programar un robot seguidor de línea negra que logre esquivar los obstáculos presentes y regrese al camino marcado.

- ***Procedimiento***

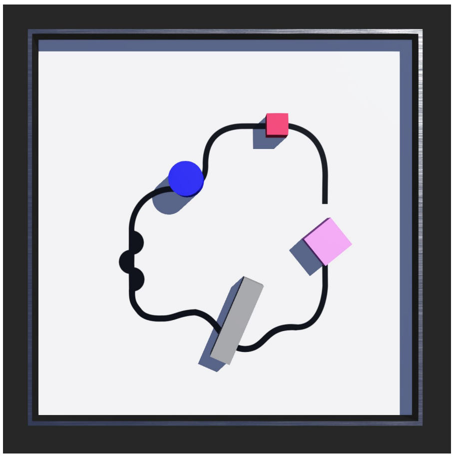
    - *Desarrollo de la Arena*

        - Primero agregamos un Rectangle Arena a nuestro mundo.
        - Después modificamos los siguientes campos dentro de la arena:
            - floor Size: 0.9 0.9
            - floor Tile Size: 0.9 0.9
        - Agregamos una apariencia (PBR Appearance) a nuestra arena y le agregamos una imagen (Image Texture) en el campo base ColorMap.
            - En el campo url es donde vamos a agregar la imagen de la línea negra.

    - *Desarrollo de los Obstáculos*

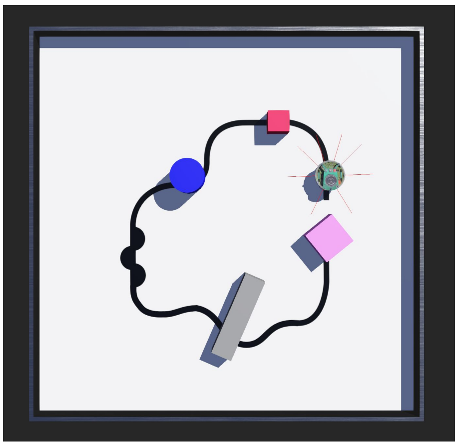
        - Vamos a agregar 4 objetos sólidos (Solid) a nuestro mundo.
        - En el campo de children vamos a agregar una forma (Shape) y posteriormente una apariencia (PBR Appearance) y geometría (Box o Cylinder).
        - Apariencia (PBR Appearance):
            - baseColor: en este caso rojo, azul, gris y rosa
            - roughness 0.5

        - metales 0
    - Geometría: para este proyecto utilizamos dos tipos de obstáculos, cajas y cilindros, y solo modificamos los tamaños y la orientación de estos objetos.
    - En el campo de bounding Object solo agregamos la geometría correspondiente de cada obstáculo.



- *Implementación del Robot E-Puck y sus modificaciones*

    - Agregamos un robot E-puck a nuestro mundo.
    - Después modificamos los siguientes campos del robot:
        - Colocamos al robot sobre la línea negra (translation y rotation).
        - controller: seleccionamos el archivo con el código del robot.
        - ground Sensors Slot: agregamos los sensores (E-puckGroundSensors).



- *Control del robot y sus módulos*

    - Buscamos el código del E-puck correspondiente al seguidor de línea negra.
    - Este código incluye los siguientes módulos:

        - Seguidor de línea (line following module)

            - Este módulo está creado bajo el concepto de los vehículos de Braitenberg. Tiene sensores primitivos (midiendo algún estímulo en un punto) y ruedas (cada una dirigida por su propio motor) que funcionan como actuadores o efectores. El sensor está directamente conectado a un efector, de modo que una señal percibida produce inmediatamente un movimiento de la rueda. Esto quiere decir que parecen esforzarse por alcanzar determinadas situaciones y evitar otras, cambiando de rumbo cuando la situación cambia.

        - Esquivar obstáculos (obstacle avoidance)

            - Este módulo, el E-puck detecta si hay un obstáculo en su camino. Este guarda la información de en qué lado se encuentra el obstáculo y lo esquiva dando la vuelta. Este módulo se activa si se encuentra un obstáculo frente al robot y se desactiva cuando no hay nada que le impida el movimiento.

