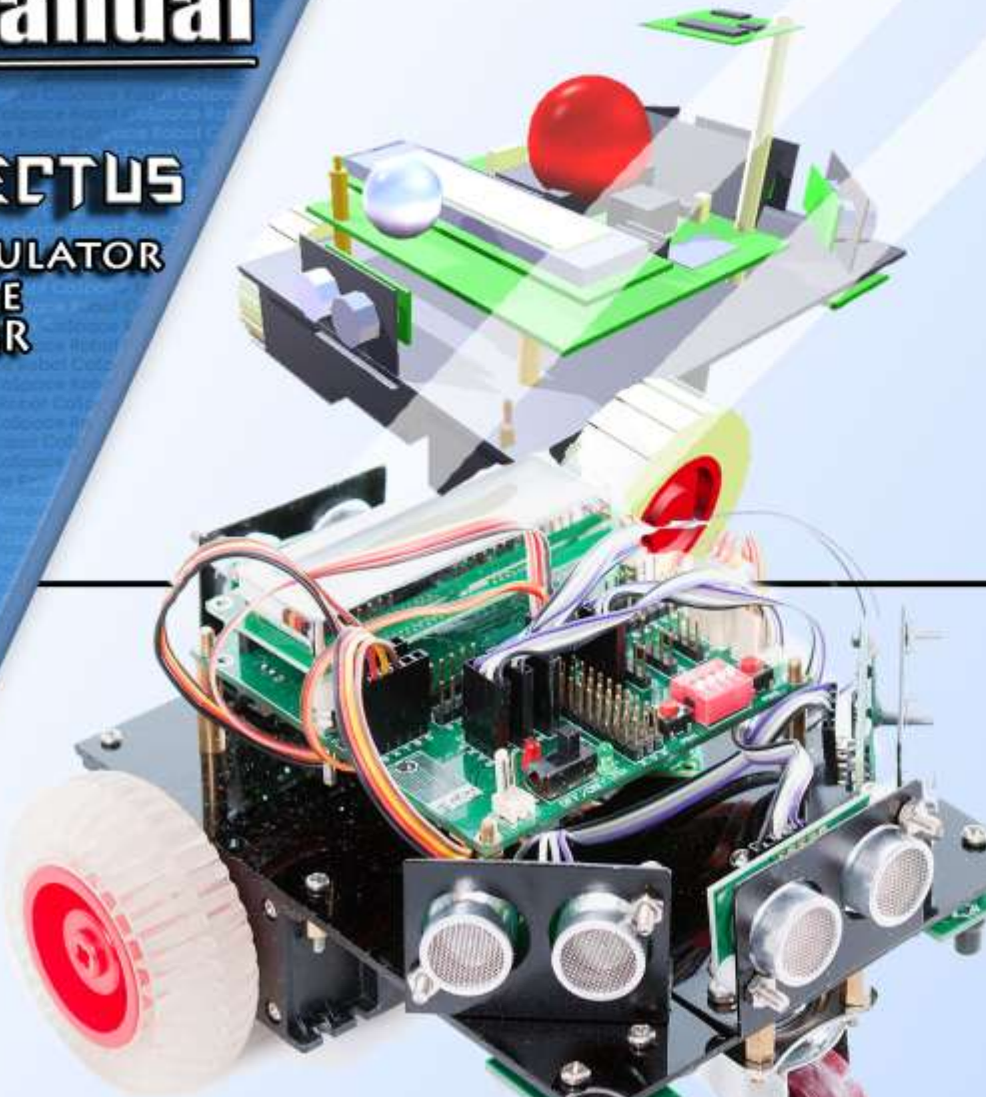
CoSpace Rescue Challenge

User Manual

ROBO ERECTUS

VIRTUAL SIMULATOR SOFTWARE RE-VSS-CSR



RoboCup SINGAPORE

Email : CoSpace@robocupsingapore.org
http://www.robocupsingapore.org/cospace/

Advanced Robotics & Intelligent Control Centre
SINGAPORE POLYTECHNIC

To Create a Learning Environment for Today, and to Foster Understanding Among Humans and Technology for Tomorrow

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1. Introduction

Popular interest in robotics has increased astonishingly in the last few years. Robotics is seen by many as offering major new benefits in education at all levels. Is it a fashion? No. Robots are excellent tools to train students' competency in both academic and workplace. Robotics in Education can enhance their knowledge in science, mathematics, physics, mechanics, and programming, as well as time management, project management, problem solving skills, creativity, and teamwork. Many schools have their own robotics lab for extra curricula activities, but most schools still lack the resources. Students may not be able to own a robot all by themselves. If it can be shown that robotics has sustained potential in education, the virtual robot and easy programming tool will give students an alternative platform for learning in the area of robotics.

Fig. 1 – 1 : Students participating in RoboCupJunior CoSpace Rescue (Demo) Challenge

RoboCupJunior CoSpace Rescue Challenge is an educational initiative to promote knowledge and skills in engineering design, programming, electronic control, and the 3D simulation through robotics for young minds. The CoSpace Challenge aims to fuse real and virtual robotic technologies towards bridging two prominent areas of the future namely, Interactive Digital Media and Robotics.

In CoSpace Rescue (Demo) Challenge – treasure hunt challenge, a treasure map with a list of treasures will be provided to each participating team. The team has to develop appropriate strategies for a virtual autonomous robot to navigate through the treacherous terrain by avoiding obstacles and collecting treasures in the 3D virtual environment while competing with another robot that is performing the same mission. The strategies will then be applied to a real robot to search the treasures in the real world.

2. Microsoft Robotics Developer Studio (MRDS) and Robo-Erectus Virtual Simulator Software for CoSpace Rescue

Microsoft Robotics Developer Studio (MRDS) is a development platform for the robotics community, supporting a wide variety of users, hardware, and application scenarios. MRDS is not a tool to program code that will execute directly on the microcontroller of a robot. Instead, researchers and scientists can use MRDS to develop a user friendly graphical interactive programming interface and virtual environment for their own robots. Students without programming experience can then use the programming interface and virtual environment developed to program and control both real and virtual robots. The high resolution visual simulation environment that integrates 3D software physics supplied by the Ageia Technologies PhysX engine let students have an actual virtual 3D or CoSpace experience.

The virtual robot and the user friendly interactive programming interface – the Virtual Simulator Software for CoSpace Rescue, RE–VSS–CSR, is developed by the Advanced Robotics and Intelligent Control Centre (ARICC), a Technology & Innovation Centre in Singapore Polytechnic. This educational package is powered by Microsoft® Robotics Developer Studio. It gives users an opportunity to work with both virtual and real robots. The RE–VSS–CSR platform provides a venue for users to understand the physical structure, sensors, motors, and the programming of a robot. Students will be able to program a robot to perform its mission in both real and virtual environment using this educational package.

The RE–VSS–CSR offers hands on technological experience to motivate young minds to learn and share knowledge with fellow participants. It also helps in the social and emotional development of the students as they work together in groups and build inter-personal skills required for their successful future in the real world.

3. Visual Simulated Environment

The Visual Simulation Environment (VSE) simulates physical objects and their interactions including collisions, friction and gravity. To launch the RE–VSS–CSR, you need to double click the icon "" on desktop. Fig. 3 – 1 shows the Visual Simulation Environment* (VSE) for CoSpace Rescue. It consists of many virtual entities, such as virtual robots, a rescue arena, ground, sky, sun, and camera (invisible), etc.

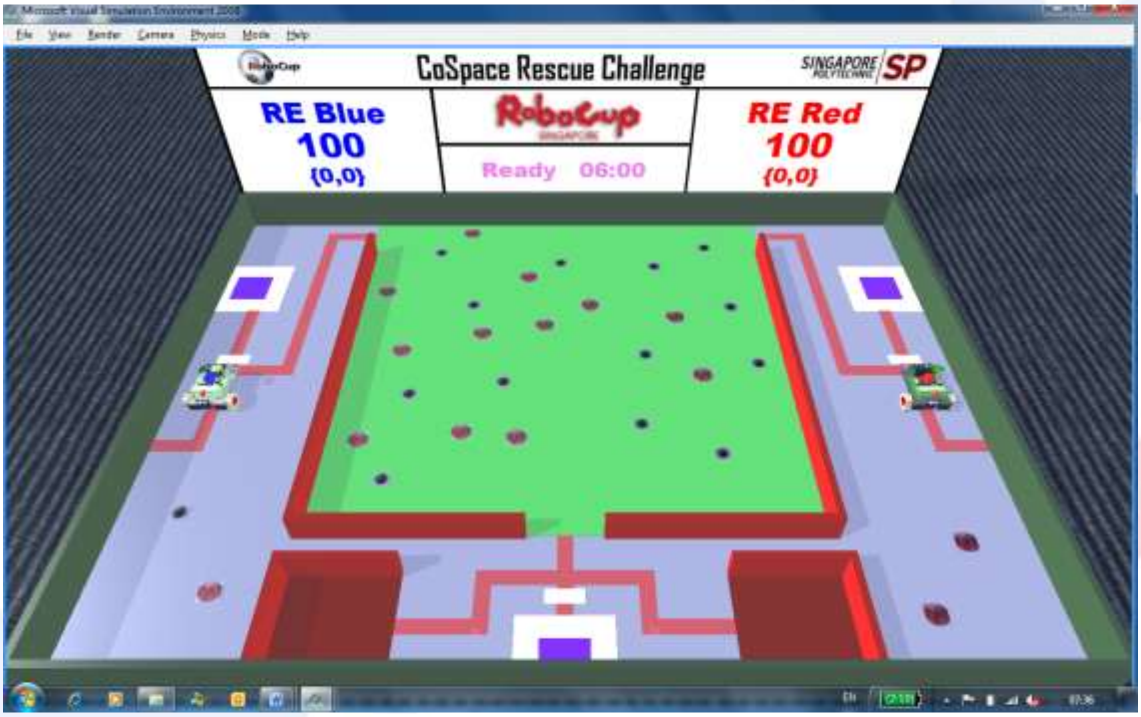


Fig. 3-1: Microsoft visual simulation environment

When the simulator is running in the Visual Simulation Environment, you can move the camera viewpoint by dragging the mouse pointer across the screen. It does not change the camera position but it changes the point that the camera is looking at.

* You will need to fill up a registration form in order to launch the VSE.

The quick user guide for the Virtual Simulation Environment is attached in Appendix A.

4. CoSpace Virtual Robot

The platform supports all types of real robots equipped with the RE-controller board. It can be integrated with Lego brick, Vex components, and other commercial sensors, servos, and motors. The CoSpace virtual robot RE-VWheelie02 is equipped with 4 ultrasonic sensors, 2 colour sensors, and 1 compass sensor as shown in Fig. 4 – 1. They are used to detect obstacles/boundaries, colour objects and direction.

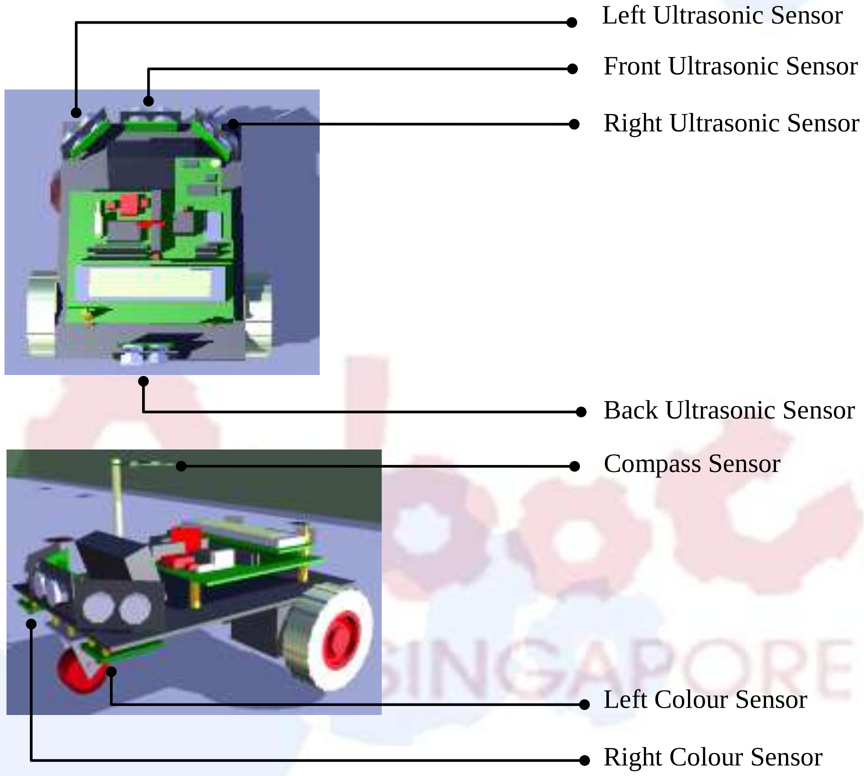


Fig. 4 – 1: CoSpace virtual Robot RE-VWheelie02

5. 3D Virtual Environment

Fig. 5 – 1 shows the 3D virtual environment for the CoSpace Rescue Challenge. It consists of two virtual robots, some obstacles, and a set of different coloured objects. The information centre displays the current date and time, the team name, and the score.

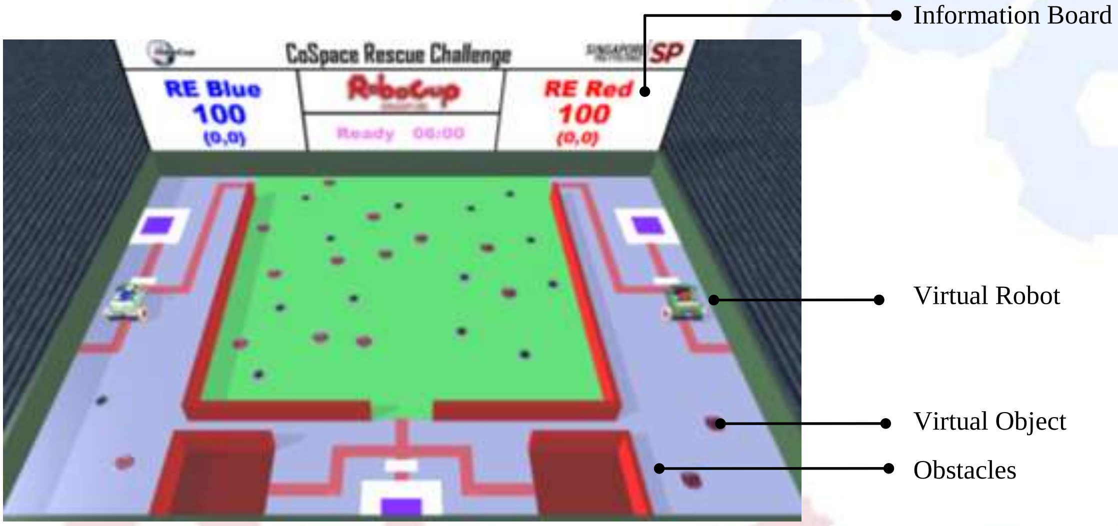


Fig. 5 – 1: RE–VSS–CSR 3D virtual environment

Obstacles

The obstacles are 10cm in height.

Virtual Objects

There are two types of objects – red objects and black objects.

Virtual Robots

Two virtual robots, red robot and blue robot are used to represent two teams.

Information Board

The Information board shows the team name, score, etc

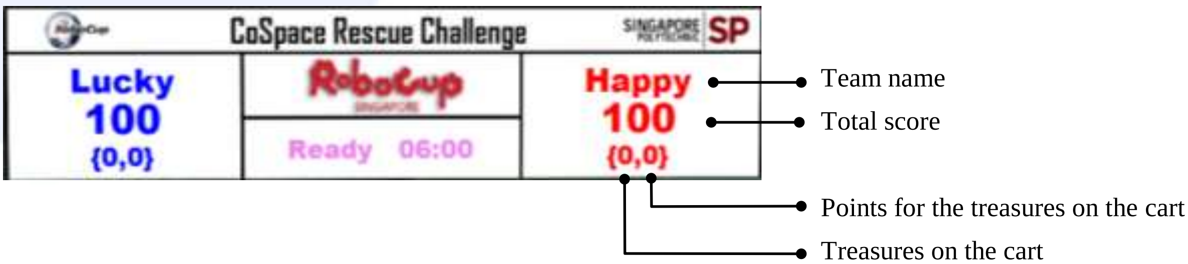


Fig. 5 – 2: Information Board

6. RE-VSS-CSR Control Panel

Fig. 6 – 1 shows the RE–VSS–CSR control panel. The control panel consists of two sub-panels, namely ***Robot Control Panel*** and ***Competition control Panel***.

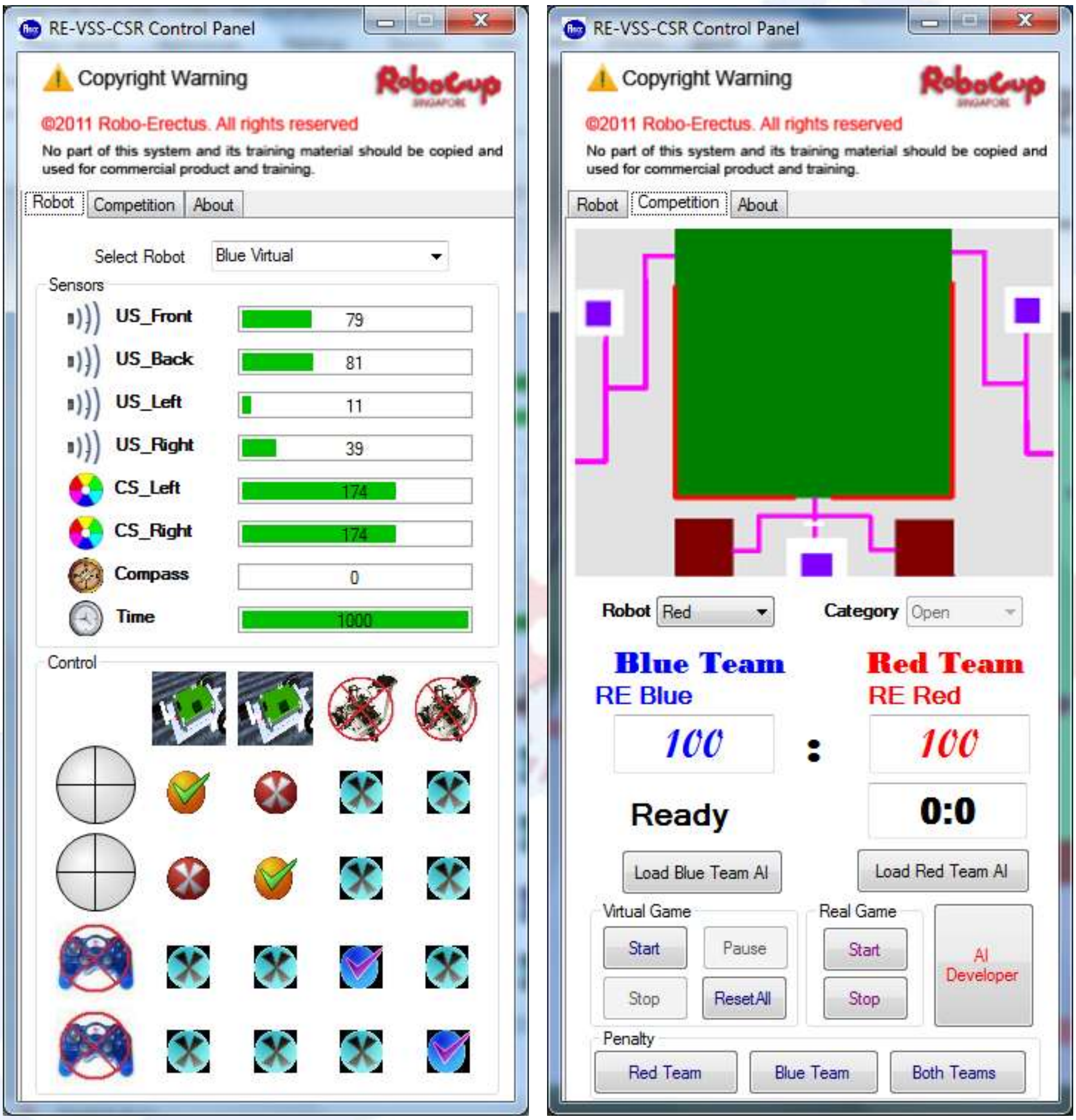


Fig. 6 – 1: RE–VSS–CSR control panel.

6.1 The Robot Control Panel

Fig. 6 – 2 shows the robot control panel. In this panel, you are able to

- View the real-time sensor feedback of a selected robot;
- Control real/virtual robot(s) via dashboard or game controller;

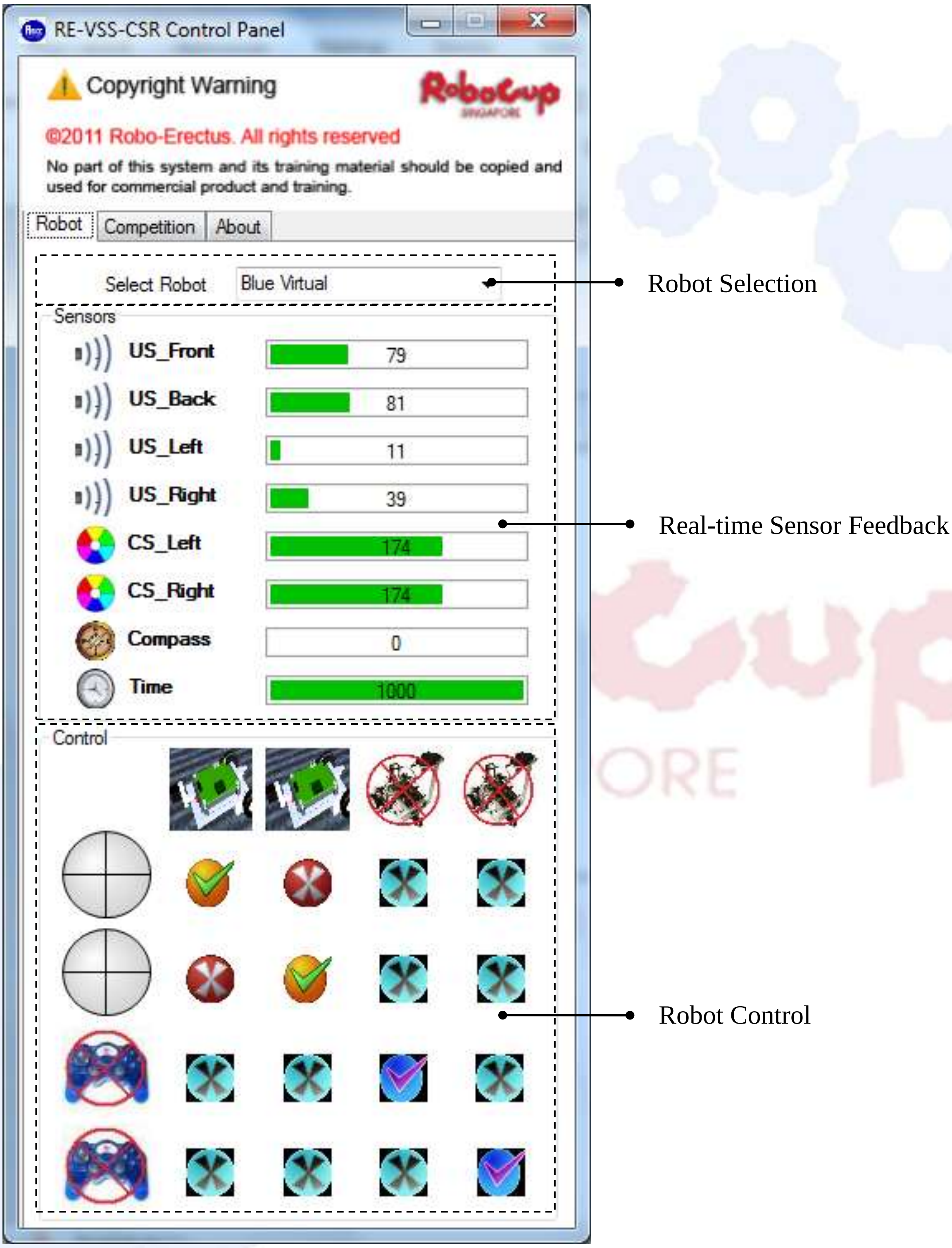


Fig. 6 – 2: RE–VSS–CSR Robot Control Panel

Robot selection

Fig. 6 – 3 shows the robot selection. It allows user to select a robot and view the real-time sensor reading. The real robot will only be selected once it is connected to the server.