        - Seguir obstáculo (obstacle following)

            - Esta función se encarga de hacer que el E-puck rodeé al obstáculo que se encuentra en su camino. Aquí el robot tiene una tendencia de girar hacia el lado donde se encuentra el objeto hasta que logra darle toda la vuelta.

        - Regreso a la línea (line entering)

            - Este módulo simplemente se encarga de regresar al E-puck a la línea negra cuando este previamente esquivó un obstáculo que se encontraba en su camino.

        - Main

.

- ***Código del Robot***

```
/*
 * Copyright 1996-2020 Cyberbotics Ltd.
 *
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Version 2.0 (the "License");
 * you may not use this file except in
compliance with the License.
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CONDITIONS OF ANY KIND, either express
or implied.
 * See the License for the specific language
governing permissions and
 * limitations under the License.
 */

#include <stdio.h>
#include <webots/distance_sensor.h>
#include <webots/led.h>
#include <webots/light_sensor.h>
#include <webots/motor.h>
#include <webots/robot.h>

// Global defines
#define TRUE 1
#define FALSE 0
#define NO_SIDE -1
#define LEFT 0
#define RIGHT 1
#define WHITE 0
#define BLACK 1
#define SIMULATION 0  // for
wb_robot_get_mode() function
#define REALITY 2     // for
wb_robot_get_mode() function
#define TIME_STEP 32  // [ms]

// 8 IR proximity sensors
#define NB_DIST_SENS 8
#define PS_RIGHT_00 0
#define PS_RIGHT_45 1
#define PS_RIGHT_90 2
#define PS_RIGHT_REAR 3
#define PS_LEFT_REAR 4
#define PS_LEFT_90 5
#define PS_LEFT_45 6
#define PS_LEFT_00 7
const int
PS_OFFSET_SIMULATION[NB_DIST_SEN
S] = {300, 300, 300, 300, 300, 300, 300, 300};
const int
PS_OFFSET_REALITY[NB_DIST_SENS] =
{480, 170, 320, 500, 600, 680, 210, 640};
WbDeviceTag ps[NB_DIST_SENS]; /*
proximity sensors */
int ps_value[NB_DIST_SENS] = {0, 0, 0, 0, 0,
0, 0, 0};

// 3 IR ground color sensors
#define NB_GROUND_SENS 3
#define GS_WHITE 900
#define GS_LEFT 0
#define GS_CENTER 1
#define GS_RIGHT 2
WbDeviceTag gs[NB_GROUND_SENS]; /*
ground sensors */
unsigned short
gs_value[NB_GROUND_SENS] = {0, 0, 0};

// Motors
WbDeviceTag left_motor, right_motor;

// LEDs
#define NB_LEDS 8
WbDeviceTag led[NB_LEDS];

//------------------------------------------------------
----------------------
//
//    BEHAVIORAL MODULES
//
//------------------------------------------------------
----------------------

//////////////////////////////////////////
// LFM - Line Following Module
```

```
//
// This module implements a very simple,
Braitenberg-like behavior in order
// to follow a black line on the ground. Output
speeds are stored in
// lfm_speed[LEFT] and lfm_speed[RIGHT].

int lfm_speed[2];

#define LFM_FORWARD_SPEED 200
#define LFM_K_GS_SPEED 0.4

void LineFollowingModule(void) {
  int DeltaS = gs_value[GS_RIGHT] -
gs_value[GS_LEFT];

  lfm_speed[LEFT] =
LFM_FORWARD_SPEED -
LFM_K_GS_SPEED * DeltaS;
  lfm_speed[RIGHT] =
LFM_FORWARD_SPEED +
LFM_K_GS_SPEED * DeltaS;
}

//////////////////////////////////////////
// OAM - Obstacle Avoidance Module
//
// The OAM routine first detects obstacles in
front of the robot, then records
// their side in "oam_side" and avoid the
detected obstacle by
// turning away according to very simple
weighted connections between
// proximity sensors and motors. "oam_active"