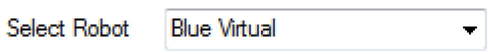


Fig. 6 – 3: Robot selection

Real-time sensor feedback

Fig. 6 – 4 shows the real-time sensor feedback segment. It allows users to monitor the real-time sensor readings when the selected virtual robot navigates through the 3D virtual environment, or the selected real robot moves in the real world.

Fig 6 – 4: Real-time sensor feedback

Robot control

The robot control segment as shown in Fig. 6 – 5 provides the real-time control of virtual/real robots via a build-in dashboard controller and external game controller.

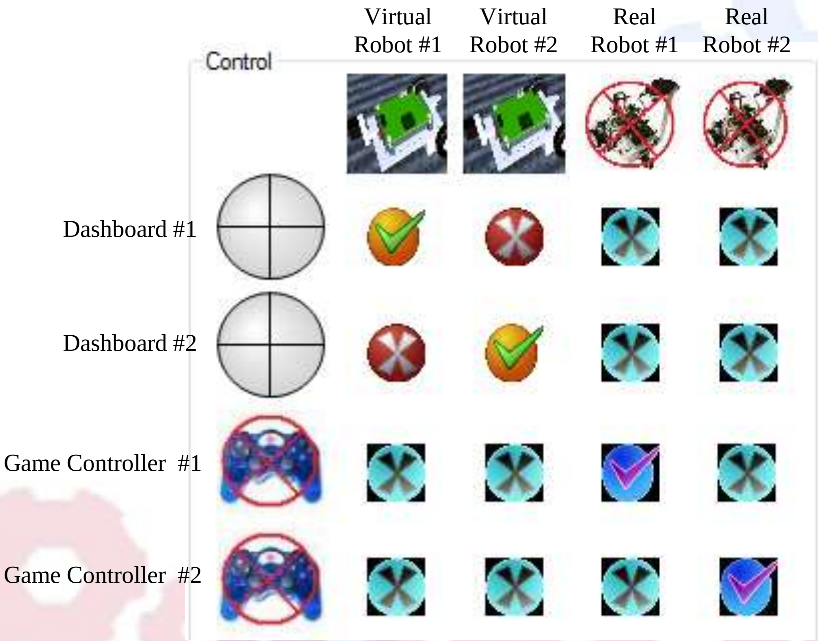


Fig. 6 – 5: Robot control segment

The configuration in Fig. 6 – 5 shows that the virtual robot #1 is controlled by Dashboard #1 and virtual robot #2 is controlled by dashboard #2. If you wish to use Dashboard #1 to control the virtual robot #1 and #2, you just simply click on the corresponding " " which connects virtual robot #1 and #2 and change it to " ". The Dashboard #1 will then controls the virtual robot #1 and #2. The Dashboard #2 will only control the virtual robot #2. Fig. 6 – 6 shows the configuration.

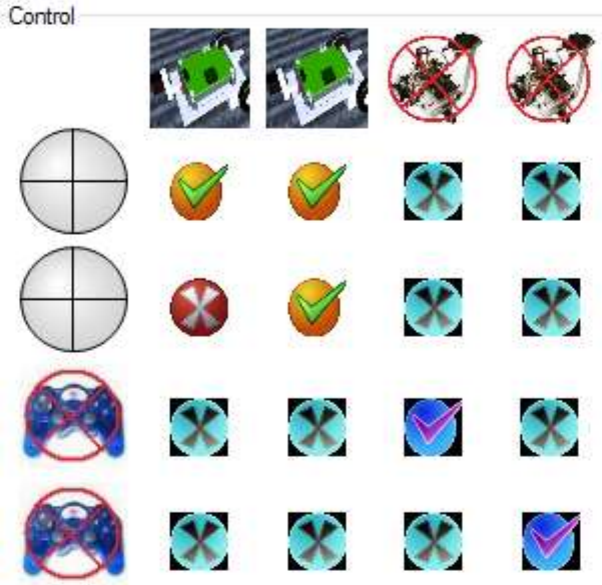


Fig. 6 – 6: Robot control configuration

Fig. 6 – 6 shows that the real robots and game controller are not connected. **Session 10** shows the procedure of connecting a real robot to the CoSpace server.

<u>Dashboard and Game Controller</u>

The dashboard and game controller are used to control both real and virtual robots movement in their corresponding real world and 3D virtual environment. The sensor feedback segment will display the real-time sensor reading during the robots navigation.

6.2 Competition Control Panel

The Competition Control Panel as shown in Fig. 6 – 7 is used for both virtual and real CoSpace Rescue competition.

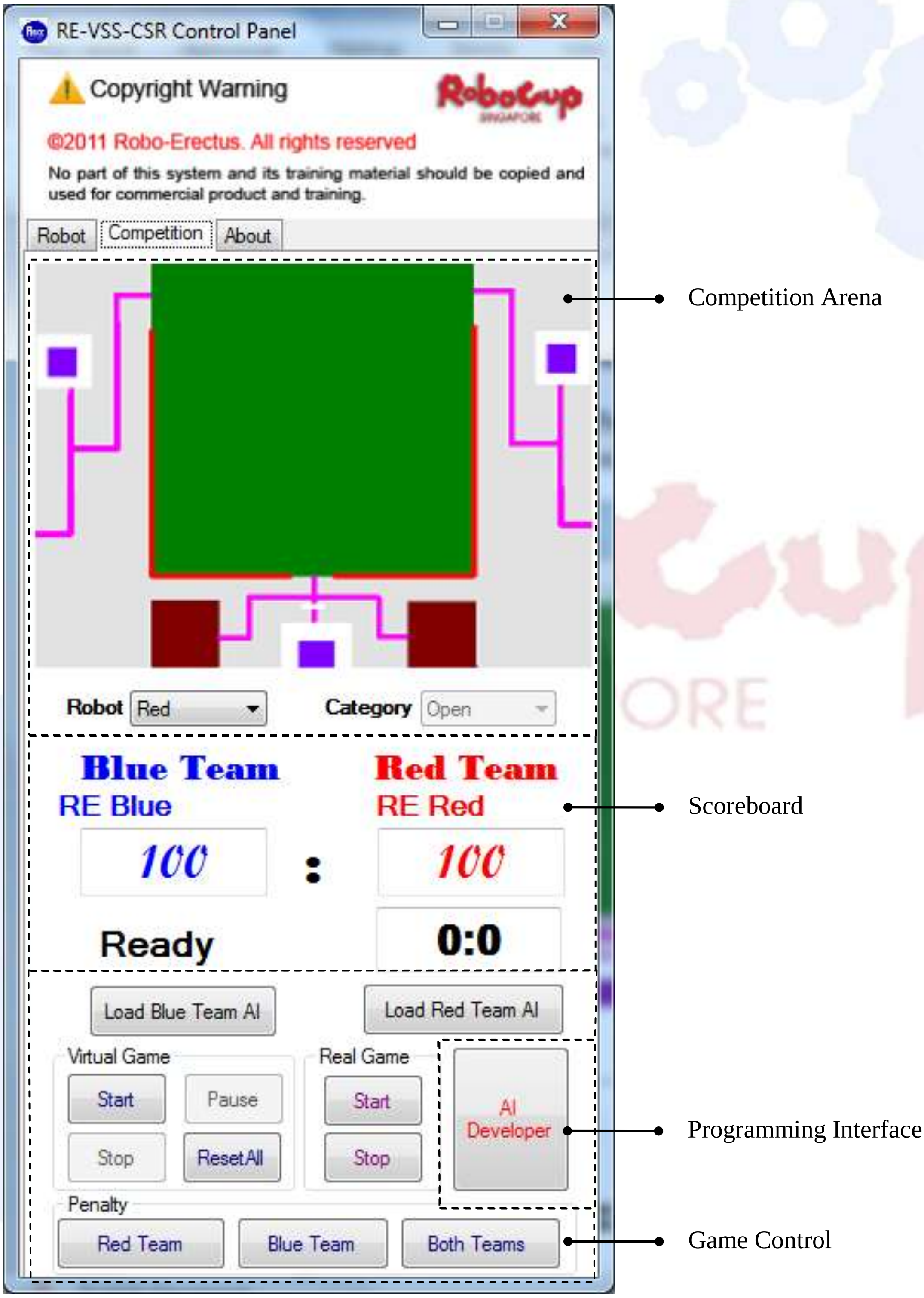


Fig. 6 – 7: Competition Control Panel

Competition arena

The interactive competition arena allows you to place the virtual robot on to the virtual competition arena by clicking at the designated place in the virtual arena. For example, if you choose 

, the red robot will be selected and placed on the respective location in the virtual competition arena.

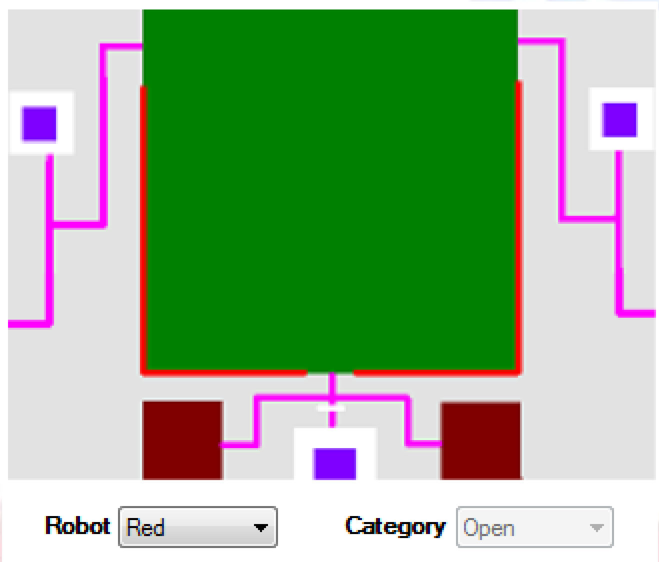


Fig. 6 – 8: Interactive competition arena

Scoreboard

The scoreboard displays the team names, scores, and the running clock.

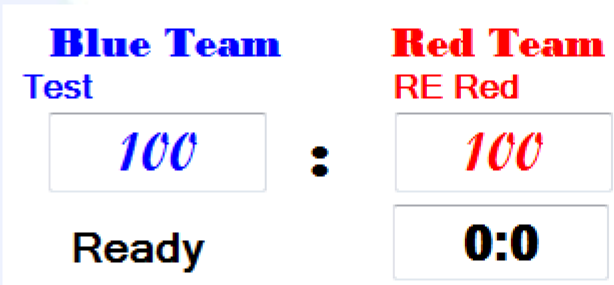


Fig. 6 – 9: Scoreboard

Game control

The game control as shown in Fig. 6 – 10 provides the overall control of the competition. It allows judges to load the AI strategies and run the game.

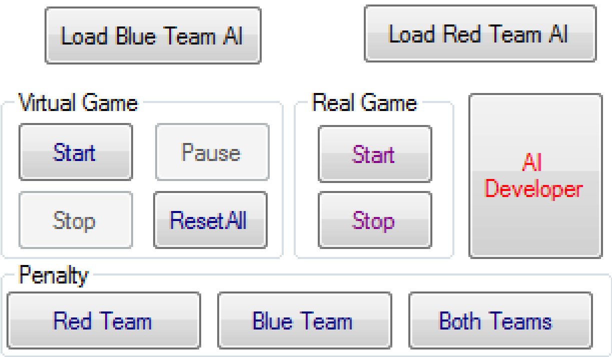


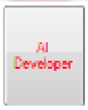
Fig. 6 – 10: The game control

- Load Blue Team AI/Load Red Team AI – to load the AI strategy designated for Blue Team or Red Team. The AI strategy is designed via AI Developmnt Panel. The AI strategy file has an extension of ".dll" as shown in Fig. 6 – 11.

Fig. 6 – 11: Load a AI strategy

- Virtual Game / Start – to start a virtual game.
- Virtual Game / Pause – to pause a virtual game.
- Virtual game / Stop – to stop a virtual game.
- Virtual Game / Reset All – to reset the virtual game. Score will be reset to the initial value.
- Real Game / Start – to start a real robot in the real world. The communication between the server and real robot is via ZigBee communication protocol.
- Real Game / Stop – to stop a real game in the real world.
- Penalty / Red Team – the Red team will receive penalty as described in the rule.
- Penalty / Blue Team – the Blue team will receive penalty as described in the rule.
- Penalty / Both Teams – both teams will receive penalty as described in the rule.

Programming interface

The programming interface 

is to launch the AI development panel.

7. AI Development Panel

7.1 Introduction of AI Development Environment

The RE – VSS – CSR Robot programming uses an event-driven approach. The graphical AI development panel in the RE – VSS – CSR as shown in Fig. 7 – 1 is designed for participants in three different levels.

If you are a new programmer without any programming knowledge and skills, the RE – VSS – CSR provides a perception-action based programming techniques which allows you to write a simple program using the graphical programming interface to control the robot. If you have experience in using Lego NXT, VEX or other robot platforms, your knowledge in programming will help you to program the CoSpace robot with ease as the RE – VSS – CSR provides advanced programming techniques. The RE – VSS – CSR also provides a C++ programming interface which enables professional programmers to test the AI strategy using the CoSpace platform.

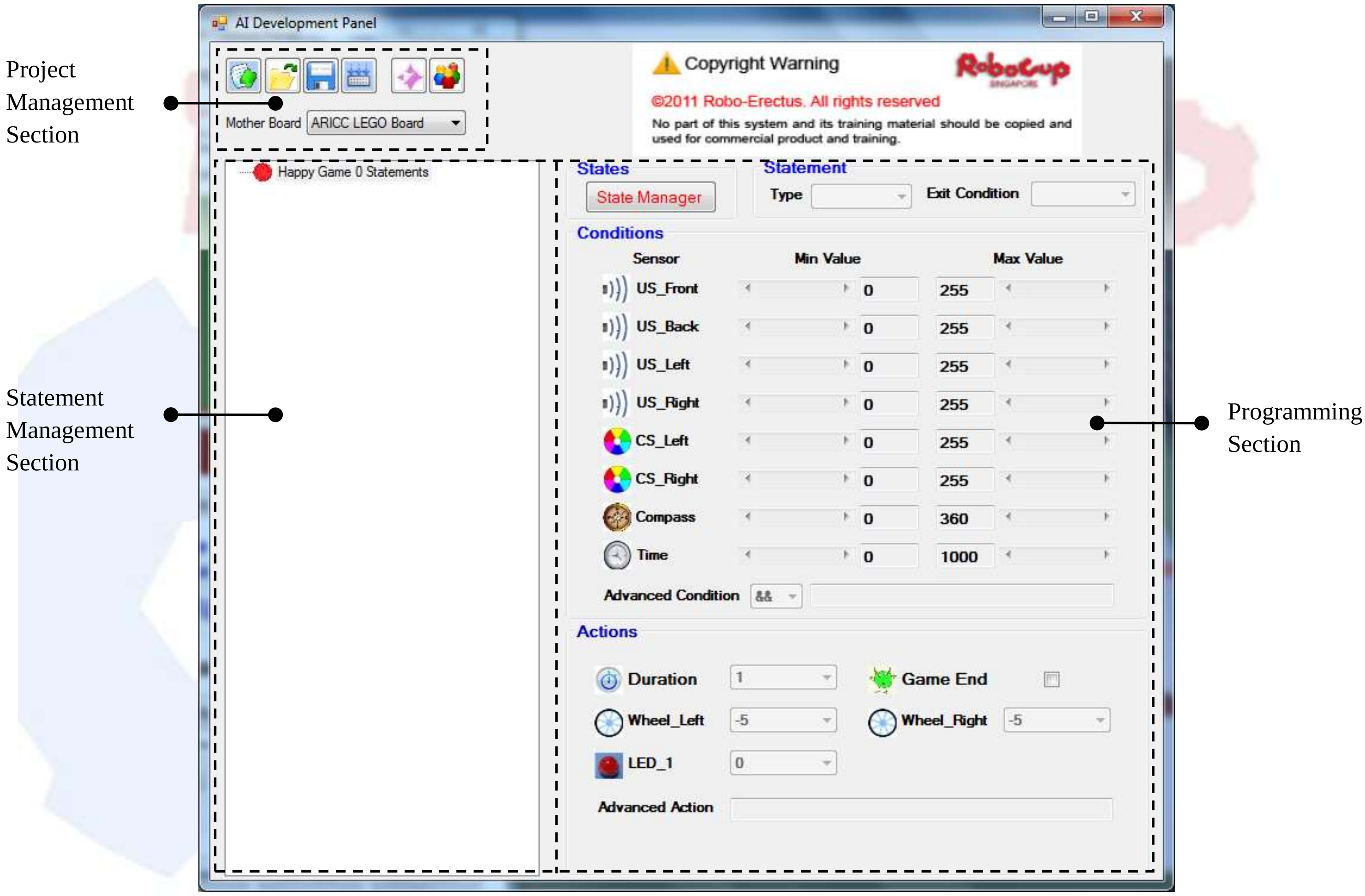


Fig. 7 – 1 : RE – VSS – CSR AI development environment

The RE – VSS – CSR AI programming interface consists of 3 sections, i.e. project management section, statement management section, and the programming section.

7.2 Project Management Section

Fig. 7 – 2 shows the project management section. In this section, you are able to

- Create and initialize a new project;
- Load a project;
- Save a project;
- Build a project;
- Define global variables;
- Define a team name;
- Select a controller board;

Fig. 7 – 2: Project management section

7.2.1 Create and initialize a new project

This function is to create and initialize a new project. When a new project is created, a project folder will be created in the designated path. You may change the path if you wish. To create a new project, double click on the new project "" button.

Fig. 7 – 3: Create a new project

7.2.2 Load a project

This function is to load a project. The project file has an extension of ".smp". To load a project, click the  button. The project can be edited after loading.

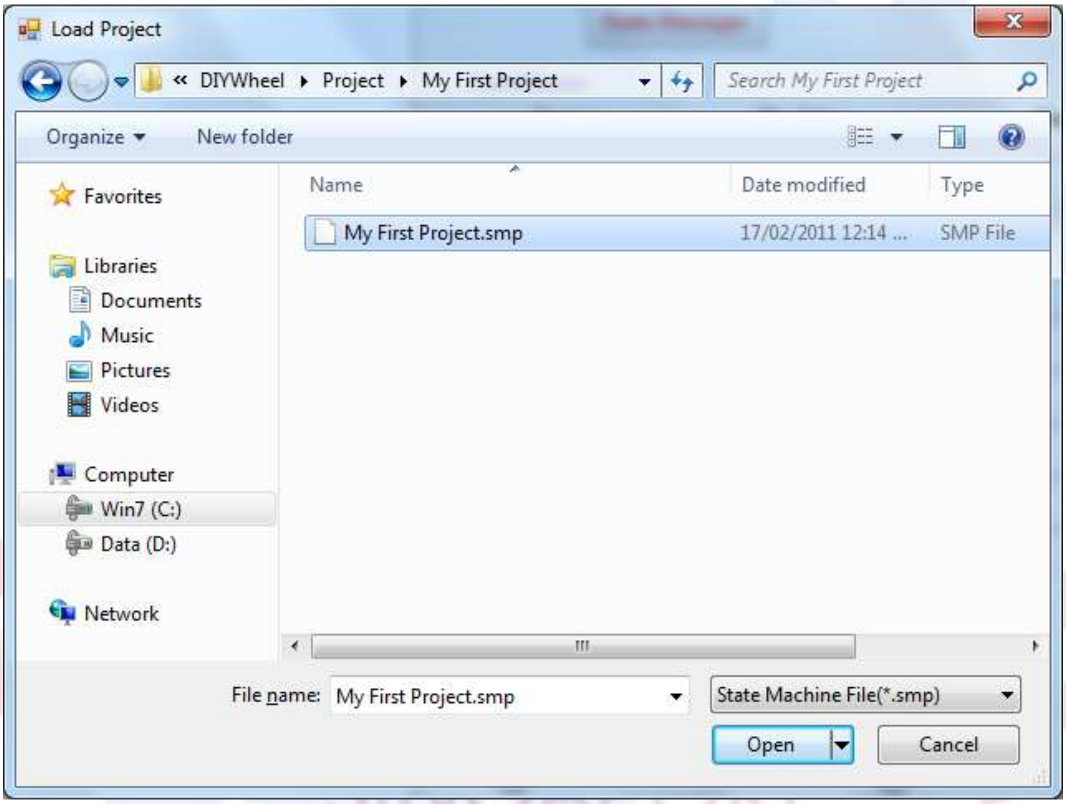


Fig. 7 – 4 : Load a project

7.2.3 Save a project

This function is to save a project. The project file has an extension of ".smp". To save a project, click the  button. The project can be loaded for editing using "Load a project" function. The saved project will have the same file name as the project name by default. You may wish to save it as another project by simply changing the project name..

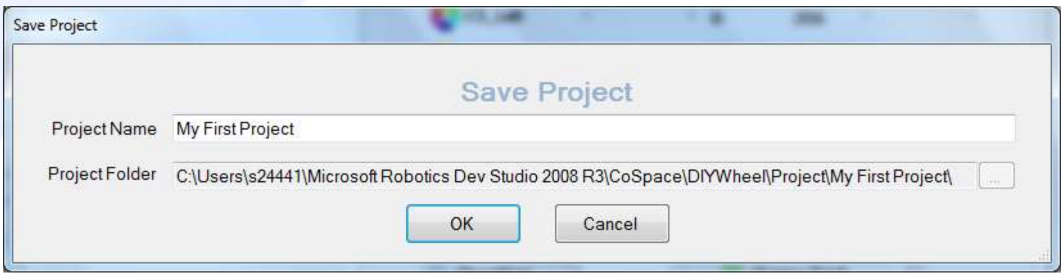


Fig. 7 – 5: Save a project

7.2.4 Build a project

This function is to build a project. The built project has an extension of ".dll". The built project can be loaded in the control panel via loading AI function. To build a project, click the button.

7.2.5 Define a new variable

The RE – VSS – CSR has a set of pre-defined variables. They are Duration, bGameEnd, CurAction, and CurGame. In addition to the pre-defined global variables, additional variables can be added for the project. Click on the "Add Variable" to add a variable. All parameters, such as variable name, initial value, variable type, etc, associated with the variable are to be set as shown in Fig. 7 – 6.

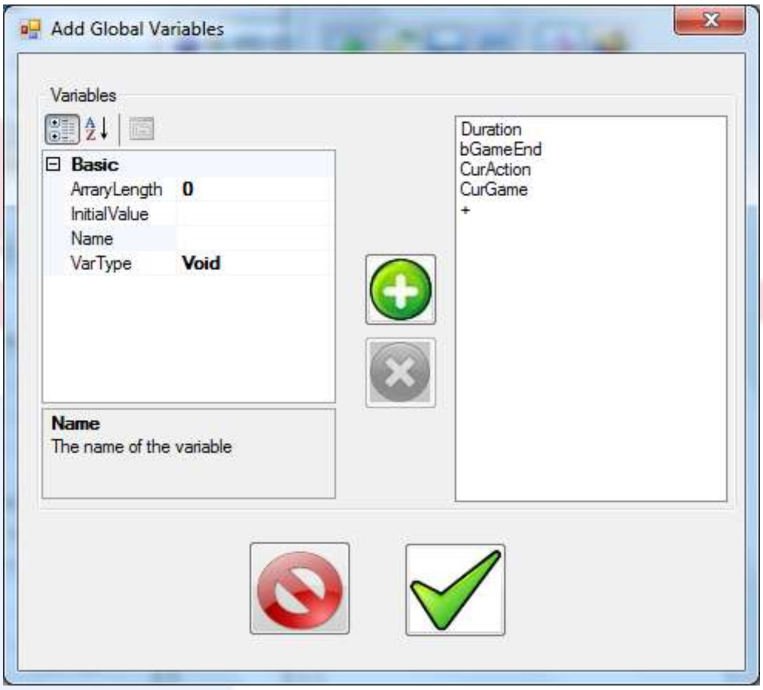


Fig. 7 – 6: Add a global variable

Parameter	**What it means …**
ArrayLength	The length of the array if the global variable is defined as an array. Set this parameter to be 0 for other variable types.
Initial value	The initial value of the variable.
Name	Name of the variable. It can only contain 'a ~ z', 'A ~ Z', and '0 ~ 9'.
VarType	Type of the variable. It can be Byte, Int16, Boolean, Float, String, Byte Array, and Int16 Array.

Step 3: Click to add the defined variable to the list.

Step 4: Click to save.

If you wish to delete a global variable from the list, click on “”. If you do not wish to save, click on “”.

7.2.6 Add a team name

This function is to add a team name to the designed project. To add a team name, click the button “Team Name button ”. The team name must be less than 8 characters.

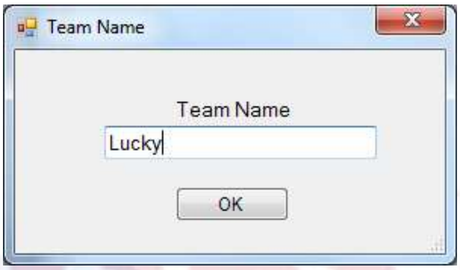


Fig. 7 – 7: Add a team name

The added team name will be displayed in the scoreboard as well as in the virtual environment as shown in Fig. 7 – 8..

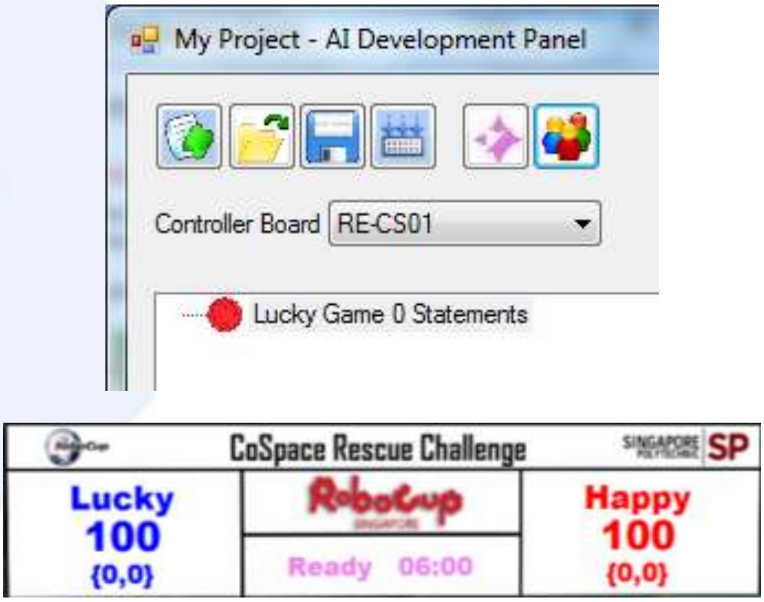


Fig. 7 – 8: New team nme is displayed

7.2.7. *Select a controller board*

There are two types of controller board, RE – CS01 board and RE – CS02 board (for Lego sensors and motors) are used for the CoSpace robot. You can select the controller board used from the dropdown list as shown in Fig. 7 – 9.

Fig. 7 – 9:Select a controller board

7.3 Statement Management Section

Fig. 7 – 10 shows the statement management section. In this section, you are able to

- Add a new statement and a new subroutine;
- Define the statement type and state;

Fig. 7 – 10: Statement management section

The RE – VSS – CSR CoSpace platform uses sequential programming technique. The compiler executes the program statements sequentially in a "top-down" manner. Therefore, the order of the statements in the program plays a very important role in deciding the priority of statements with the same priority.

In order to synchronise the real and virtual robots and maintain real-time data updating, the CoSpace platform RE – VSS – CSR automatically scans all sensors' readings in an interval of 60 ms. In other words, all the variables associated with sensors will be updated every 60 ms. Fig. 7 – 11 shows the program execution flow.

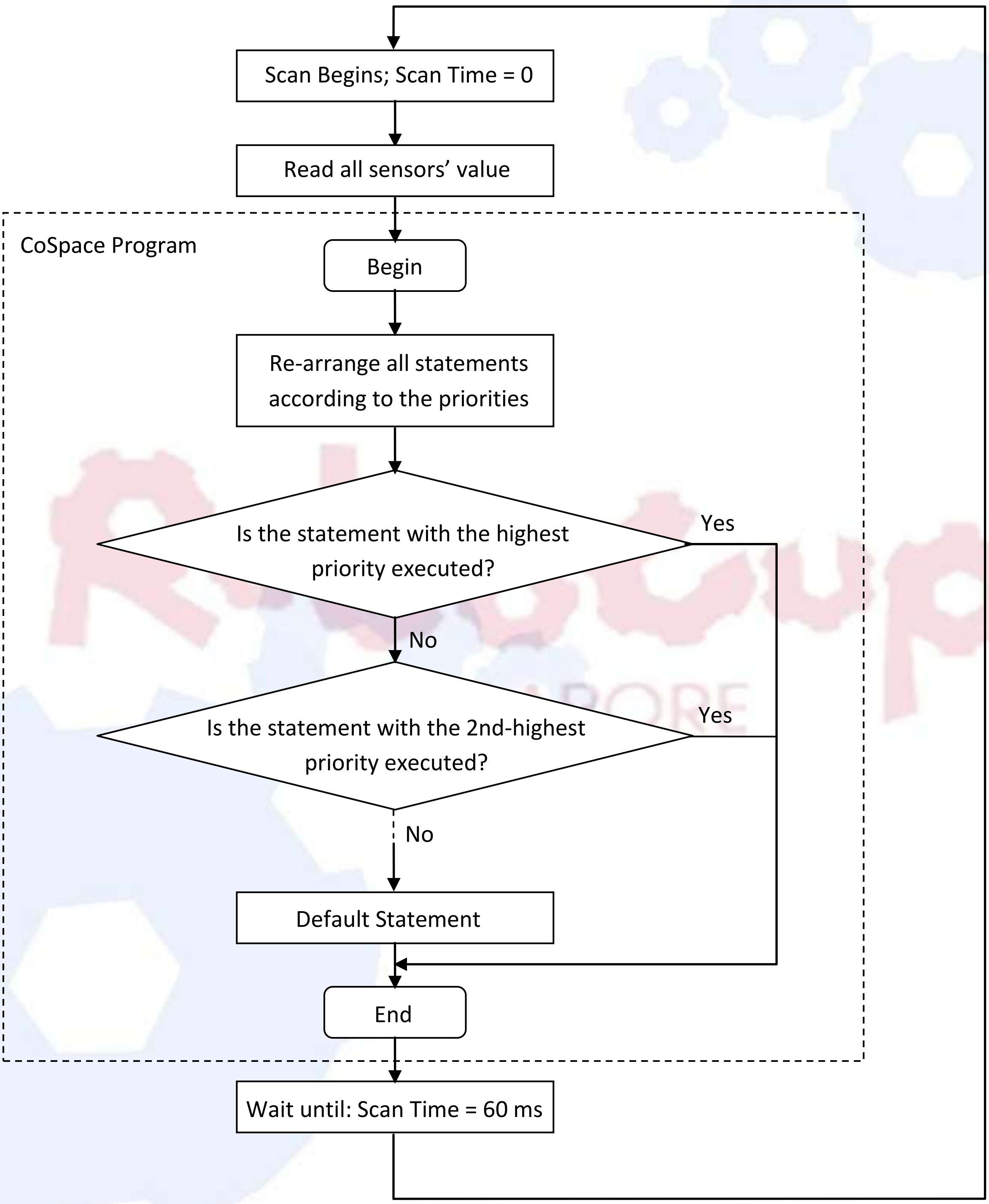


Fig. 7 – 11: Program execution flow

7.3.1 Add a new statement

Statement specifies action. A program is formed by one or more statements in sequence. Each statement will have an expression.

Procedure of adding new statement:

Step1: Select the statement/subroutine which you wish the new statement to be appended in the project and then click the right mouse button. Choose "Add a new statement within the Bundle" or "Add a new statement" as shown in Fig. 7 – 12.

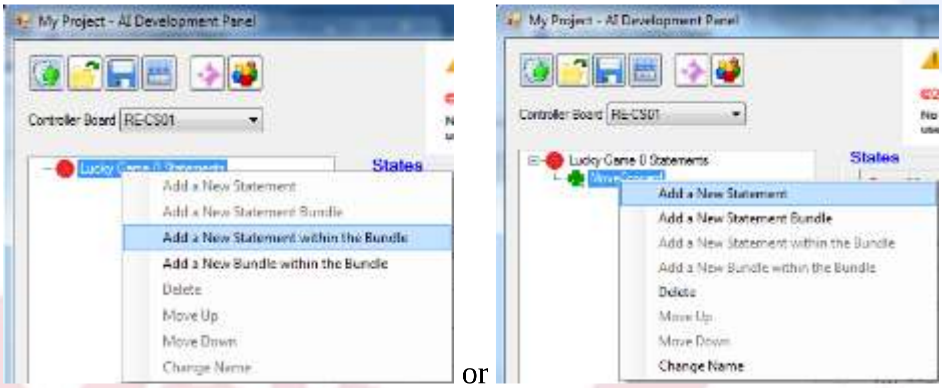


Fig. 7 – 12: Adding a new statement

Step 2: Assign a meaningful name to the statement created. The new statement will then be added as shown in Fig 7 – 13.

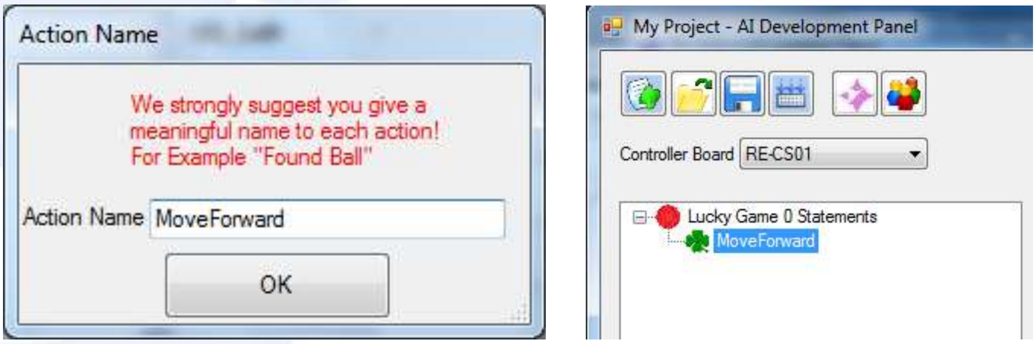


Fig. 7 – 13: Assigning a new statement name

The statement type, conditions and actions associated with the new statement need to be specified. It will be illustrated in later section.

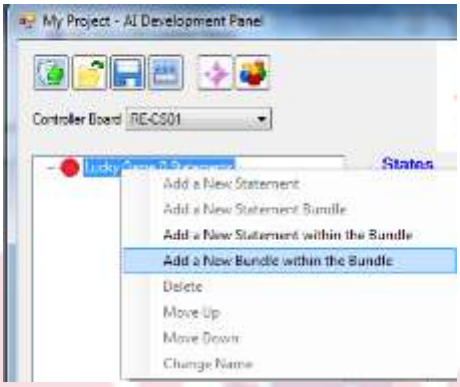
You can continue to add more statements to the program.

7.3.2 Add a new subroutine

A subroutine (also called procedure, method, function, or routine) is a portion of code within a larger program that performs a specific task and is relatively independent of the remaining code.

Procedures of adding a new subroutine:

Step 1: Select the previous statement/subroutine in the project that you wish to have the subroutine appended and click the right mouse button. Choose “Add a new Bundle within the Bundle” or “Add a new Bundle” as shown in Fig. 7 – 14.



or

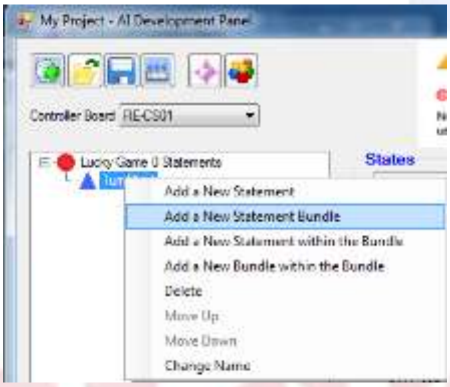


Fig. 7 – 14: Adding a subroutine

Step 2: Assign a meaningful name to the subroutine created. The new subroutine will then be added as shown in Fig 7 – 15.

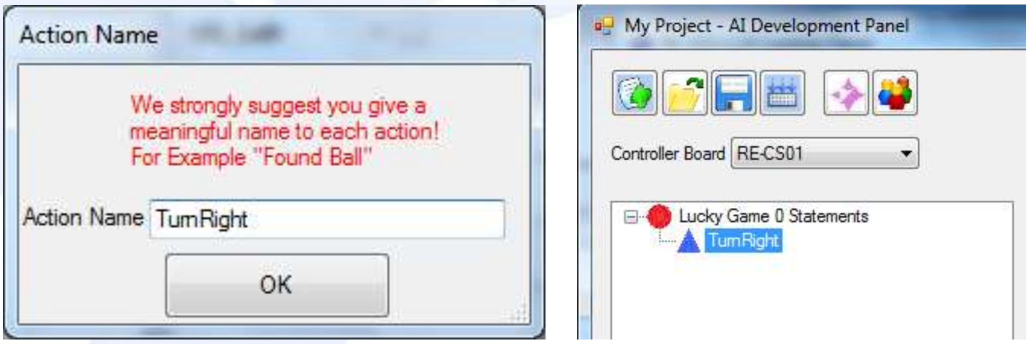


Fig. 7 - 15: Assigning a new subroutine name

The subroutine is a set of statements. You can add more statements or subroutines to an existing subroutine.

7.3.3 *Managing statements and subroutines*

You can delete, move up, move down, and change the statement or subroutine's name. To do so, you need to select the statement or subroutine and right click to select the appropriate action as shown in Fig. 7 – 16.

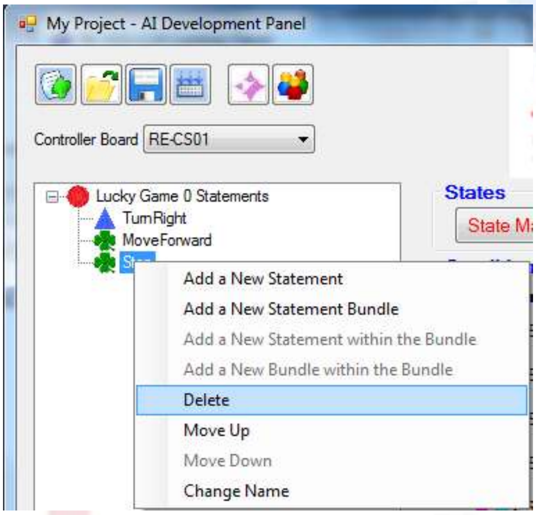


Fig. 7 - 16: Managing statement

7.3.4 *Statement type*

The type of the statement has to be specified when each new statement is added. There are three types statements for different requirements, namely default action, non-interrupt action, and super action as shown in Fig. 7 – 17.

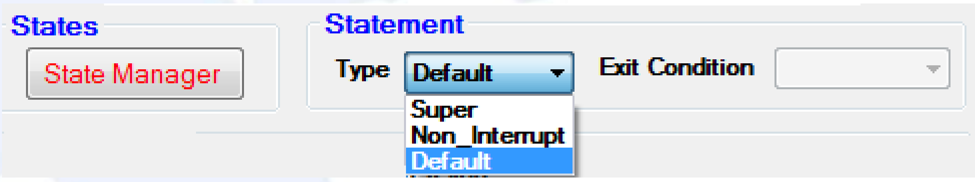


Fig. 7 – 17: Statement types

- *<u>Default action</u>*

  The default action statement has the lowest priority. A project can have many default action statements.

- *<u>Non-interrupt action</u>*

  The non-interrupt statement has the same priority as the default statement. When the non-interrupt statement is executed, it will not be interrupted or terminated unless

  1) The exit action condition is fulfilled.

  2) The super action statement is executed.

When the non-interrupt action is specified, it is necessary to define an exit condition for this action. That means the non-interrupt statement will only be terminated when the specified exit condition is true.

The Section 7.3.5 on managing states will illustrate the details.

A project can contain many non-interrupt action statements.

- Super action:

  The super-action statement has the highest priority. Once the condition for the statement is true, it will be executed immediately. All other actions will be interrupted.

  A project can contain many super action statements.

7.3.5 Managing states

State Manager allows you to add/delete new state variables and define the states.

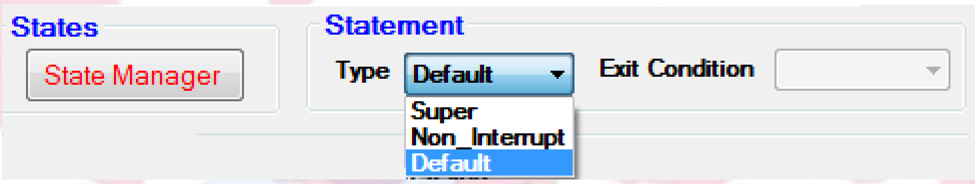


Fig. 7 – 18: State manager

A state is needed for a non-interrupt statement. When a new state is defined, it is compulsory to specify the exit-action condition. The non-interrupt statement will only be terminated when the exit-condition is true. Fig. 7 – 19 shows the state manager environment.

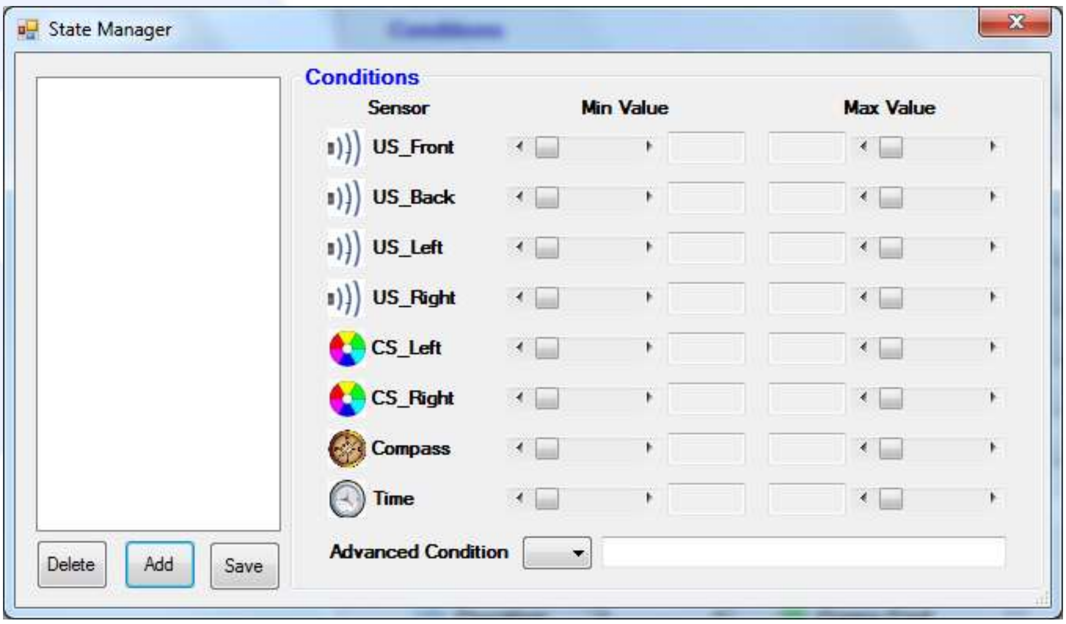


Fig. 7 – 19: State manager

- Add a new state

To add a new state, double click the 

and specify the new state.

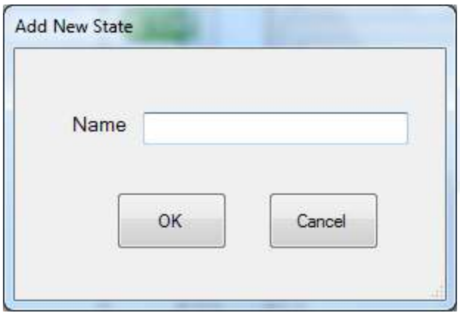


Fig. 7 – 20: Add a new state

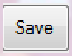
The new state name can only contain ‘a ~ z’, ‘A ~ Z’, and ‘0 ~ 9’.

- Delete a state

To delete a state, highlight the state you wish to delete and click the 

.

- Save a state

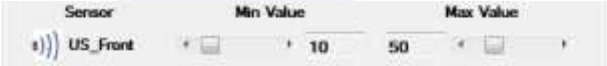
Just simply click on the 

button. The state manager window will be closed and the states will be saved.

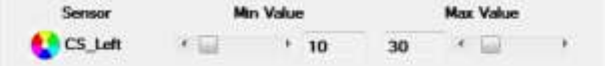
- Define an exit-action condition

In this platform, we can define the exit-condition based on the sensor readings from 4 ultrasonic sensors (Ultrasonic Sensor Front, Ultrasonic Sensor Back, Ultrasonic Sensor Left, Ultrasonic Sensor Right), 1 Direction Sensors, 2 colour sensors (Colour Sensor Left, Colour Sensor Right), time sequence and other self-defined variables.

For example,



specifies the ultrasonic front sensor reading is in between 10 and 50 cm. That means that distance between the front obstacle and the front ultrasonic sensor is in between 10 – 50 cm.



specifies the left colour sensor reading is in between 10 – 30.

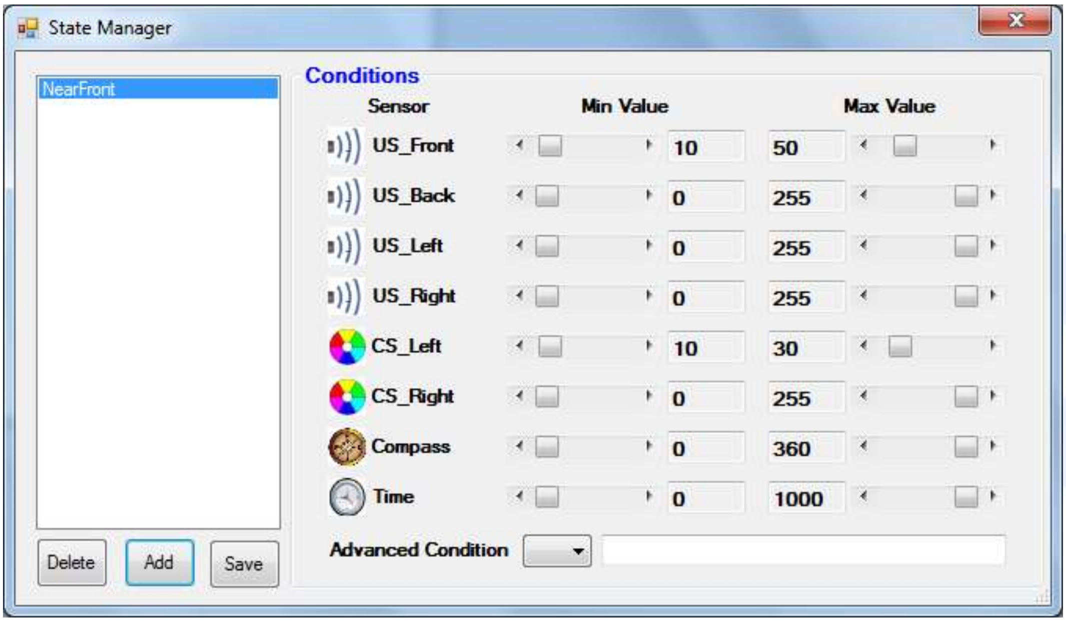


Fig. 7 – 21: Define a state

Fig. 7 – 21 shows the front ultrasonic sensor reading is in between 10 – 50 and left colour sensor reading is in between 10 – 30.

The advanced condition can be used to specify more complex conditions, such as (US_Front>=10&&US_Front<=50)||(CS_Left>=10&&CS_Left<=30) . Fig. 7 – 22 shows the implementation of advanced condition.