becomes active when as soon as
// an object is detected and "oam_reset"
inactivates the module and set
// "oam_side" to NO_SIDE. Output speeds are
in oam_speed[LEFT] and
oam_speed[RIGHT].

int oam_active, oam_reset;
int oam_speed[2];
int oam_side = NO_SIDE;

#define OAM_OBST_THRESHOLD 100
#define OAM_FORWARD_SPEED 150
#define OAM_K_PS_90 0.2
#define OAM_K_PS_45 0.9
#define OAM_K_PS_00 1.2
#define OAM_K_MAX_DELTAS 600
```

```
void ObstacleAvoidanceModule(void) {
  int max_ds_value, i;
  int Activation[] = {0, 0};

  // Module RESET
  if (oam_reset) {
    oam_active = FALSE;
    oam_side = NO_SIDE;
  }
  oam_reset = 0;

  // Determine the presence and the side of an
obstacle
  max_ds_value = 0;
  for (i = PS_RIGHT_00; i <= PS_RIGHT_45;
i++) {
    if (max_ds_value < ps_value[i])
      max_ds_value = ps_value[i];
    Activation[RIGHT] += ps_value[i];
  }
  for (i = PS_LEFT_45; i <= PS_LEFT_00;
i++) {
    if (max_ds_value < ps_value[i])
      max_ds_value = ps_value[i];
    Activation[LEFT] += ps_value[i];
  }
  if (max_ds_value >
OAM_OBST_THRESHOLD)
    oam_active = TRUE;

  if (oam_active && oam_side == NO_SIDE)
// check for side of obstacle only when not
already detected
  {
    if (Activation[RIGHT] > Activation[LEFT])
      oam_side = RIGHT;
    else
      oam_side = LEFT;
  }

  // Forward speed
  oam_speed[LEFT] =
OAM_FORWARD_SPEED;
  oam_speed[RIGHT] =
OAM_FORWARD_SPEED;

  // Go away from obstacle
  if (oam_active) {
    int DeltaS = 0;
```

```
    // The rotation of the robot is determined by
the location and the side of the obstacle
    if (oam_side == LEFT) {

//(((ps_value[PS_LEFT_90]-PS_OFFSET)<0)
?0:(ps_value[PS_LEFT_90]-PS_OFFSET)));
      DeltaS -= (int)(OAM_K_PS_90 *
ps_value[PS_LEFT_90]);

//(((ps_value[PS_LEFT_45]-PS_OFFSET)<0)
?0:(ps_value[PS_LEFT_45]-PS_OFFSET)));
      DeltaS -= (int)(OAM_K_PS_45 *
ps_value[PS_LEFT_45]);

//(((ps_value[PS_LEFT_00]-PS_OFFSET)<0)
?0:(ps_value[PS_LEFT_00]-PS_OFFSET)));
      DeltaS -= (int)(OAM_K_PS_00 *
ps_value[PS_LEFT_00]);
    } else {  // oam_side == RIGHT

//(((ps_value[PS_RIGHT_90]-PS_OFFSET)<0
)?0:(ps_value[PS_RIGHT_90]-PS_OFFSET)))
;
      DeltaS += (int)(OAM_K_PS_90 *
ps_value[PS_RIGHT_90]);

//(((ps_value[PS_RIGHT_45]-PS_OFFSET)<0
)?0:(ps_value[PS_RIGHT_45]-PS_OFFSET)))
;
      DeltaS += (int)(OAM_K_PS_45 *
ps_value[PS_RIGHT_45]);

//(((ps_value[PS_RIGHT_00]-PS_OFFSET)<0
)?0:(ps_value[PS_RIGHT_00]-PS_OFFSET)))
;
      DeltaS += (int)(OAM_K_PS_00 *
ps_value[PS_RIGHT_00]);
    }
    if (DeltaS > OAM_K_MAX_DELTAS)
      DeltaS = OAM_K_MAX_DELTAS;
    if (DeltaS < -OAM_K_MAX_DELTAS)
      DeltaS = -OAM_K_MAX_DELTAS;

    // Set speeds
    oam_speed[LEFT] -= DeltaS;
    oam_speed[RIGHT] += DeltaS;
  }
}

//////////////////////////////////////////
// LLM - Line Leaving Module
//
// Since it has no output, this routine is not
completely finished. It has
// been designed to monitor the moment while
the robot is leaving the
// track and signal to other modules some
related events. It becomes active
// whenever the "side" variable displays a
rising edge (changing from -1 to 0 or 1).

int llm_active = FALSE,
llm_inibit_ofm_speed, llm_past_side =
NO_SIDE;
int lem_reset;

#define LLM_THRESHOLD 800

void LineLeavingModule(int side) {
  // Starting the module on a rising edge of
"side"
  if (!llm_active && side != NO_SIDE &&
llm_past_side == NO_SIDE)
    llm_active = TRUE;