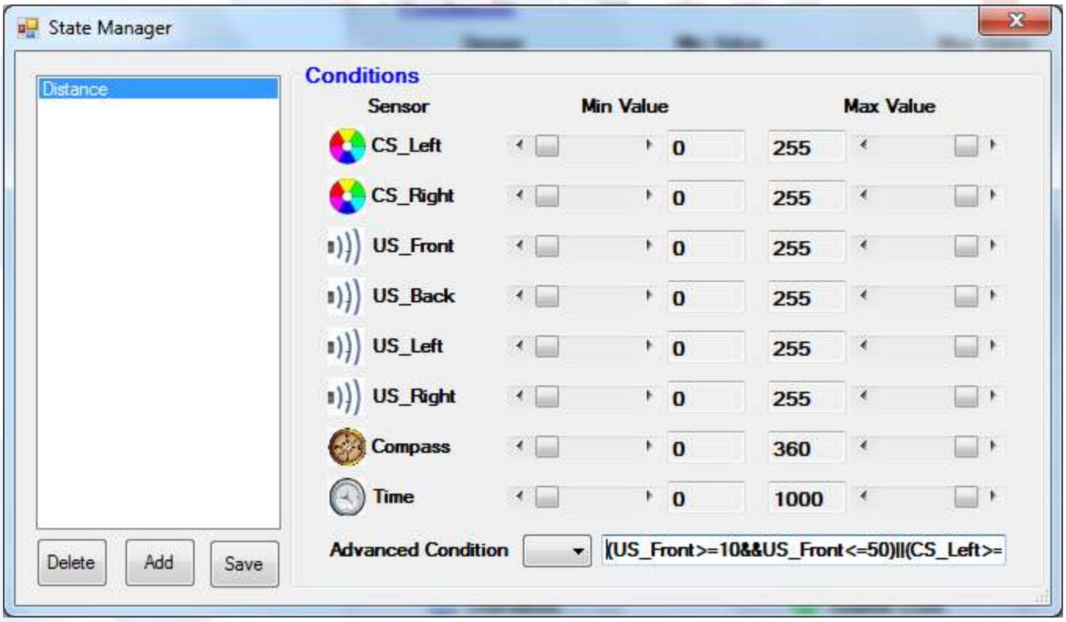


Fig. 7 – 22: Define a state with advanced condition

The basic conditions can be combined with the advanced condition. Fig. 7 – 23 shows `(US_Front>=0&&US_Front<=50)`**&&**`(CS_Left<50)`. Fig. 7 – 24 shows `(US_Front>=0&&US_Front<=50)`**||**`(CS_Left<50)`**.**

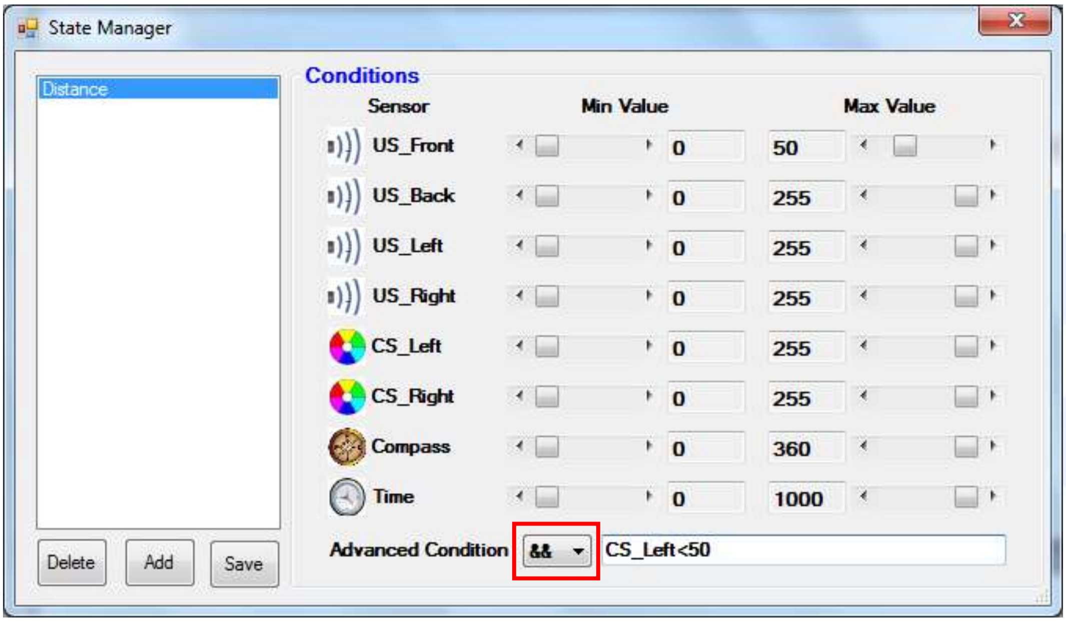


Fig. 7 – 23: Define a state

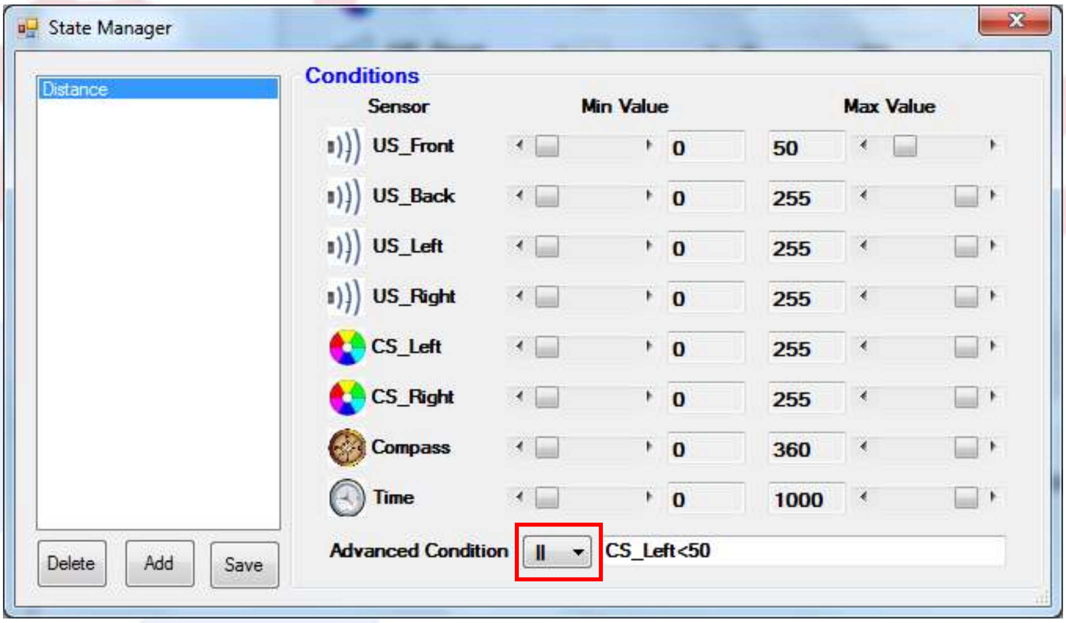


Fig. 7 – 24: Define a state

7.4 Programming Section

Robot programming uses an event-driven approach. That means that the robot acts based on the sensors' feedback. The condition and action section is to specify the perception-action of a robot. Once a new statement is created, the corresponding conditions and actions have to be specified.

This graphical perception-action programming interface as shown in Fig 7 – 25 is suitable for a novice programmer. If you are an experienced programmer, the advanced function would better suit your needs. Of course, the package also provides an interface for proficient C++ programmers to write their own C++ code.

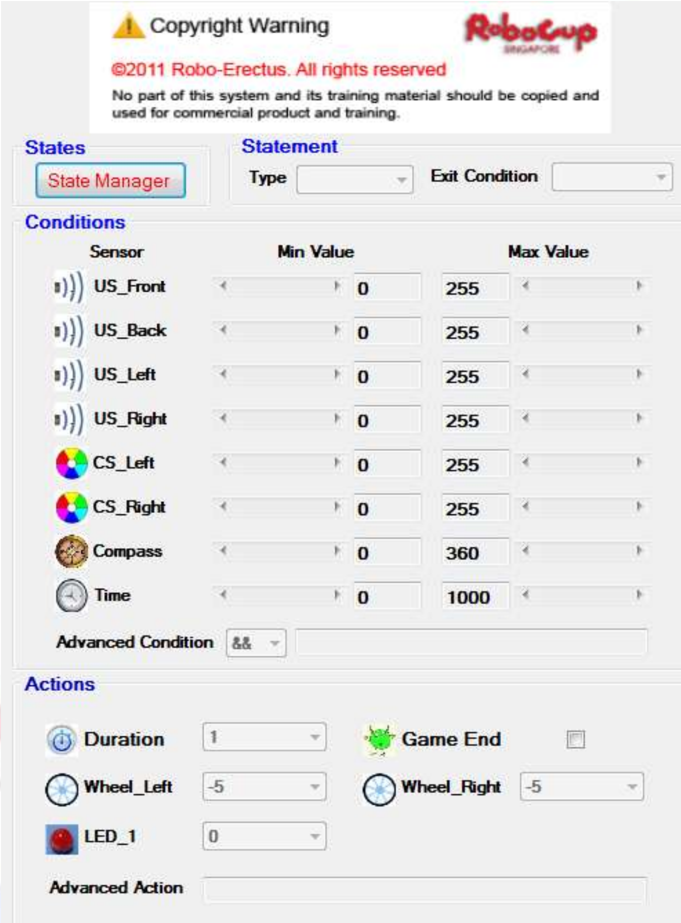


Fig. 7 – 25: Graphical Programming Interface

7.4 1 Basic conditions

The following sensors readings are used for specifying conditions.

- US_Front – feedback value from the front ultrasonic sensor
- US_Back – feedback value from the back ultrasonic sensor
- US_Left – feedback value from the left ultrasonic sensor
- US_Right – feedback value from the right ultrasonic sensor
- CS_Left – feedback value from the left colour sensor
- CS_Right – feedback value from the right colour sensor
- Direction – feedback value from the compass sensor
- Time – Time sequence

You can also use self-defined variables.

RE–VSS–CSR uses a perception based programming strategy. You just need to specify the conditions and action. Fig. 7 – 26 shows the condition/action panel.

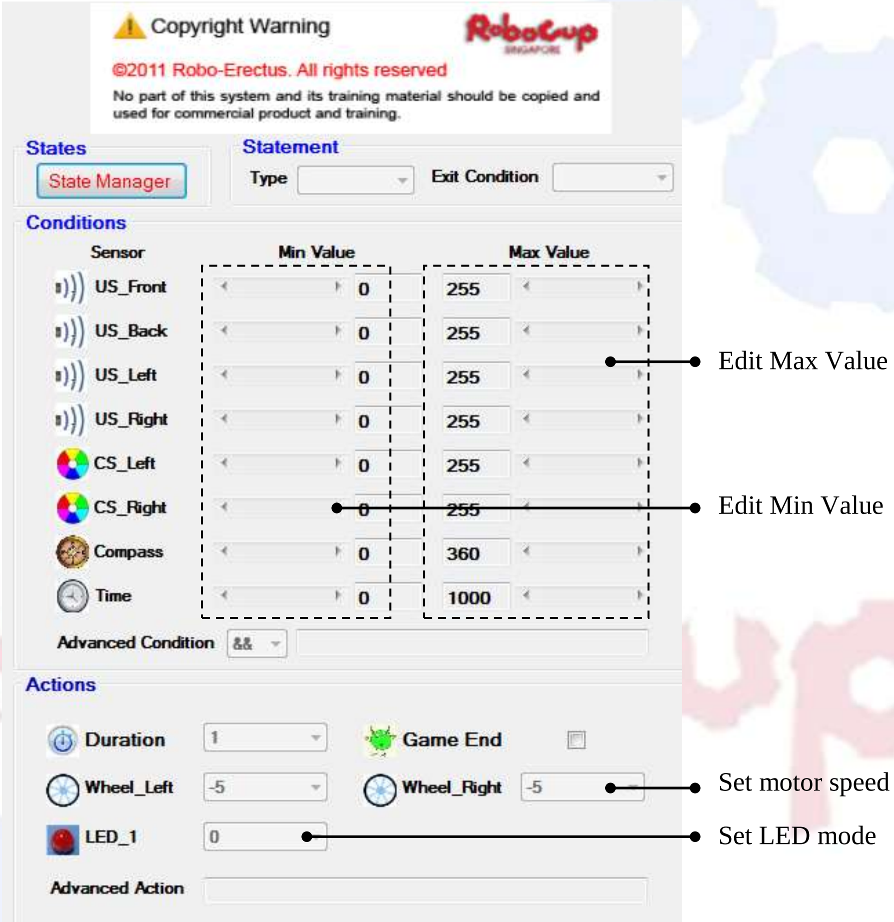
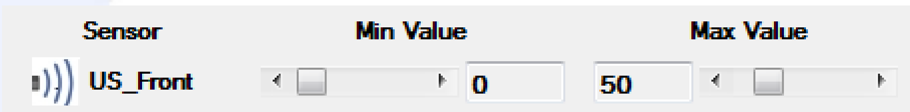
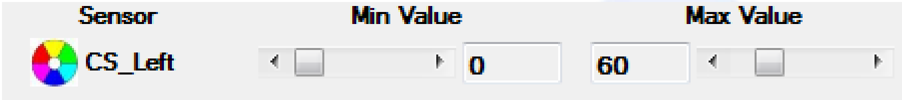


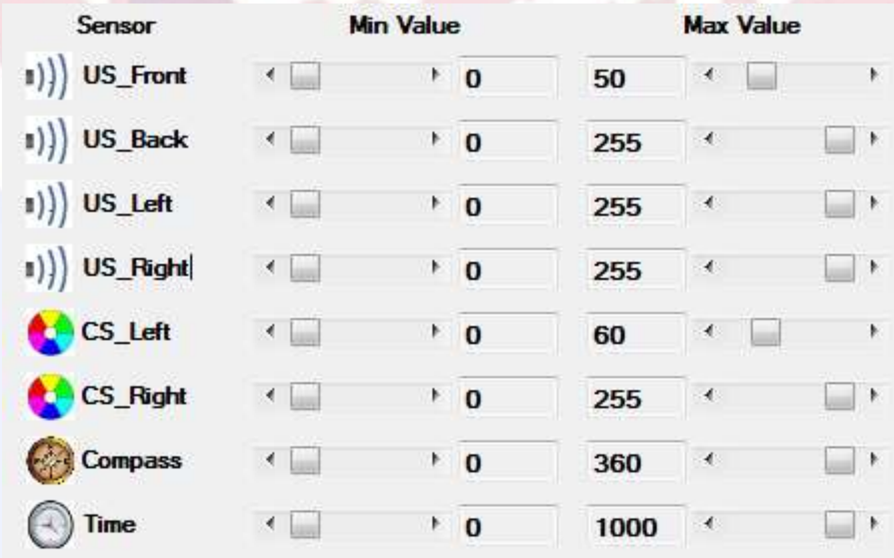
Fig. 7 – 26: Programming panel

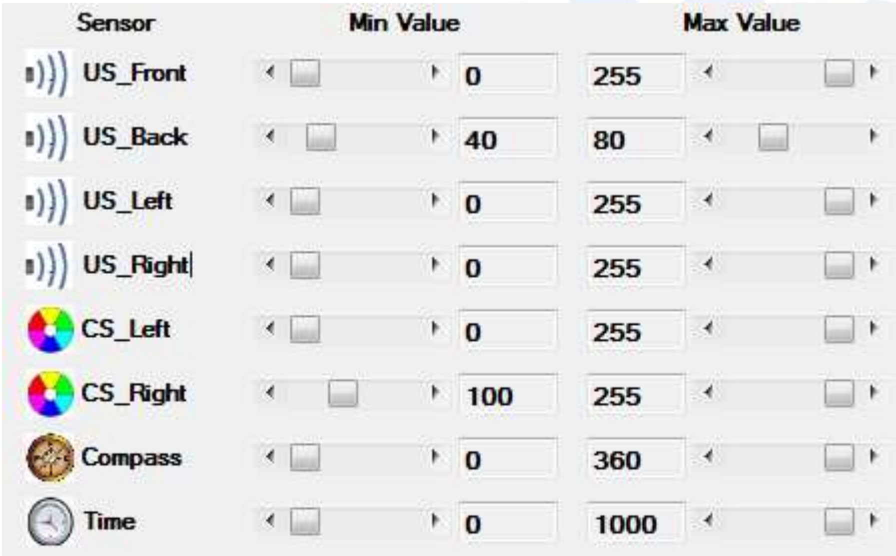
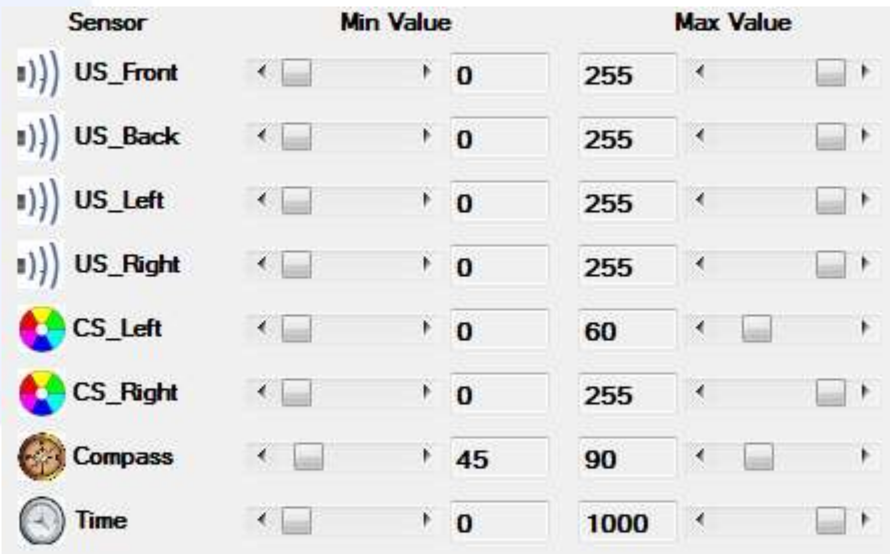
The simple conditions can be defined using the slider to specify the data range.

Examples	
Condition	0 ≤ Front Ultrasonic Sensor Reading ≤ 50
How do you program…	
Condition	40 ≤ Back Ultrasonic Sensor Reading ≤ 80
How do you program…	

Condition	0 ≤ Left Colour Sensor Reading ≤ 60
How do you program…	
Condition	0^o ≤ Compass Sensor Reading ≤ 45^o
How do you program…	

You can combine any two or more conditions using the same method. Please note that the relationship between these conditions will be "Logical AND".

Examples	
Condition	0 ≤ Front Ultrasonic Sensor Reading ≤ 50 and 0 ≤ Left Colour Sensor Reading ≤ 60
How do you program…	
Condition	0 ≤ Front Ultrasonic Sensor Reading ≤ 50 or 0 ≤ Left Colour Sensor Reading ≤ 60
How do you program…	Use advanced condition

<table>
<tr><td>Condition</td><td>40 ≤ Back Ultrasonic Sensor Reading ≤ 80
and
Right Colour Sensor Reading ≥ 100</td></tr>
<tr><td>How do you program…</td><td>
</td></tr>
<tr><td>Condition</td><td>40 ≤ Back Ultrasonic Sensor Reading ≤ 80
or
Right Colour Sensor Reading ≥ 100</td></tr>
<tr><td>How do you program…</td><td>Use advanced condition</td></tr>
<tr><td>Condition</td><td>0 ≤ Left Colour Sensor Reading ≤ 60
and
45^{o} ≤ Compass Sensor Reading ≤ 90^{o}</td></tr>
<tr><td>How do you program…</td><td>
</td></tr>
</table>

7.4.2 Basic action

- Define robot moving direction

Movement	**Left Wheel**	**Right Wheel**
Robot moves forward	Positive Value, e.g. "+1"	Positive Value
Robot turns right	Positive Value	Negative Value, e.g. "- 1"
Robot turns left	Negative Value	Positive Value
Robot moves backwards	Negative Value	Negative Value

- Define robot moving speed

Speed Setting	**Motor Speed**
0	Stop
1	Robot moves at 20% of its full speed
2	Robot moves at 40% of its full speed
3	Robot moves at 60% of its full speed
4	Robot moves at 80% of its full speed
5	Robot moves at full speed

- Set LED display

LED Setting	**What it means…**
0	LED – off
1	LED – blinks
2	LED – steady display

- Duration

  Duration is used to specify the duration for the action. The action will be continuously executed for the period that is specified in duration. The unit for duration is 60ms.

- Game End

  If the Game End box is checked, the entire game will end when this statement is executed.

Examples	
Actions	Robot moves forward with 40% of the full speed for 120 ms
How do you program…	
Actions	Robot moves forward with 40% of the full speed for 120 ms while LED is flashing.
How do you program…	
Actions	Robot moves forward with 40% of the full speed for 120 ms. At mean time, The internal variable "Alpha" is set to 5.
How do you program…	Use advanced action.

7.4.3 Advanced programming function

In the advanced function, you can write simple codes for specific conditions and actions.

The Advanced programming supports the symbols for C arithmetic operations and relational operators.

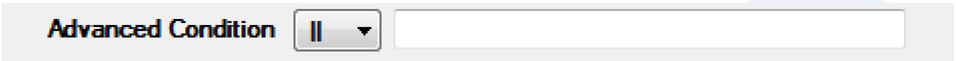
Symbol	Meaning
+	Addition
-	Subtraction
*	Multiplication
/	Division

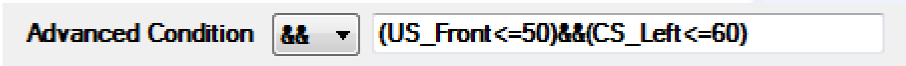
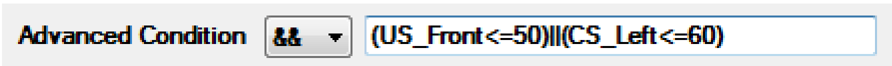
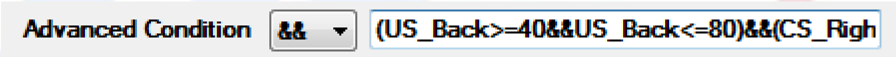
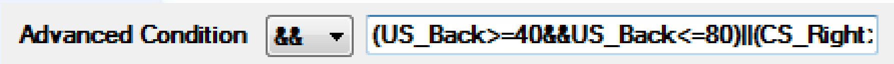
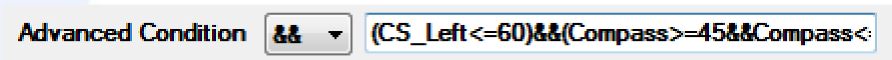
Operator	Meaning
>	Greater than
>=	Greater than or Equal to
<	Less than
<=	Less than or Equal to
==	Equal to
!=	Not Equal to

You can use all pre-defined variables and global variables specified in the advanced conditions and actions.

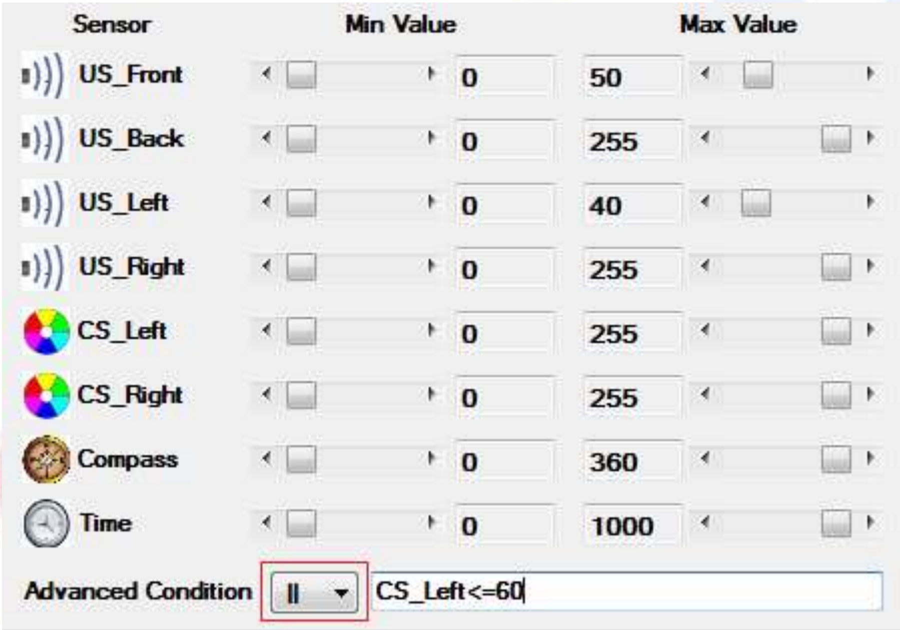
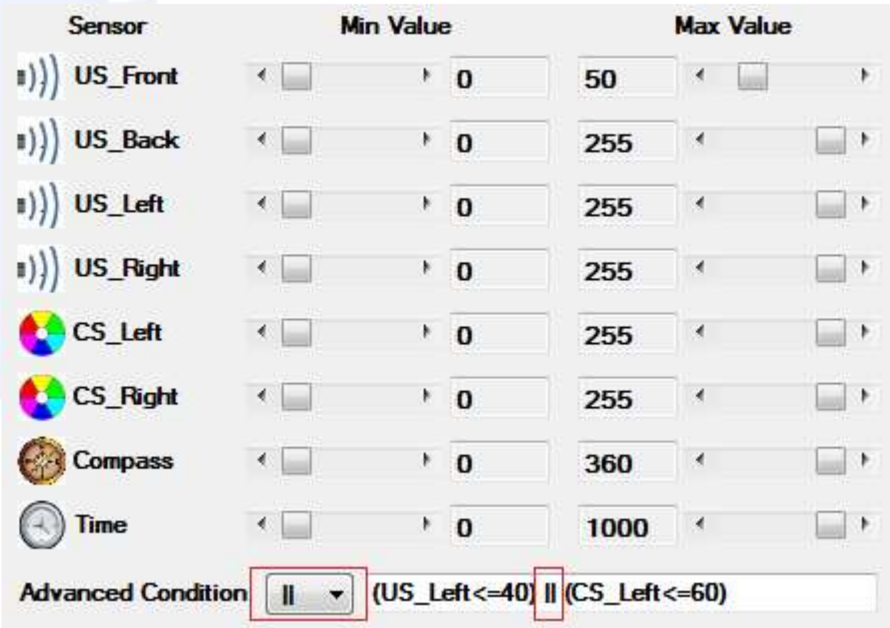
Advanced Conditions

The advanced conditions are used for more complicated combination of conditions.