  // Updating the memory of the "side" state at
the previous call
  llm_past_side = side;

  // Main loop
  if (llm_active) {  // Simply waiting until the
line is not detected anymore
    if (side == LEFT) {
      if ((gs_value[GS_CENTER] +
gs_value[GS_LEFT]) / 2 >
LLM_THRESHOLD) {  // out of line
        llm_active = FALSE;
        // * PUT YOUR CODE HERE *
        llm_inibit_ofm_speed = FALSE;
        lem_reset = TRUE;
        // * PUT YOUR CODE HERE *
      } else {  // still leaving the line
        // * PUT YOUR CODE HERE *
        llm_inibit_ofm_speed = TRUE;
        // * PUT YOUR CODE HERE *
      }
    } else {
// side == RIGHT
      if ((gs_value[GS_CENTER] +
gs_value[GS_RIGHT]) / 2 >
LLM_THRESHOLD) {  // out of line
        llm_active = FALSE;
```

```
        // * PUT YOUR CODE HERE *
        llm_inibit_ofm_speed = FALSE;
        lem_reset = TRUE;
        // * PUT YOUR CODE HERE *
      } else {  // still leaving the line
        // * PUT YOUR CODE HERE *
        llm_inibit_ofm_speed = TRUE;
        // * PUT YOUR CODE HERE *
      }
    }
  }
}

////////////////////////////////////////////
// OFM - Obstacle Following Module
//
// This function just gives the robot a tendency to steer toward the side
// indicated by its argument "side". When used in competition with OAM it
// gives rise to an object following behavior. The output speeds are
// stored in ofm_speed[LEFT] and ofm_speed[RIGHT].

int ofm_active;
int ofm_speed[2];

#define OFM_DELTA_SPEED 150

void ObstacleFollowingModule(int side) {
  if (side != NO_SIDE) {
    ofm_active = TRUE;
    if (side == LEFT) {
      ofm_speed[LEFT] = -OFM_DELTA_SPEED;
      ofm_speed[RIGHT] = OFM_DELTA_SPEED;
    } else {
      ofm_speed[LEFT] = OFM_DELTA_SPEED;
      ofm_speed[RIGHT] = -OFM_DELTA_SPEED;
    }
  } else {  // side = NO_SIDE
    ofm_active = FALSE;
    ofm_speed[LEFT] = 0;
    ofm_speed[RIGHT] = 0;
  }
}

////////////////////////////////////////////
// LEM - Line Entering Module
//
// This is the most complex module (and you might find easier to re-program it
// by yourself instead of trying to understand it ;-). Its purpose is to handle
// the moment when the robot must re-enter the track (after having by-passed
// an obstacle, e.g.). It is organized like a state machine, which state is
// stored in "lem_state" (see LEM_STATE_STANDBY and following #defines).
// The inputs are (i) the two lateral ground sensors, (ii) the argument "side"
// which determines the direction that the robot has to follow when detecting
// a black line, and (iii) the variable "lem_reset" that resets the state to
// standby. The output speeds are stored in lem_speed[LEFT] and
// lem_speed[RIGHT].

int lem_active;
int lem_speed[2];
int lem_state, lem_black_counter;
int cur_op_gs_value, prev_op_gs_value;

#define LEM_FORWARD_SPEED 100
#define LEM_K_GS_SPEED 0.5
#define LEM_THRESHOLD 500

#define LEM_STATE_STANDBY 0
#define LEM_STATE_LOOKING_FOR_LINE 1
#define LEM_STATE_LINE_DETECTED 2
#define LEM_STATE_ON_LINE 3

void LineEnteringModule(int side) {
  int Side, OpSide, GS_Side, GS_OpSide;

  // Module reset
  if (lem_reset)
    lem_state = LEM_STATE_LOOKING_FOR_LINE;
  lem_reset = FALSE;

  // Initialization
  lem_speed[LEFT] = LEM_FORWARD_SPEED;
```

```
  lem_speed[RIGHT] =
LEM_FORWARD_SPEED;
  if (side == LEFT) {  // if obstacle on left side
-> enter line rightward
    Side = RIGHT;      // line entering direction
    OpSide = LEFT;
    GS_Side = GS_RIGHT;
    GS_OpSide = GS_LEFT;
  } else {        // if obstacle on left side -> enter
line leftward
    Side = LEFT;  // line entering direction
    OpSide = RIGHT;
    GS_Side = GS_LEFT;
    GS_OpSide = GS_RIGHT;
  }

  // Main loop (state machine)
  switch (lem_state) {
    case LEM_STATE_STANDBY:
      lem_active = FALSE;
      break;
    case
LEM_STATE_LOOKING_FOR_LINE:
      if (gs_value[GS_Side] <
LEM_THRESHOLD) {
        lem_active = TRUE;
        // set speeds for entering line
        lem_speed[OpSide] =
LEM_FORWARD_SPEED;
        lem_speed[Side] =
LEM_FORWARD_SPEED;  // -
LEM_K_GS_SPEED * gs_value[GS_Side];
        lem_state =
LEM_STATE_LINE_DETECTED;
        // save ground sensor value
        if (gs_value[GS_OpSide] <
LEM_THRESHOLD) {
          cur_op_gs_value = BLACK;
          lem_black_counter = 1;
        } else {
          cur_op_gs_value = WHITE;
          lem_black_counter = 0;
        }
        prev_op_gs_value = cur_op_gs_value;
      }
      break;
    case LEM_STATE_LINE_DETECTED:
      // save the oposite ground sensor value
      if (gs_value[GS_OpSide] <
LEM_THRESHOLD) {
        cur_op_gs_value = BLACK;
        lem_black_counter++;
      } else
        cur_op_gs_value = WHITE;
      // detect the falling edge
BLACK->WHITE
      if (prev_op_gs_value == BLACK &&
cur_op_gs_value == WHITE) {
        lem_state = LEM_STATE_ON_LINE;
        lem_speed[OpSide] = 0;
        lem_speed[Side] = 0;
      } else {
        prev_op_gs_value = cur_op_gs_value;
        // set speeds for entering line
        lem_speed[OpSide] =
LEM_FORWARD_SPEED +
LEM_K_GS_SPEED * (GS_WHITE -
gs_value[GS_Side]);
        lem_speed[Side] =
LEM_FORWARD_SPEED -
LEM_K_GS_SPEED * (GS_WHITE -
gs_value[GS_Side]);
      }
      break;
    case LEM_STATE_ON_LINE:
      oam_reset = TRUE;
      lem_active = FALSE;
      lem_state = LEM_STATE_STANDBY;
      break;
  }
}

//------------------------------------------------------
-----------------------
//
//    CONTROLLER
//
//------------------------------------------------------
-----------------------

/////////////////////////////////////////////
// Main
int main() {
  int ps_offset[NB_DIST_SENS] = {0, 0, 0, 0,
0, 0, 0, 0}, i, speed[2], Mode = 1;
  int oam_ofm_speed[2];

  /* intialize Webots */
  wb_robot_init();

  /* initialization */
  char name[20];
```

```
  for (i = 0; i < NB_LEDS; i++) {
    sprintf(name, "led%d", i);
    led[i] = wb_robot_get_device(name); /* get
a handler to the sensor */
  }
  for (i = 0; i < NB_DIST_SENS; i++) {
    sprintf(name, "ps%d", i);
    ps[i] = wb_robot_get_device(name); /*
proximity sensors */
    wb_distance_sensor_enable(ps[i],
TIME_STEP);
  }
  for (i = 0; i < NB_GROUND_SENS; i++) {
    sprintf(name, "gs%d", i);
    gs[i] = wb_robot_get_device(name); /*
ground sensors */
    wb_distance_sensor_enable(gs[i],
TIME_STEP);
  }
  // motors
  left_motor = wb_robot_get_device("left
wheel motor");
  right_motor = wb_robot_get_device("right
wheel motor");
  wb_motor_set_position(left_motor,
INFINITY);
  wb_motor_set_position(right_motor,
INFINITY);
  wb_motor_set_velocity(left_motor, 0.0);
  wb_motor_set_velocity(right_motor, 0.0);

  for (;;) {  // Main loop
    // Run one simulation step
    wb_robot_step(TIME_STEP);

    // Reset all BB variables when switching