Examples	
Condition	0 ≤ Front Ultrasonic Sensor Reading ≤ 50 and 0 ≤ Left Colour Sensor Reading ≤ 60
How do you program…	
Condition	0 ≤ Front Ultrasonic Sensor Reading ≤ 50 or 0 ≤ Left Colour Sensor Reading ≤ 60
How do you program…	
Condition	40 ≤ Back Ultrasonic Sensor Reading ≤ 80 and Right Colour Sensor Reading ≥ 100
How do you program…	`(US_Back>=40&&US_Back<=80)`**&&**`(CS_Right>=100)` 
Condition	40 ≤ Back Ultrasonic Sensor Reading ≤ 80 or Right Colour Sensor Reading ≥ 100
How do you program…	`(US_Back>=40&&US_Back<=80)`**||**`(CS_Right>=100)` 
Condition	0 ≤ Left Colour Sensor Reading ≤ 60 and 45^{o} ≤ Compass Sensor Reading ≤ 90^{o}
How do you program…	`(CS_Left<=60)&&(Compass>=45&&Compass<=90)` 

The advanced conditions can be combined with the basic conditions to fulfill more comprehensive requirement.

<table>
<tr><th colspan="2">Examples</th></tr>
<tr><td>Condition</td><td>0 ≤ Front Ultrasonic Sensor Reading ≤ 50
and
0 ≤ Left Ultrasonic Sensor Reading ≤ 40
or
0 ≤ Left Colour Sensor Reading ≤ 60</td></tr>
<tr><td>How do you program…</td><td>
</td></tr>
<tr><td>Condition</td><td>0 ≤ Front Ultrasonic Sensor Reading ≤ 50
or
0 ≤ Left Ultrasonic Sensor Reading ≤ 50
or
0 ≤ Left Colour Sensor Reading ≤ 60</td></tr>
<tr><td>How do you program…</td><td>
</td></tr>
</table>

Advanced Actions

The advanced actions are used for more complicated combination of actions.

Advanced Action [ ]

Examples	
Actions	Robot moves forward with 40% of the full speed for 120 ms
How do you program…	Advanced Action: Wheel_Left=2; Wheel_Right=2; Duration=2;
Actions	Robot moves forward with 40% of the full speed for 120 ms while LED is flashing.
How do you program…	Advanced Action: Wheel_Left=2; Wheel_Right=2; Duration=2; LED_1=1;
Actions	Robot moves forward with 40% of the full speed for 120 ms. At mean time, The internal variable "Alpha" is set to 5.
How do you program…	Advanced Action: Wheel_Left=2; Wheel_Right=2; Duration=2; Alpha=5;

Please note that when the advanced action is created, it overwrites the basic actions for the same variables.

7.5 C++ Programming Interface

When a project is built, there will be two files, namely "ai.cs" and "ai.c" generated automatically.

- "ai.cs" is a CSharp program. It is generated according to the graphical programming. The "ai.cs" can be further modified and then be compiled and run in the virtual environment.

  "ai.cs" can be opened using Note Pad or Microsoft Visual Studio.net.

```
using System;

namespace AI
{
    public static class AI
    {
        static int Duration = 0;
        static int SuperDuration = 0;
        static bool bGameEnd = false;
        static int CurAction = 0;
        static int CurGame = 0;
        static int US_Front = 0;
        static int US_Back = 0;
        static int US_Left = 0;
        static int US_Right = 0;
        static int CS_Left = 0;
        static int CS_Right = 0;
        static int Compass = 0;
        static int Time = 0;
        static int Wheel_Left = 0;
        static int Wheel_Right = 0;
        static int LED_1 = 0;

        public static string GetTeamName()
        {
             return "Happy";
        }


        public static void SetGameID(int GameID)
        {
            CurGame = GameID;
            bGameEnd = false;
        }


        public static int GetGameID()
        {
            return CurGame;
        }


        public static bool IsGameEnd()
        {
            return bGameEnd;
        }
```

```
        public static void OnTimer()
        {
            switch (CurGame)
            {
                case 100:
                    break;
                case 101:
                    Wheel_Left=0;
                    Wheel_Right=0;
                    LED_1=0;
                    break;
                case 0:
                    Game0();
                    break;
                default:
                    break;
            }
        }
        public static void SetData(int Sensor0 , int Sensor1 , int Sensor2
, int Sensor3 , int Sensor4 , int Sensor5 , int Sensor6 , int Sensor7)
        {
            US_Front = Sensor0;
            US_Back = Sensor1;
            US_Left = Sensor2;
            US_Right = Sensor3;
            CS_Left = Sensor4;
            CS_Right = Sensor5;
            Compass = Sensor6;
            Time = Sensor7;
        }
        public static void GetCommand(ref int Actuator0 , ref int Actuator1
, ref int Actuator2)
        {
            Actuator0 = Wheel_Left;
            Actuator1 = Wheel_Right;
            Actuator2 = LED_1;
        }
        private static void Game0()
        {

            if(SuperDuration>0)
            {
                SuperDuration--;
            }
            else if(Duration>0)
            {
                Duration--;
            }
            else if(US_Front>=0 && US_Front<=30)
            {
                Duration = 0;
                CurAction =0;
            }
            else if(true)
            {
                Duration = 0;
                CurAction =1;
            }
            switch(CurAction)
            {
```

```
                case 0:
                    Wheel_Left=0;
                    Wheel_Right=0;
                    LED_1=0;
                    break;
                case 1:
                    Wheel_Left=2;
                    Wheel_Right=2;
                    LED_1=0;
                    break;
                default:
                    break;
            }

        }


    }
}
```

- "ai.c" is a C program. It is generated according to the graphical programming. The "ai.c" can be further modified and then be compiled and downloaded onto the real robot. The real robot will perform in the real environment according the program edited in the environment.

```
////////////////////////////
//The ID : It must be three digital number. Value is from "001" to "999". "000" is reserved.
char AI_MyID[3] = "002";
///////////////////////////////////
#define true 1
#define false 0
int AI_MotorType = 0;
int Duration = 0;
int SuperDuration = 0;
int bGameEnd = false;
int CurAction = 0;
int CurGame = 0;
int US_Front = 0;
int US_Back = 0;
int US_Left = 0;
int US_Right = 0;
int CS_Left = 0;
int CS_Right = 0;
int Compass = 0;
int Time = 0;
int Wheel_Left = 0;
int Wheel_Right = 0;
int LED_1 = 0;
int AI_SensorNum = 7;

void SetGameID(int GameID)
{
    CurGame = GameID;
    bGameEnd = false;
}


int GetGameID()
{
    return CurGame;
}


int IsGameEnd()
{
    return bGameEnd;
}

void SetData(int *packet, int *CCP , int *ADC , int compass, int play_time)
{

    int sum = 0;

    US_Front = CCP[0]; packet[0] = US_Front; sum += US_Front;
    US_Back = CCP[1]; packet[1] = US_Back; sum += US_Back;
    US_Left = CCP[2]; packet[2] = US_Left; sum += US_Left;
    US_Right = CCP[3]; packet[3] = US_Right; sum += US_Right;
    CS_Left = ADC[2]; packet[4] = CS_Left; sum += CS_Left;
```

```
    CS_Right = ADC[3]; packet[5] = CS_Right; sum += CS_Right;
    Compass = compass; packet[6] = Compass; sum += Compass;
    Time = play_time;
    packet[7] = sum;

}
void GetCommand(int *Motor, int *LegoMotor, int *LED)
{
    Motor[0] = Wheel_Left;
    Motor[2] = Wheel_Right;
    LED[0] = LED_1;
    LED[1] = LED_1;
}
void Game0()
{

    if(SuperDuration>0)
    {
        SuperDuration--;
    }
    else if(Duration>0)
    {
        Duration--;
    }
    else if(US_Front>=0 && US_Front<=30)
    {
        Duration = 0;
        CurAction =0;
    }
    else if(true)
    {
        Duration = 0;
        CurAction =1;
    }
    switch(CurAction)
    {
        case 0:
            Wheel_Left=0;
            Wheel_Right=0;
            LED_1=0;
            break;
        case 1:
            Wheel_Left=2;
            Wheel_Right=2;
            LED_1=0;
            break;
        default:
            break;
    }

}


void OnTimer()
{
    switch (CurGame)
    {
        case 100:
            break;
        case 101:
```

```
            Wheel_Left=0;
            Wheel_Right=0;
            LED_1=0;
            break;
        case 0:
            Game0();
            break;
        default:
            break;
    }
}
```

8. Practical Guide

8.1 Manual control of robot

The RE – VSS – CSR provides a manual control interface. When you use a mouse to control the dashboard, the robot will move accordingly.

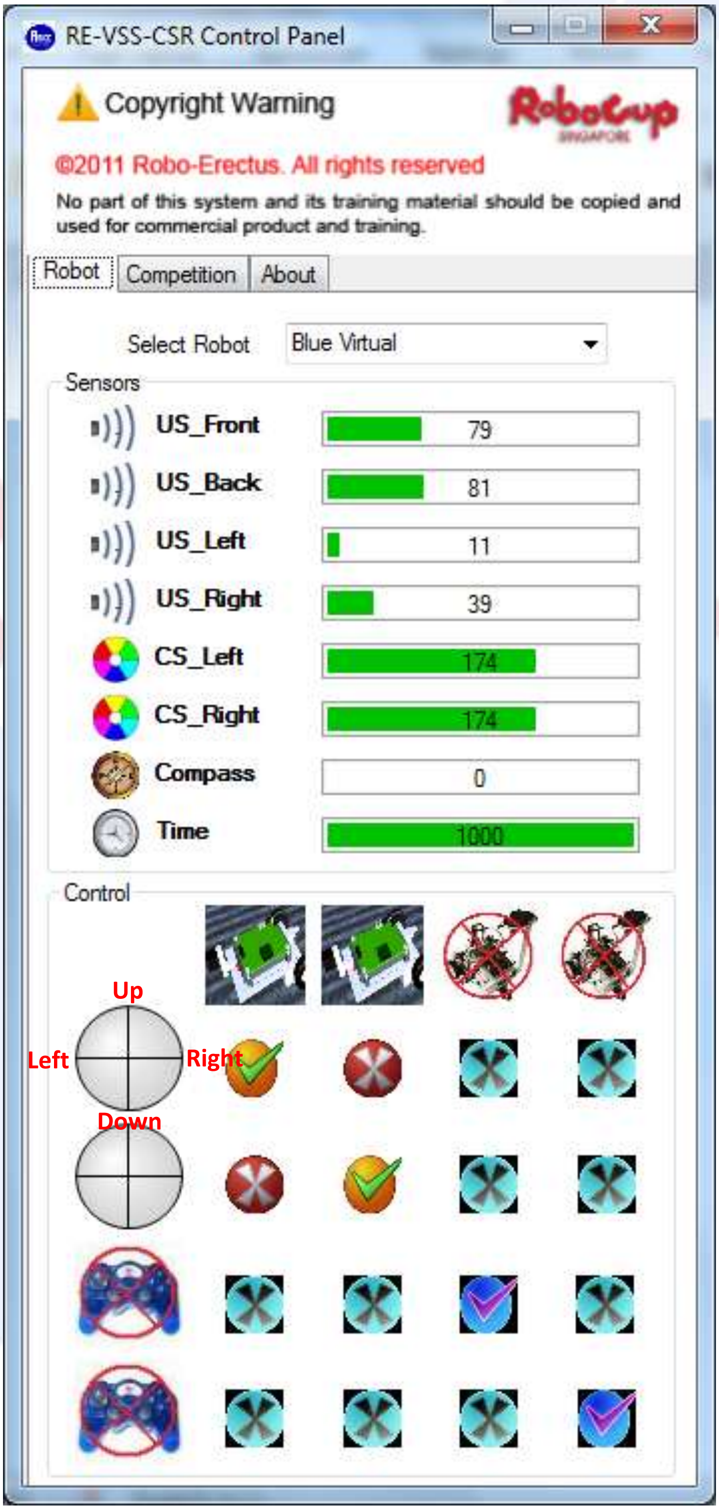


Fig. 8 – 1 Robot manual control

8.2 Working with ultrasonic sensors

Task 1:

To program a robot to move forward. It stops when it approaches the front obstacle. i.e. the distance between front obstacle and robot is less than 20 cm.

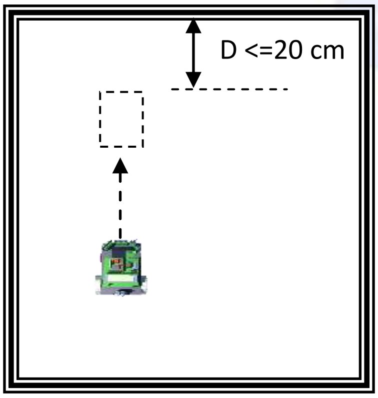


Fig. 8 – 2

Analysis:

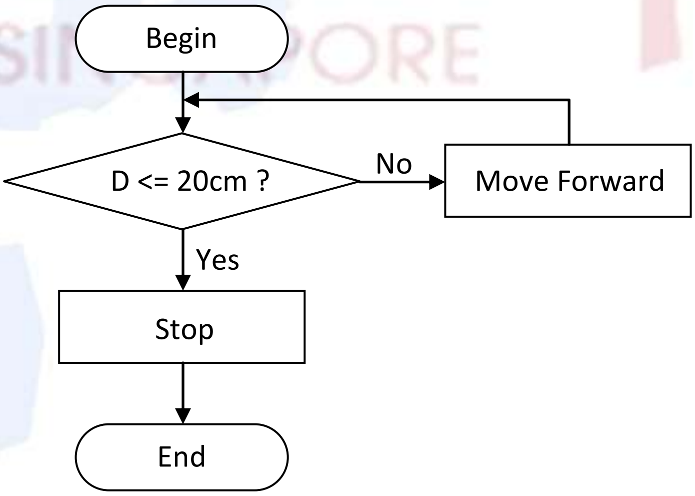


Fig. 8 – 3

Procedure:

1. Launch the RE – VSS – CSR.
2. Launch the AI developer panel
3. Create a new project.
4. Add a statement namely "Stop".

   Type: Default Action

   Condition: When the reading from front ultrasonic sensor <= 20 cm

   Action: Both wheels speed = 0 (stop position)

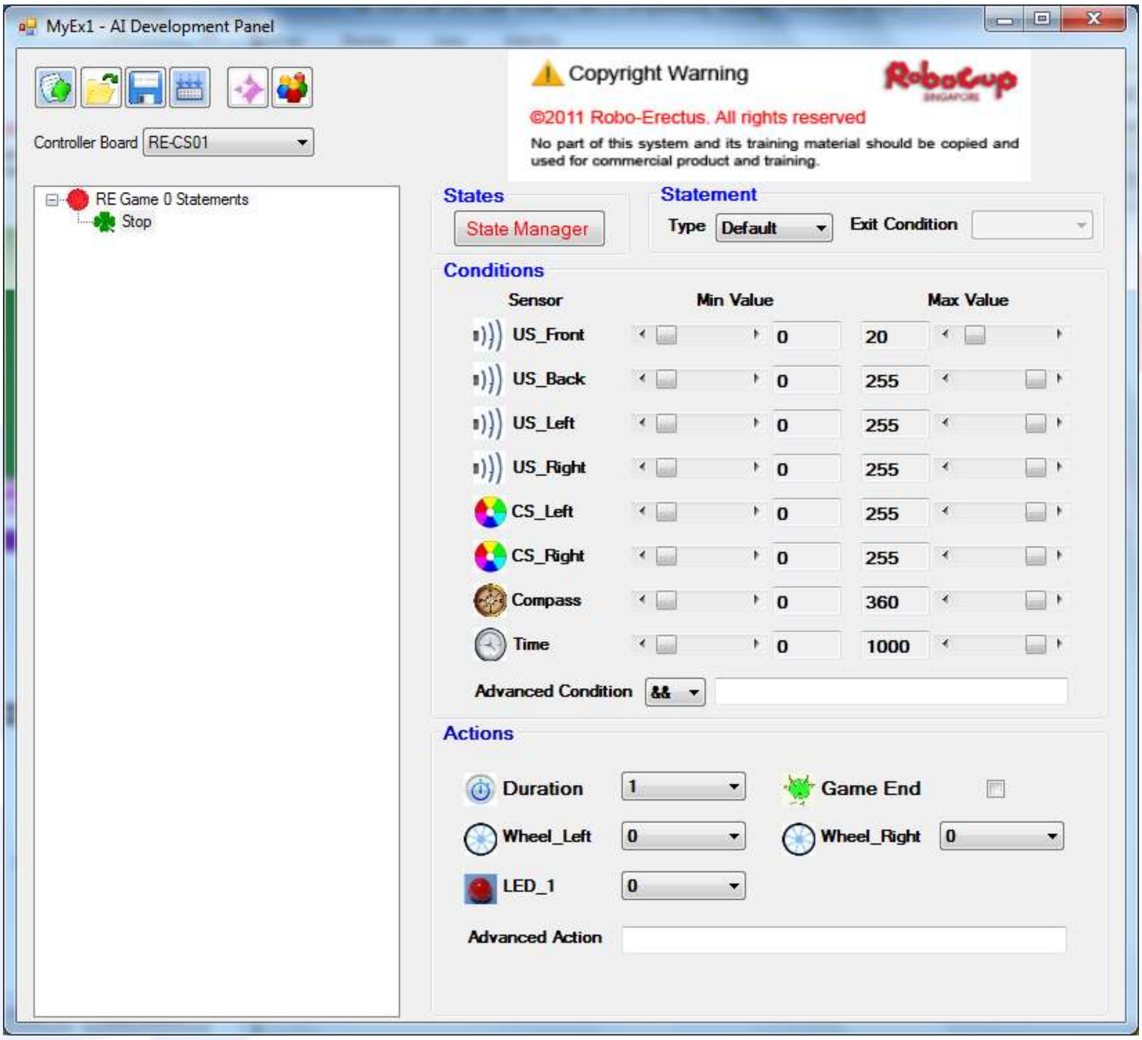


Fig. 8 – 4

5. Add a statement namely “Forward”.

   Type: Default Action

   Condition: no restrictions

   Action: Both wheels speed = “+2”

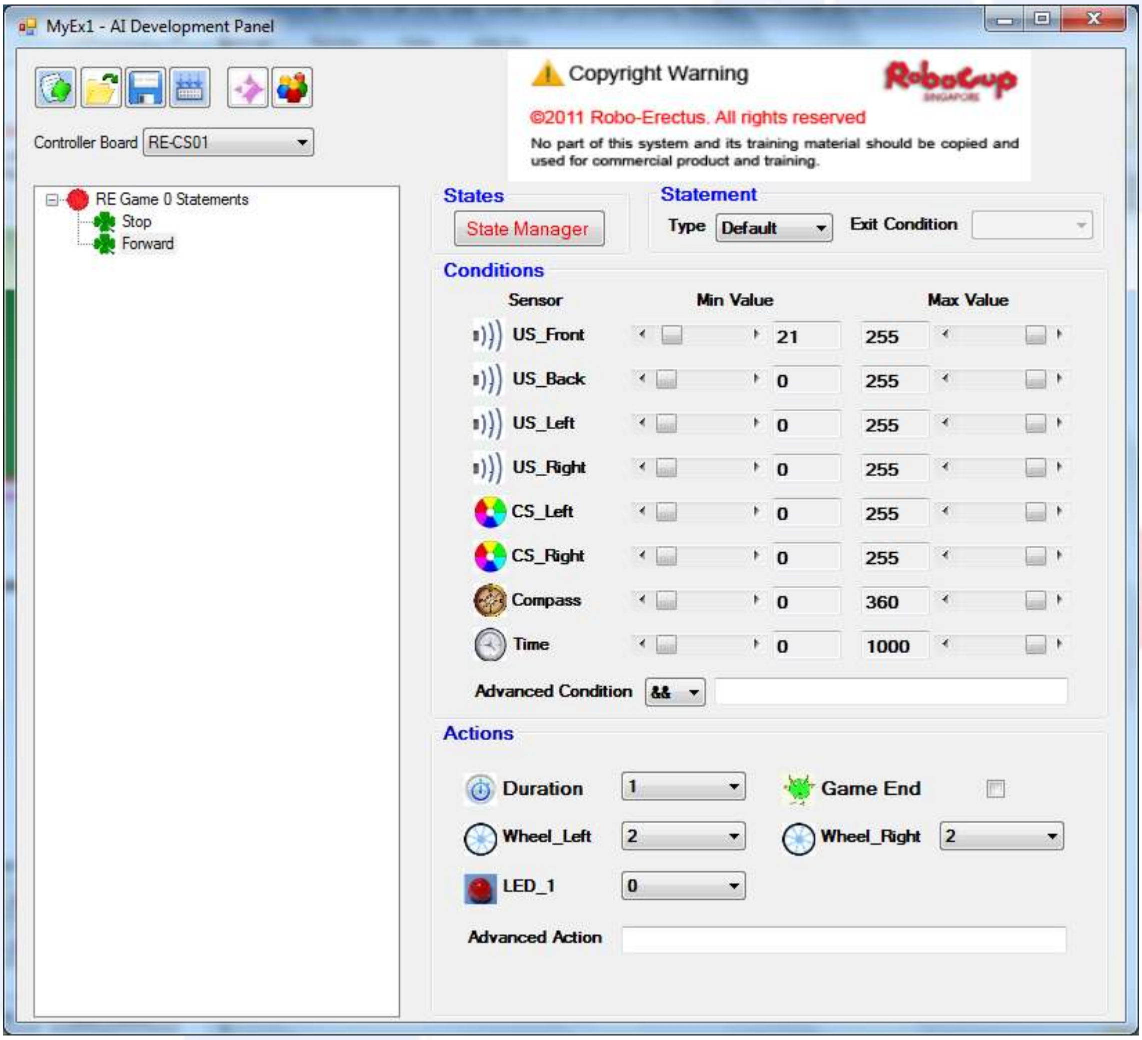


Fig. 8 – 5

6. Save project

   The saved project has an extension of “smp”. It can be reloaded for editing.

7. Build project

   The built project has an extension of “.dll”. This file can be loaded in the control panel for execution.

8. Load the built project and start the simulation.

9. Monitor the robot performance.

Task 2:

To program a robot to avoid an obstacle. That means that the robot will turn right when the front ultrasonic sensor detects an obstacle, i.e. the distance between front obstacle and robot is less than 20 am.

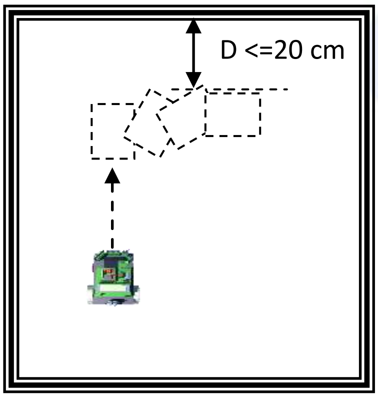


Fig. 8 – 6

Analysis:

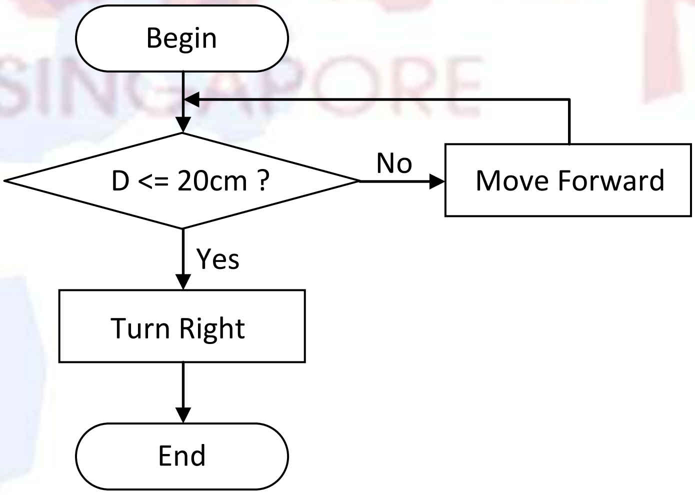


Fig. 8 – 7

Procedure:

1. Launch the RE – VSS – CSR.
2. Launch the AI developer panel
3. Create a new project.
4. Add a statement namely “Turn Right”.

   Type : Default Action

   Condition: When the reading from front ultrasonic sensor <= 20 cm

   Action: Left wheel speed = “+2”, Right wheel speed = “- 2”

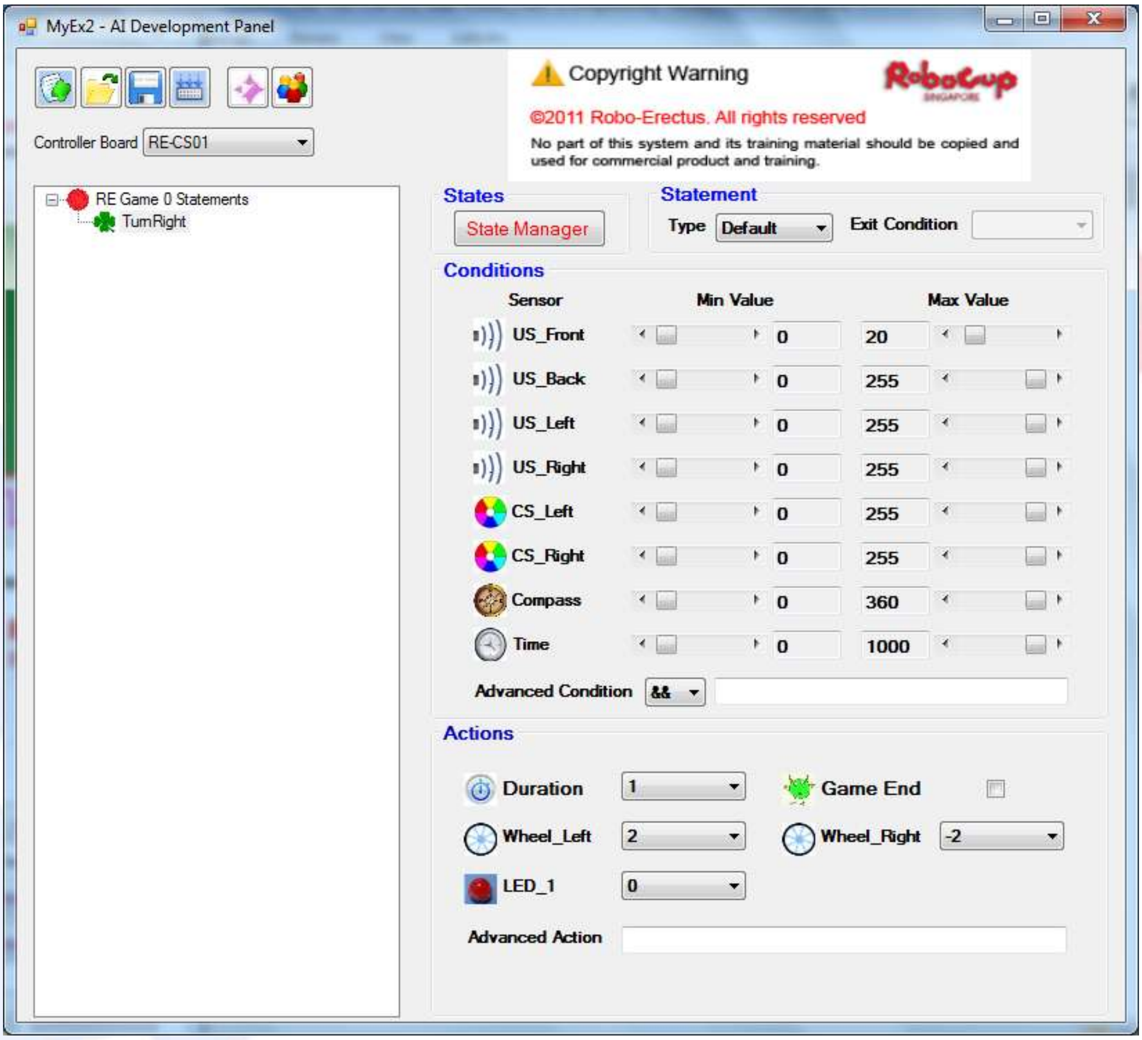


Fig. 8 – 8

5. Add a statement namely "Forward".

   Type: Default Action

   Condition: no restrictions

   Action: Both wheels speed = "+2"

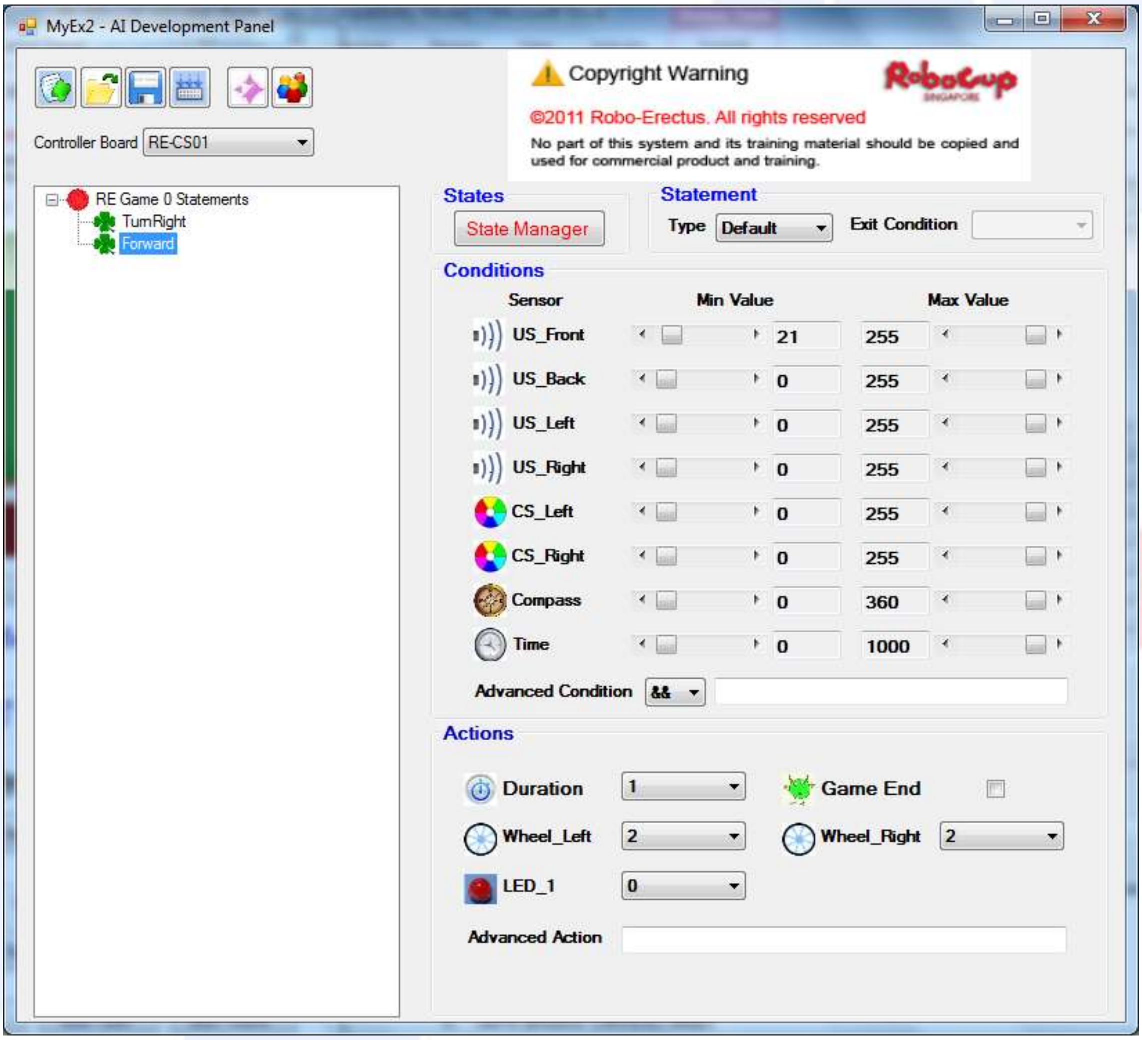


Fig. 8 – 9

6. Save project (MyEx2.smp)

   The saved project has an extension of ".smp". It can be reloaded for editing.

7. Build project (MyEx2.dll)

   The built project has an extension of "dll". This file can be loaded in the control panel for execution.

8. Load the "MyEx2.dll" in RE – VSS – CSR control panel and start the simulation.

9. Monitor the robot performance.

8.3 Working with compass sensors

Task 1:

To program a robot to turn 180^0 until it faces west (Method 1 – using default action).

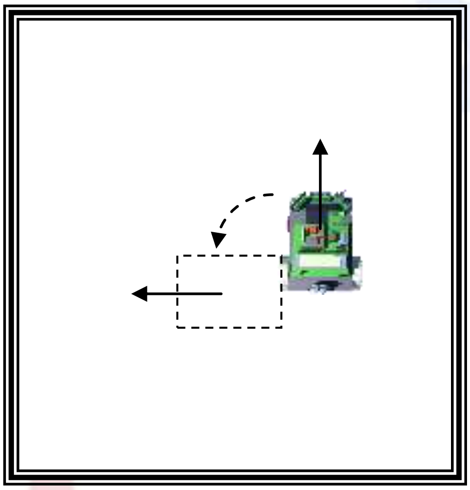


Fig. 8 – 10

Analysis:

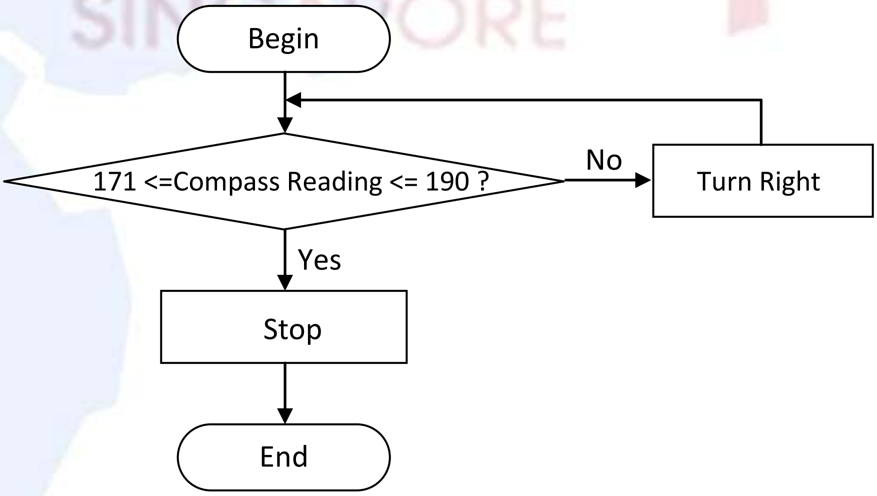


Fig. 8 – 11

Procedure:

1. Launch the RE – VSS – CDR.
2. Launch the AI developer panel
3. Create a new project.
4. Add a new statement "Stop".

   Type : Default Action

   Condition: When Compass sensor reading is in between 171 and 190 degree.

   Action: Left wheel speed = "0", Right wheel speed = "0"

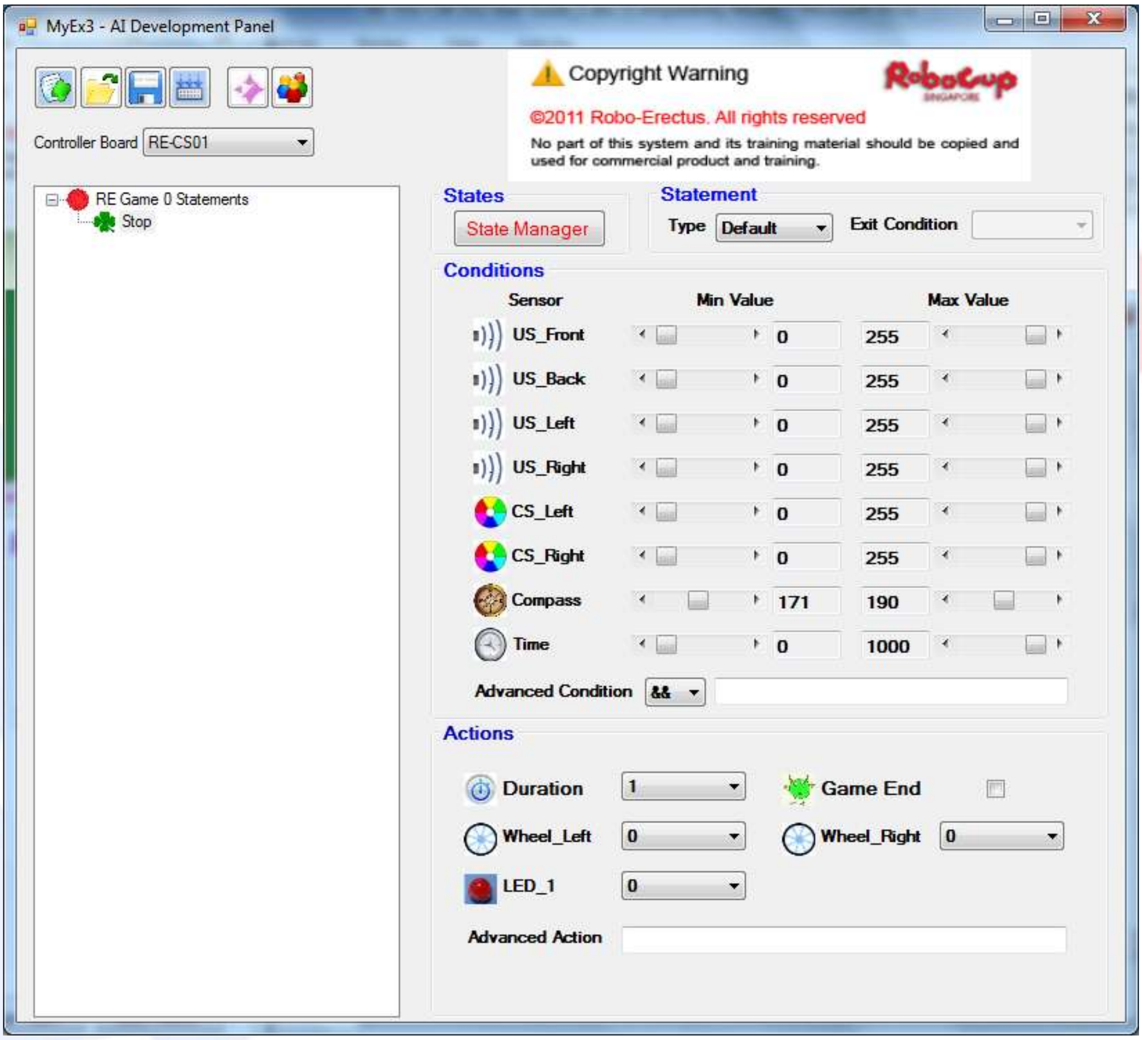


Fig. 8 – 12

5. Add a new statement “Turn Right”.

   Type : Default Action

   Condition: No restrictions.

   Action: Left wheel speed = “+1”, Right wheel speed = “-1”

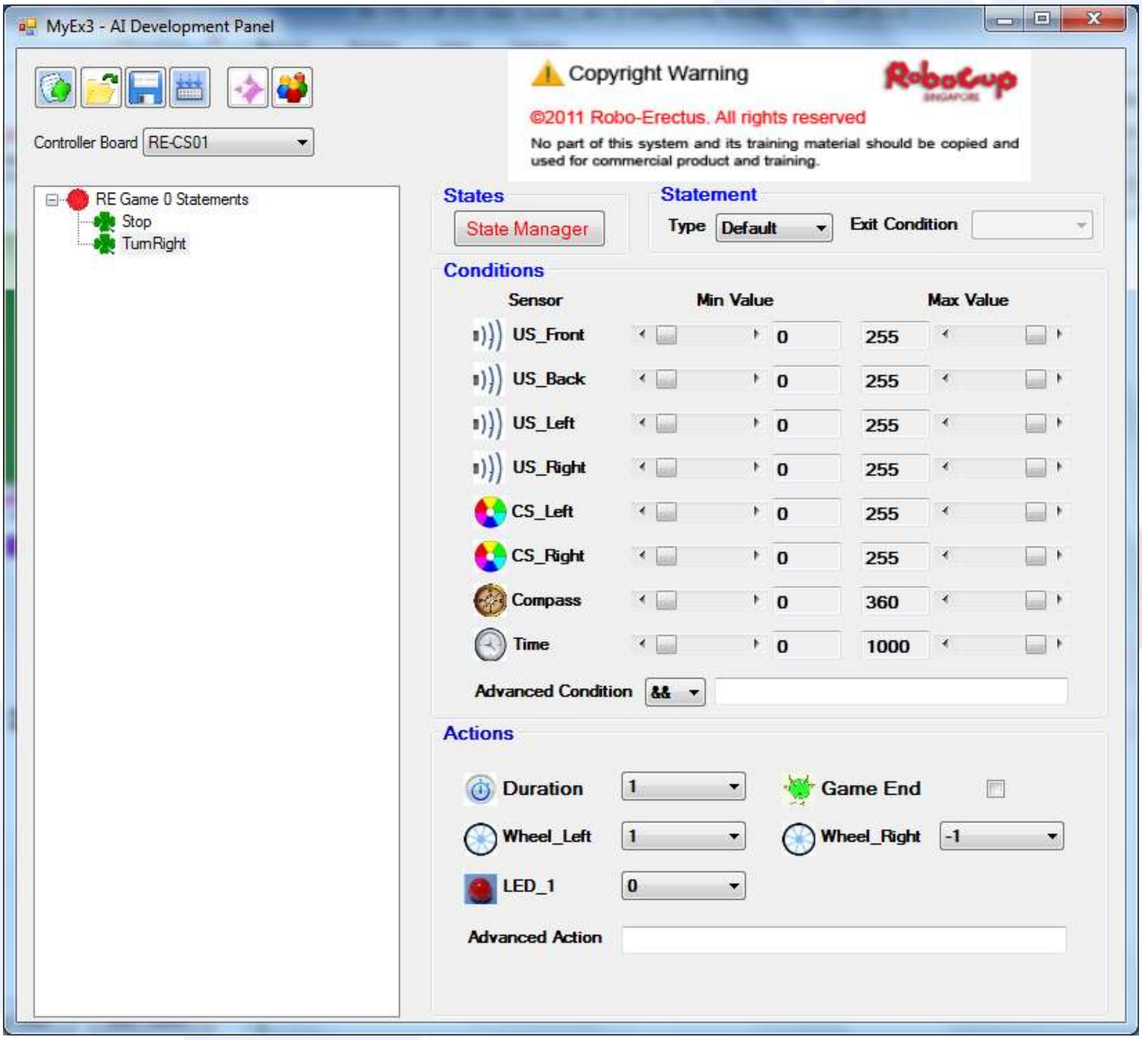


Fig. 8 – 13

6. Save the project as “MyEx3.smp”.
7. Build the project as “MyEx3.dll”.
8. Load the “MyEx3.dll” in RE – VSS – CSR control panel and start the simulation.
9. Monitor the robot performance.

Task 2:

To program a robot to turn 180^0 until it faces west (Method 2 – using Non-interrupt action).

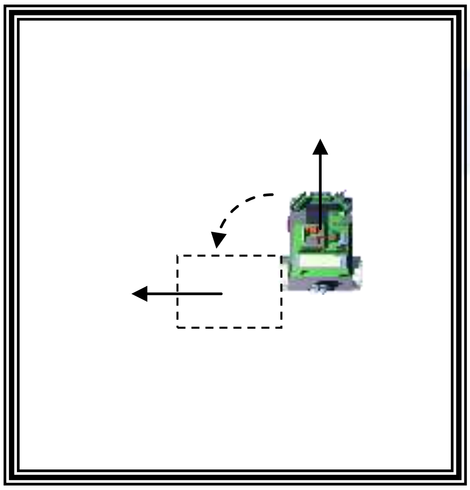


Fig. 8 – 14

Analysis:

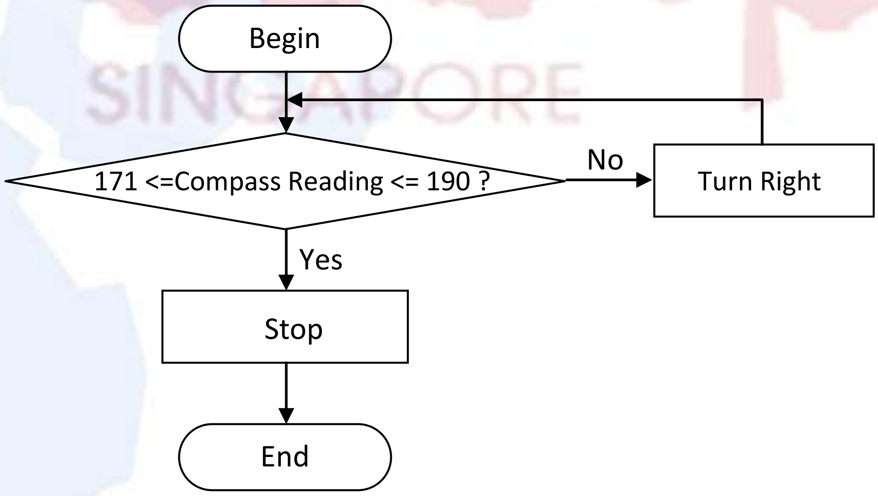


Fig. 8 – 15

Procedure:

1. Launch the RE – VSS – CSR.
2. Launch the AI developer panel.
3. Create a new project.
4. Add a new statement "Right Turn".

   Type : Non_Interrupt

   Add a new exit state using state manager:

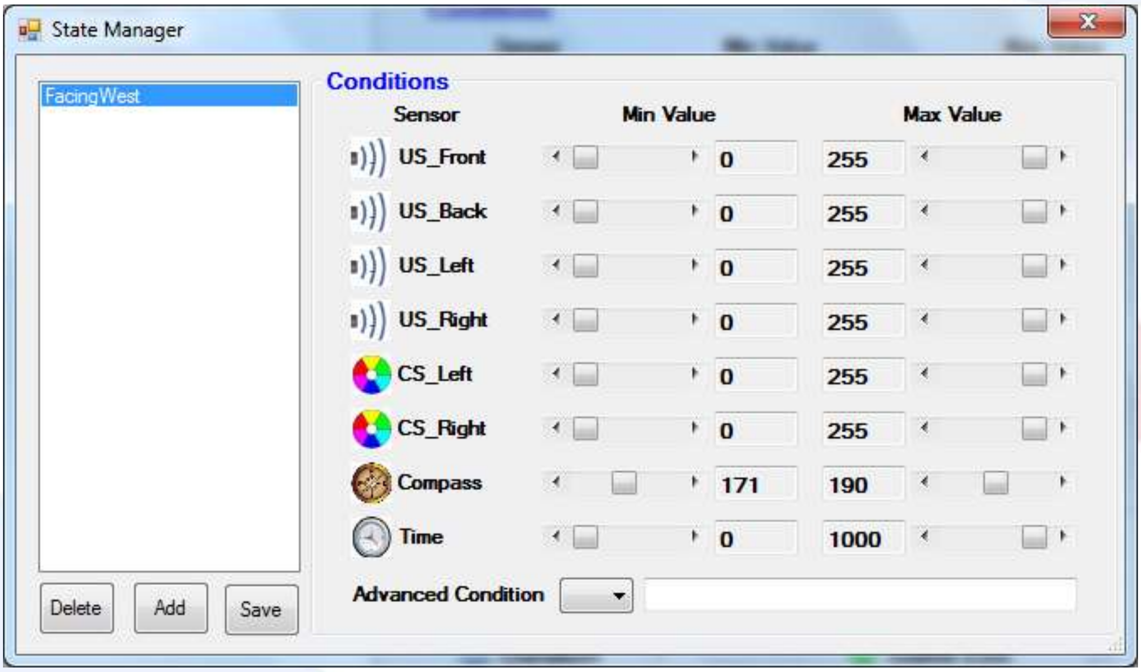


Fig. 8 – 16

Set the exit action condition to be 

, That means that when 171 <= Compass Reading <= 190 is true, the Non Interrupt action statement "Turn Right" will be terminated. The next statement in the program will be executed.