from simulation to real robot and back
    if (Mode != wb_robot_get_mode()) {
      oam_reset = TRUE;
      llm_active = FALSE;
      llm_past_side = NO_SIDE;
      ofm_active = FALSE;
      lem_active = FALSE;
      lem_state = LEM_STATE_STANDBY;
      Mode = wb_robot_get_mode();
      if (Mode == SIMULATION) {
        for (i = 0; i < NB_DIST_SENS; i++)
          ps_offset[i] =
PS_OFFSET_SIMULATION[i];
        wb_motor_set_velocity(left_motor, 0);
        wb_motor_set_velocity(right_motor, 0);
        wb_robot_step(TIME_STEP);  // Just run
one step to make sure we get correct sensor
values
        printf("\n\n\nSwitching to SIMULATION
and reseting all BB variables.\n\n");
      } else if (Mode == REALITY) {
        for (i = 0; i < NB_DIST_SENS; i++)
          ps_offset[i] =
PS_OFFSET_REALITY[i];
        wb_motor_set_velocity(left_motor, 0);
        wb_motor_set_velocity(right_motor, 0);
        wb_robot_step(TIME_STEP);  // Just run
one step to make sure we get correct sensor
values
        printf("\n\n\nSwitching to REALITY and
reseting all BB variables.\n\n");
      }
    }

    // read sensors value
    for (i = 0; i < NB_DIST_SENS; i++)
      ps_value[i] =
(((int)wb_distance_sensor_get_value(ps[i]) -
ps_offset[i]) < 0) ?
                  0 :

((int)wb_distance_sensor_get_value(ps[i]) -
ps_offset[i]);
    for (i = 0; i < NB_GROUND_SENS; i++)
      gs_value[i] =
wb_distance_sensor_get_value(gs[i]);

    // Speed initialization
    speed[LEFT] = 0;
    speed[RIGHT] = 0;

    // * START OF SUBSUMPTION
ARCHITECTURE *

    // LFM - Line Following Module
    LineFollowingModule();

    speed[LEFT] = lfm_speed[LEFT];
    speed[RIGHT] = lfm_speed[RIGHT];

    // OAM - Obstacle Avoidance Module
    ObstacleAvoidanceModule();

    // LLM - Line Leaving Module
    LineLeavingModule(oam_side);
```

```
// OFM - Obstacle Following Module
ObstacleFollowingModule(oam_side);

// Inibit A
if (llm_inibit_ofm_speed) {
  ofm_speed[LEFT] = 0;
  ofm_speed[RIGHT] = 0;
}

// Sum A
oam_ofm_speed[LEFT] =
oam_speed[LEFT] + ofm_speed[LEFT];
oam_ofm_speed[RIGHT] =
oam_speed[RIGHT] + ofm_speed[RIGHT];

// Suppression A
if (oam_active || ofm_active) {
  speed[LEFT] = oam_ofm_speed[LEFT];
  speed[RIGHT] =
oam_ofm_speed[RIGHT];
}

// LEM - Line Entering Module
LineEnteringModule(oam_side);

// Suppression B
if (lem_active) {
  speed[LEFT] = lem_speed[LEFT];
  speed[RIGHT] = lem_speed[RIGHT];
}

// * END OF SUBSUMPTION
ARCHITECTURE *

// Debug display
printf("OAM %d side %d   LLM %d inibitA
%d   OFM %d   LEM %d state %d oam_reset
%d\n", oam_active, oam_side, llm_active,
      llm_inibit_ofm_speed, ofm_active,
lem_active, lem_state, oam_reset);

// Set wheel speeds
wb_motor_set_velocity(left_motor, 0.00628
* speed[LEFT]);
wb_motor_set_velocity(right_motor,
0.00628 * speed[RIGHT]);
 }
 return 0;
}
```

- ***Conclusión***

- Este proyecto estuvo fácil de realizar después de conocer más acerca de las simulaciones de Webots. El programa fue algo nuevo para nosotros porque nunca lo habíamos utilizado para simular y programar el comportamiento de un robot. Lo más difícil fue a la hora de programar el control del E-puck, ya que el código es muy complejo y sin ayuda de los ejemplos y las simulaciones esto hubiera sido imposible. El programa cuenta con varios ejemplos muy completos que te ayudan bastante a entender el uso de los robots.