Condition:

"(Compass>=0 && Compass<=170) || (Compass>=190 && Compass<=360)"

This statement means:

When the condition (0 <= Compass sensor reading <=170) or (191 <= Compass sensor reading <=360) is fulfilled, the "Right Turn" statement will be executed.

Action:

Left wheel speed = “+1”, Right wheel speed = “-1”

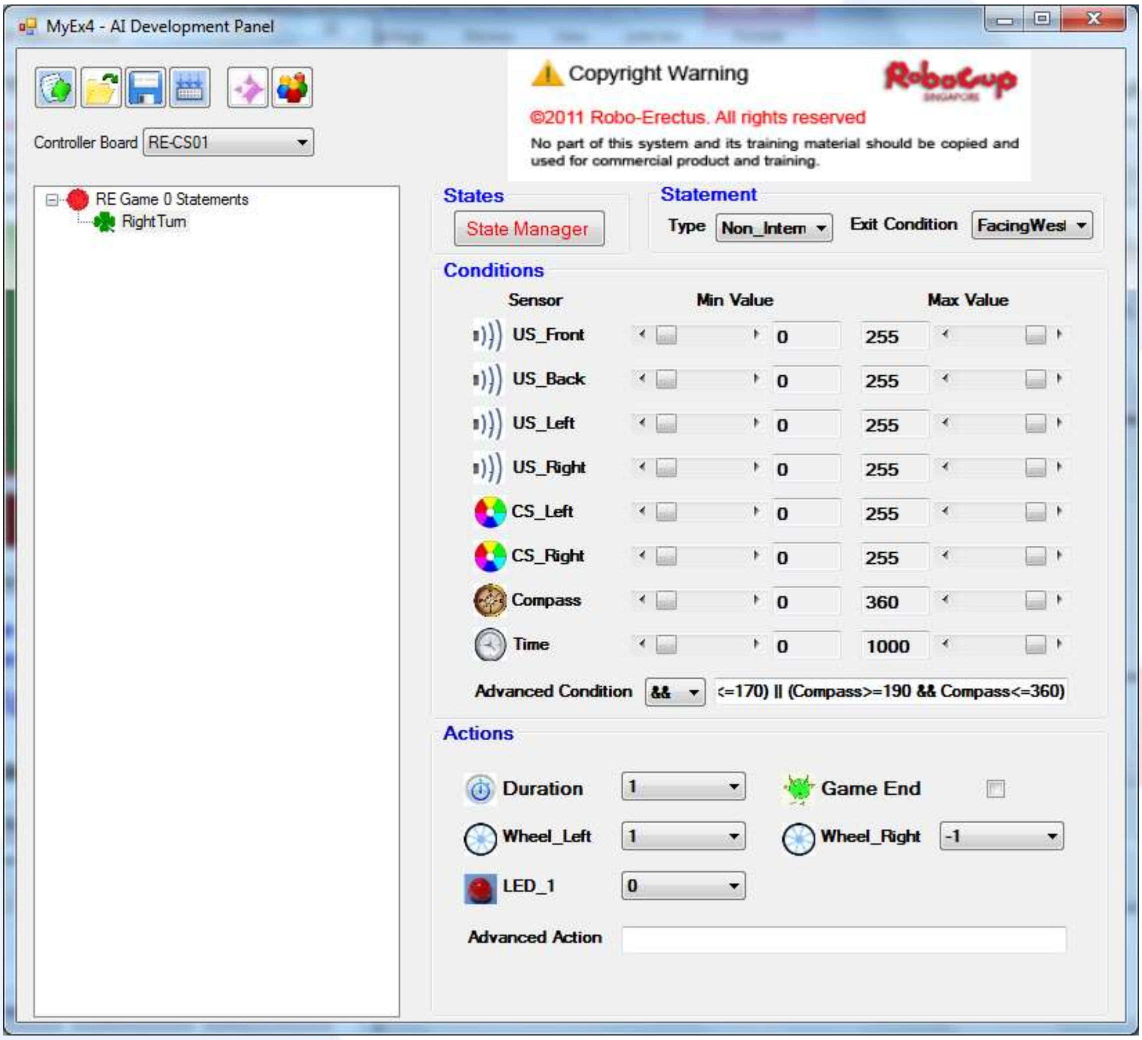


Fig. 8 – 17

5. Add a new statement "Stop".

   Type : Default Action

   Condition: No restrictions.

   Action: Left wheel speed = "0", Right wheel speed = "0"

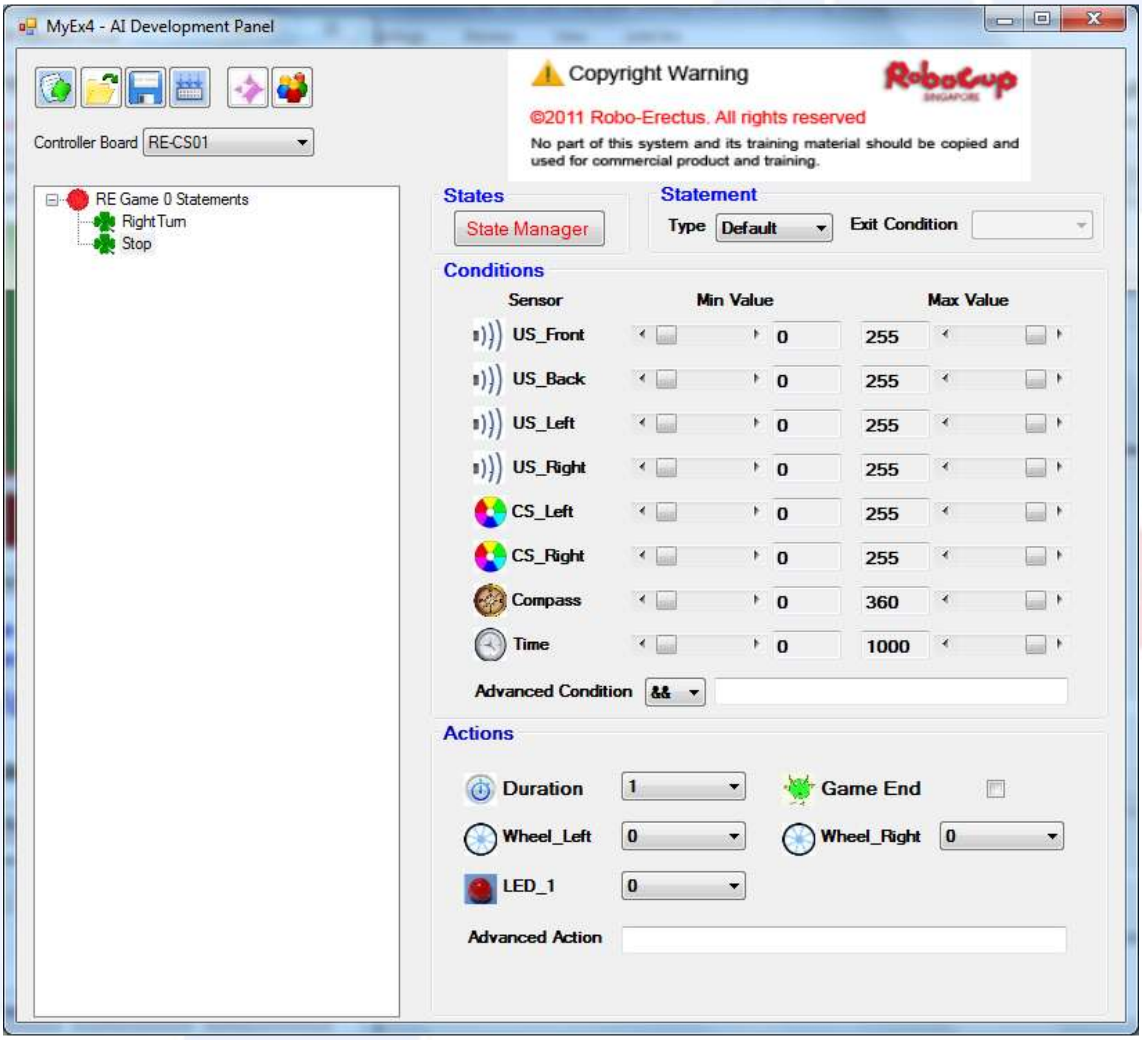


Fig. 8 – 18

6. Save the project as "MyEx4.smp".

7. Build the project as "MyEx4.dll".

8. Load the "MyEx4.dll" in RE – VSS – CSR control panel and start the simulation.

9. Monitor the robot performance.

8.4 Working with colour sensors

Task 1:

Program a robot to locate a black object in the field. The robot will stop with an LED on for the successful identification.

Analysis:

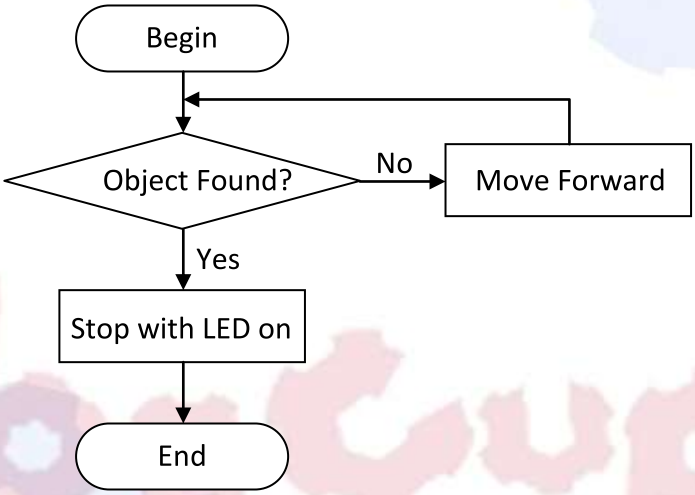


Fig. 8 – 19

Procedure:

1. Launch the RE – VSS – CSR.
2. Manually move the robot over the black object and read the colour sensor feedback. This value will be used for programming.

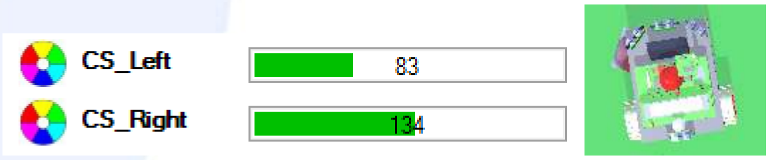


Fig. 8 – 20

This means that when the colour sensor senses the red object, the reading is about 40. The robot in RE – VSS – CSR is installed with 2 colour sensors. Both left and right colour sensors can detect the object. The readings for both left and right sensors are the same.

3. Launch the AI developer panel.

4. Create a new project.

5. Add a new statement “Left Sensor Found Object”.

   Type : Default Action

   Condition: Left colour sensor reading is less than 85.

   Action: Left wheel speed = “0”, Right wheel speed = “0”, LED is on

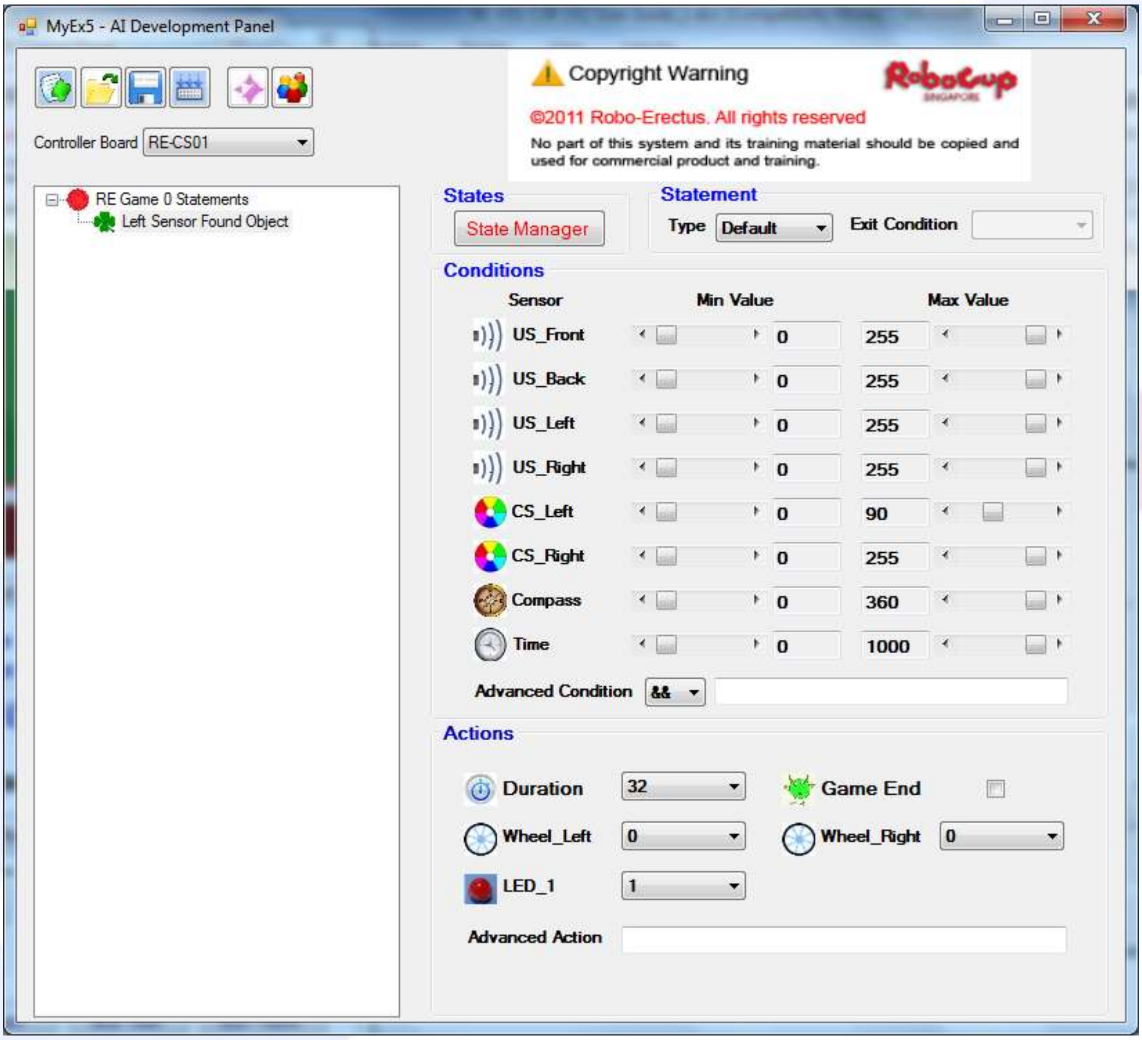


Fig. 8 – 21

6. Add a new statement "Right Sensor Found Object".

   Type : Default Action

   Condition: Right colour sensor reading is less than 42.

   Action: Left wheel speed = "0", Right wheel speed = "0", LED is on

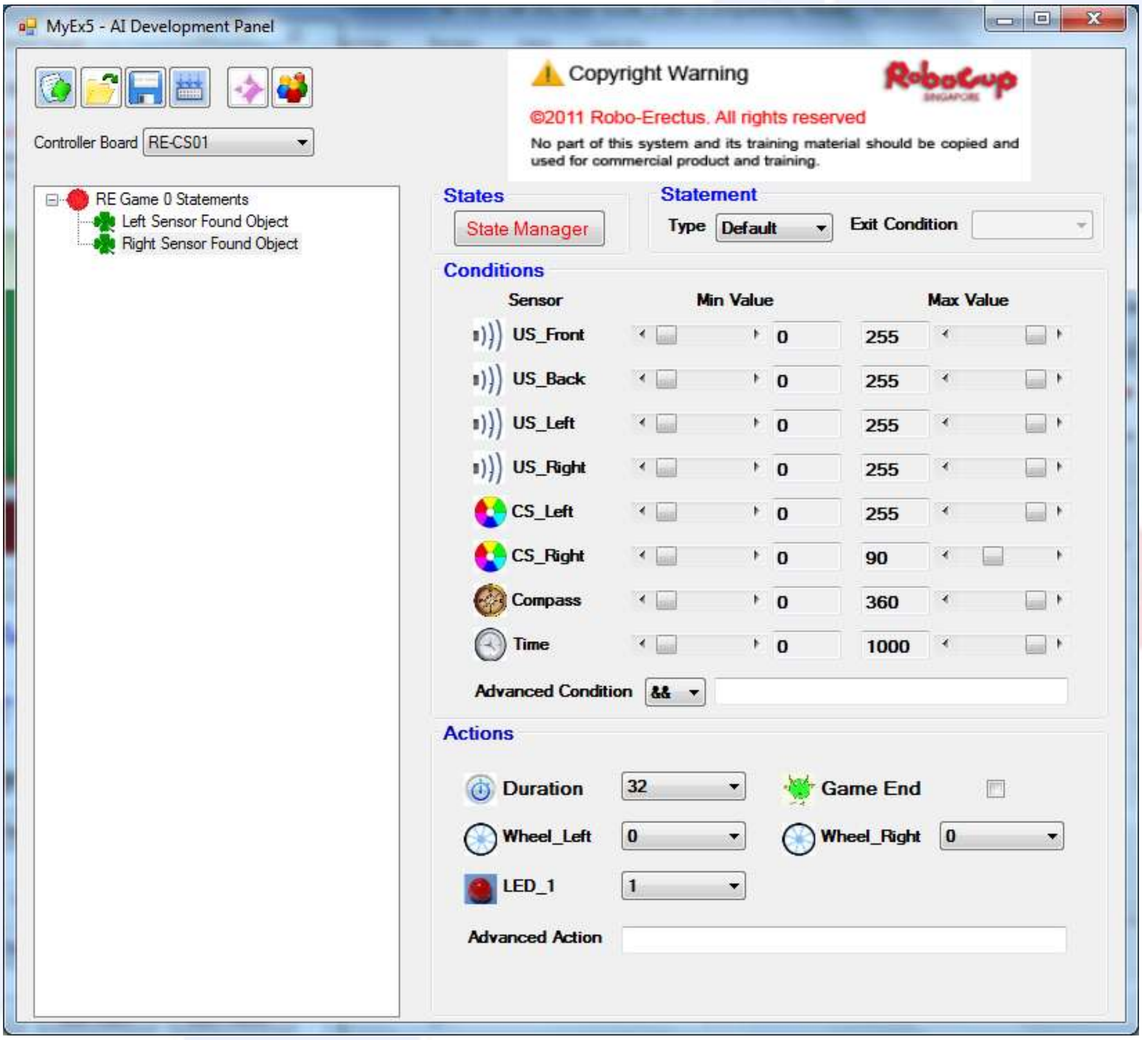


Fig. 8 – 22

7. Add a new statement "Move Forward".

Type : Default Action

Condition: No restrictions.

Action: Left wheel speed = "+1", Right wheel speed = "+1"

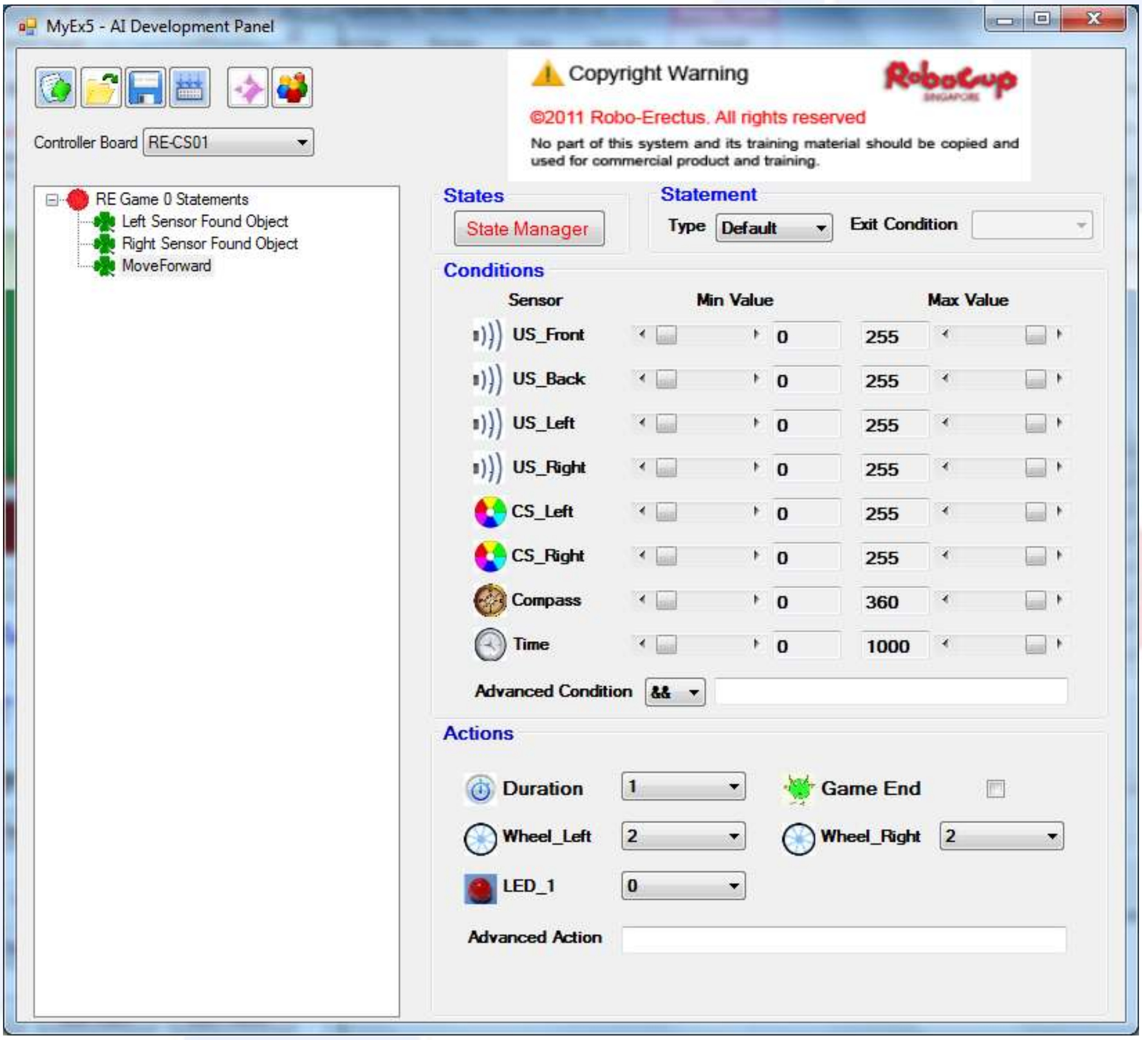


Fig. 8 – 23

8. Save the project as "MyEx5.xml".

9. Build the project as "MyEx5.dll".

10. Load the "MyEx5.dll" in RE – VSS – CSR control panel and start the simulation.

11. Monitor the robot performance.

9. MPLAB IDE, MPLAB C30 and PICkit 2 for PIC Microcontroller

9.1 Get Ready

CoSpace robot is equipped with PIC microcontroller. Therefore, MPLAB IDE, MPLABC30 Compiler, and PICkit2 are required for program compiling and downloading to real robot controller.

9.1.1 MPLAB Integrated Development Environment (IDE) and MPLAB C30 Compiler

MPLAB Integrated Development Environment (IDE) is a comprehensive editor, project manager and design desktop for application development of embedded designs using Microchip PIC MCUs and dsPIC DSCs.

MPLAB IDE provides the ability to:

- Create and edit source code using the built-in editor.
- Assemble, compile and link source code.
- Debug the executable logic by watching program flow with the built-in simulator or in real time with in-circuit emulators or in-circuit debuggers.
- Make timing measurements with the simulator or emulator.
- View variables in watch windows.
- Program firmware into devices with device programmers (for details, consult the user's guide for the specific device programmer).

9.1.2 PICkit 2 MCU Programmer/Debuger

The PICkit 2 Development Programmer/Debugger is a low-cost development programmer. It is capable of programming most of Microchips Flash microcontrollers and serial EEPROM devices.

Fig. 9 – 1: PICkit 2

9.2 Installation

9.2.1 Install/Uninstall MPLAB IDE

To install **MPLAB IDE** on your system:

- If installing from a CD-ROM, place the disk into a CD Drive. Follow the on-screen menu to install MPLAB IDE. If no on-screen menu appears, use Windows Explorer to find and execute the CD-ROM menu, menu.exe.
- If downloading MPLAB IDE from the Microchip website (www.microchip.com), locate the download (.zip) file, select the file and save it to the PC. Unzip the file and execute the resulting setup.exe file to install.

  Please note: Before the installation is completed, you will be asked to install "HI-TECH". Please select "NO" to end.

To uninstall **MPLAB IDE**:

- Select Start > Settings > Control Panel to open the **Control Panel**.
- Double click on **Add/Remove Programs**. Find MPLAB IDE on the list and click on it.
- Click **Change/Remove** to remove the program from your system.

9.2.2 Install/Uninstall MPLAB C30 Compiler

To install **MPLAB C30 Compiler** on your system:

- Download and install the following compiler from Microchip website (www.microchip.com):

  MPLAB C Compiler for PIC24 MCUS and dsPIC DSCs, academic version.

To uninstall **MPLAB C30 Compiler**:

- Select Start > Settings > Control Panel to open the Control Panel.
- Double click on Add/Remove Programs. Locate & select the "MPLAB C for dsPIC DSCs and PIC24 MCUs".
- Click "uninstall" button to uninstall it from your system.

****Both MPLAB IDE & MPLAB C30 Compiler must be installed on the system. Failure to do so may cause failure/errors when compiling the project.**

9.2.3 Install/Uninstall PICkit 2 (PICkit2need to be purchased)

<u>To install the PICkit 2 on your system</u>

- Insert the PICkit™ 2 Starter Kit CD ROM into the CD ROM drive. In a few moments, the introductory screen should appear. Follow the directions on the screen for installing the PICkit™ 2 Programming Software. If the introductory screen does not appear, browse to the CD ROM directory and select the `Setup.exe` program.

<u>To install the PICkit 2 on your system</u>

- Select Start > Settings > Control Panel to open the Control Panel.
- Double click on Add/Remove Programs. Locate & select the "PICkit 2",
- Click "uninstall" button to uninstall it from your system.

9.3 Running MPLAB IDE

To start MPLAB IDE, double click on the icon installed on the desktop after installation or select **Start > Programs > Microchip > MPLAB IDE v8.xx > MPLAB IDE**. A screen will appear displaying the MPLAB IDE logo followed by the MPLAB IDE desktop as shown in Fig. 9 – 2.

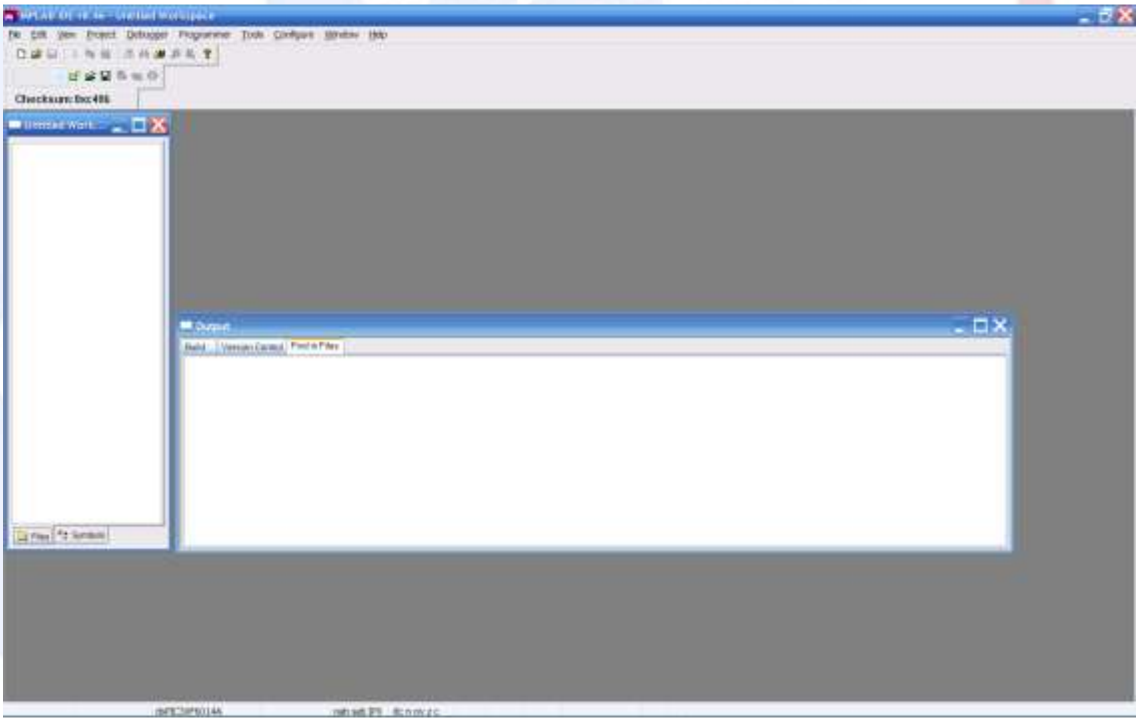


Fig. 9 – 2 : MPLAB IDE Desktop

In order to create code that is executable by the target PIC Microcontroller unit, source files need to be put into a project. The codes can then be built into executable code using selected language tools (assemblers, compilers, linkers, etc.). In MPLAB IDE, the project manager controls this process. All projects will have these basic steps:

1. Create Project
2. Select Device
3. Select Language Tools
4. Put Files in Project
5. Create Code
6. Build Project
7. Test Code with Simulator

9.3.1 Creating a Project

A project is the way the files are organized to be compiled and assembled. A project can be created using the Project Wizard.

Step 1: Choosing **Project** > **Project Wizard**

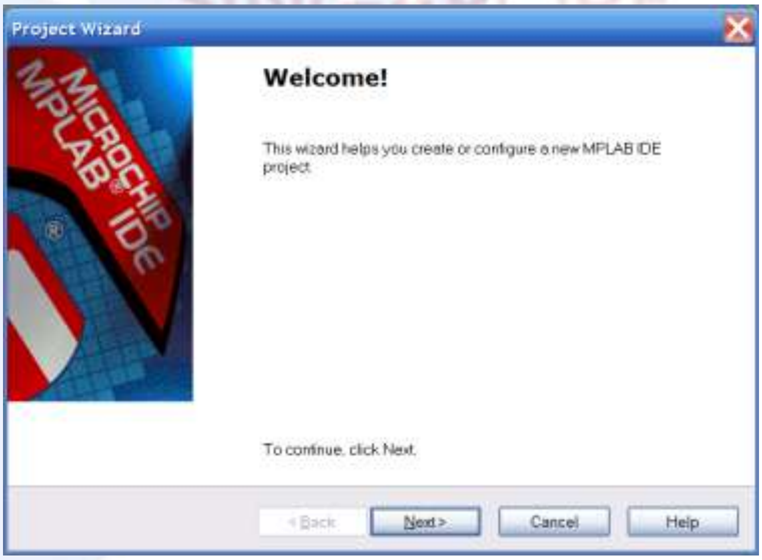


Fig. 9 – 3: Project Wizard – Welcome

From the Welcome dialog, click on “Next” to advance.

Step 2: Selecting a device

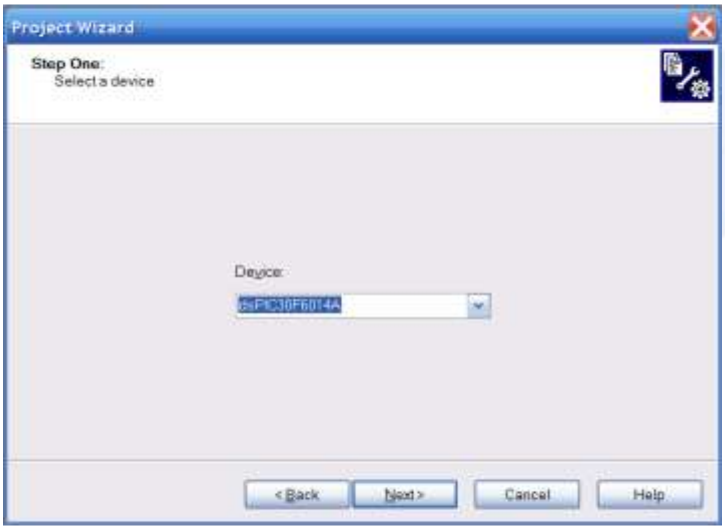


Fig. 9 – 4: Project Wizard – Select Device

From drop down list, choose the "dsPIC30F6014A" and follow by clicking on "Next" to proceed to **setup a programming language**.

Step 3: Setting up a programming language

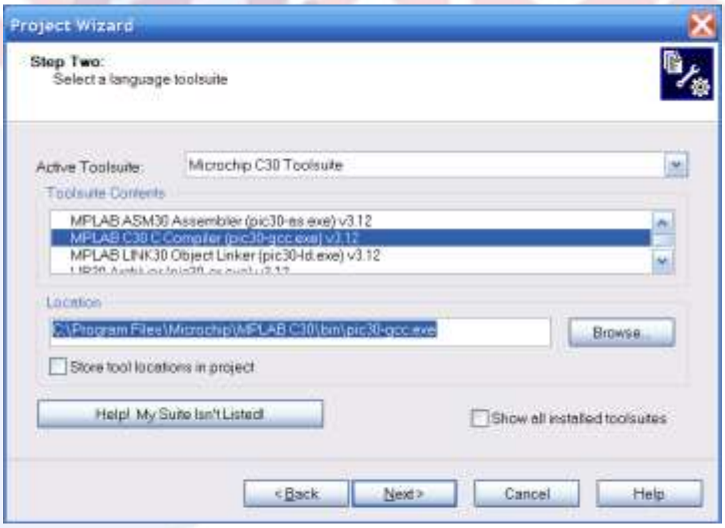


Fig. 9 – 5: Project Wizard – Select language tools

- Select "Microchip C30 Toolsuite" in the Active Toolsuite list box. Then MPLAB C30 C compiler (pic30-gcc.exe) v3.25) should be listed in the Toolsuite Contents box.
- Click each one in the list and locate them from the respective directory. If you are not sure the exact location of the file, use search function in Windows to find.
- Use the browse button to set them to the proper files in the MPLAB IDE subfolders.

When you finish, click "Next".

Step 4: Naming a new project and put it into a folder

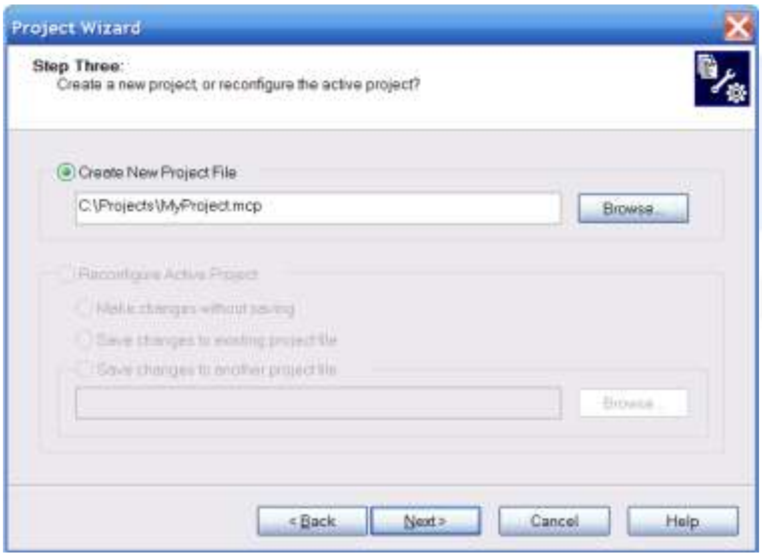


Fig. 9 – 6: Name Project

In this example, we will create a sample project will be called C:\Projects\MyProject. Type this into the text box and then click “Next”. You will be prompted to create the directory since it does not exist. Click OK.

Step 5: Adding files

Select the necessary files (**motherboard.o**, **motherboard.h**, **main.c**, and **main.h**) and click “Add” to add them into the right panel.

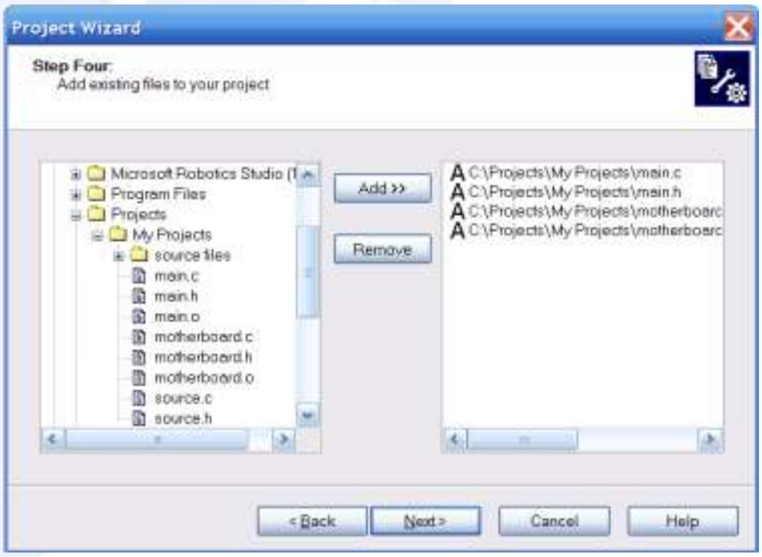


Fig. 9 – 7: Adding files

Once it is done, clicking “Next” will show up a project summary dialog.

The project summary dialog summaries the selected device, the toolsuite, and the new project file name.

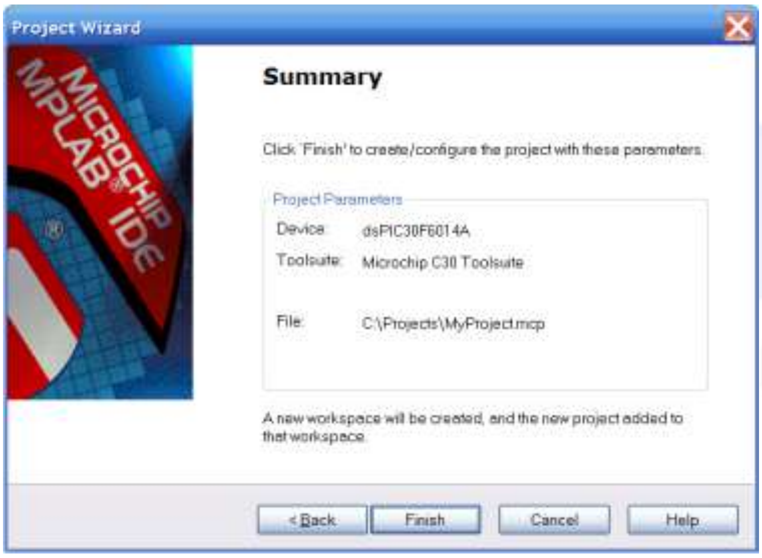


Fig. 9-8: Project summary

Click on “Finish” to generate the project and proceed to the “MPLAB WorkSpace”

<u>Step 6: Viewing the Project</u>

You can select **View** > **Project** in menu bar to view the project created.

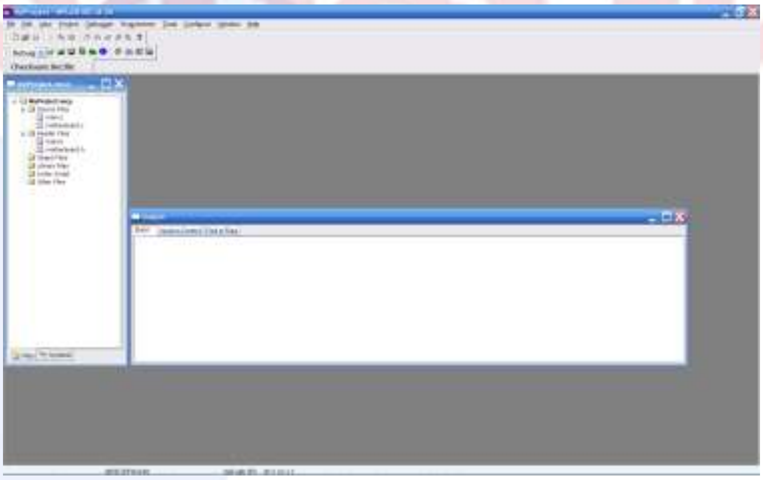


Fig. 9-9: MPLAB WorkSpace

Files can be added and project can be saved by clicking the right mouse button in the project window. In case of error, files can be manually removed from the project by selecting them; clicking the right mouse button and selecting “Remove” from the menu.

9.3.2 Building a project

“Build a project” is to compile and link all the source files for an application.

Double click on the project created. In the MPLAB IDE menu, select **Project** > **Build All**.

The output window shows the result of build process. There should be no errors or warning at any step. However, if you do receive errors, go back to the previous sections and check the project assembly steps. Errors will prevent the project from building. If you receive warnings, you may ignore them for this project as they will not prevent the project from building.

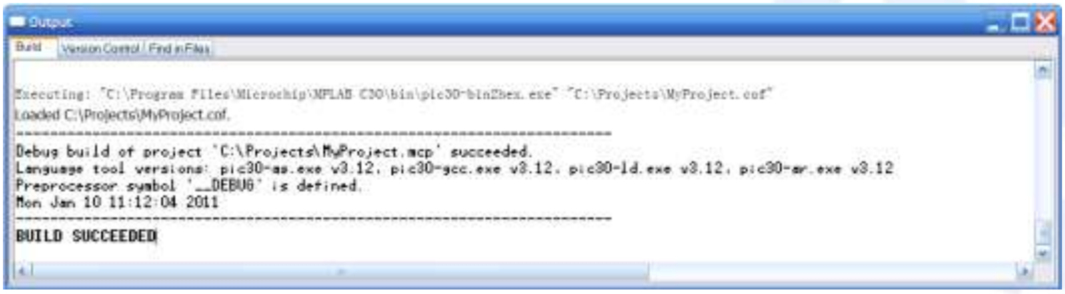


Fig. 9-10: Output window

If you follow all the steps mentioned previously, you will get the message "BUILD SUCCEEDED" as shown in Fig. 9-10 shown above on your output window when you select "Build All".

9.4 PICkit 2 Programming Interface

Start the PICkit™ 2 Programming Software by selecting Start > Programs > Microchip > PICkit 2. The programming interface appears as shown in Fig. 9 – 11.

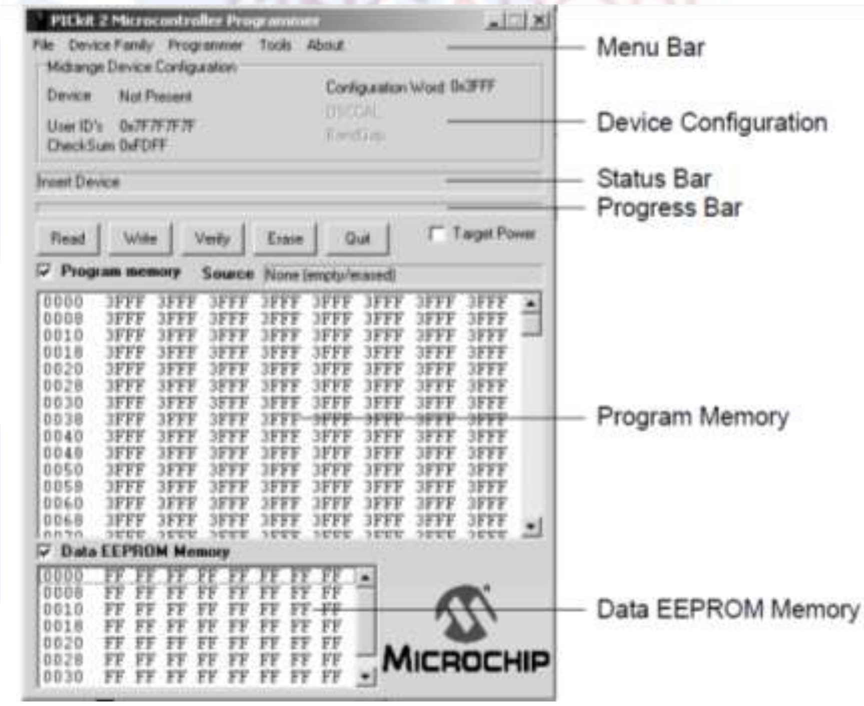


Fig. 9 – 11: PICkit 2 programming interface

9.4.1 Checking Communication

Plug PICkit 2 into both computer and Robot controller board. To test the communication. select the Tools > check communication. The message “PICkit 2 found and connected” will be displayed in the status bar.

10. Working with Real Robots

Upon successful compilation and building of a project, "ai.c" – a C code file, is automatically generated. The "ai.c" can be downloaded to the real robot. Of course, you can open the ai.c file to study the programming logics if you wish do. You can also modify the C code for further improvement. This feature allows students to program a robot controlled by a microcontroller without writing a C code for any specific microcontroller.

10.1 Install ZigBee Modules

The real robot communicates with the virtual control/competition panels via ZigBee communication protocol. Hence, it is necessary to make sure that the ZigBee modules are connected to the real robot and the computer properly. If this is your first time using ZigBee, you need to install "FT232R USB UART Driver" for the ZigBee module. Appendix B shows the procedures of determining the correct com port connected with the ZigBee module.

10.2 Manual Control of Real Robots

10.2.1 Connecting the real robot

Step 1: Identify the com port ID used to connect the ZigBee module.

Step 2: Double click the robot icon in the control panel as shown in Fig. 10 – 1.

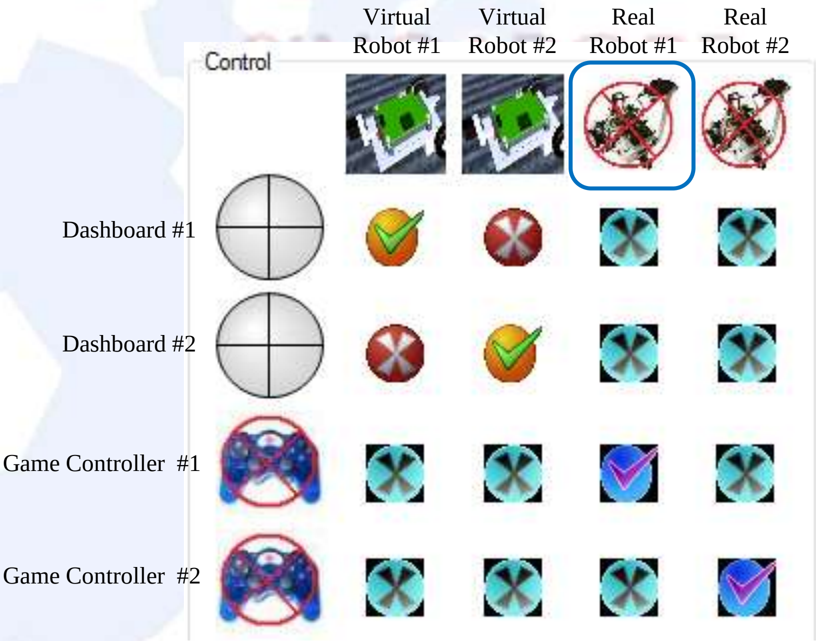


Fig. 10 – 1: Robot control configuration

Step 3: Assign the correct com port and robot ID in the pop-up window. The robot ID must be unique. It has to be the same as the robot ID assigned to the real robot.

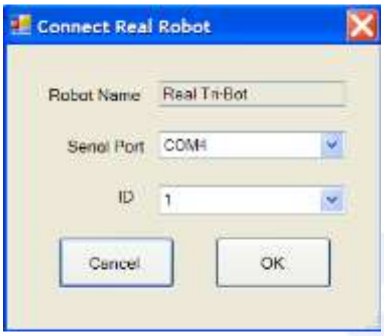


Fig. 10 – 2: Connect real robot window

10.2.2 Testing

Step 1: Double click on the blue cross button as indicated in Fig. 10 – 3. It will turn to green tick once it is connected.

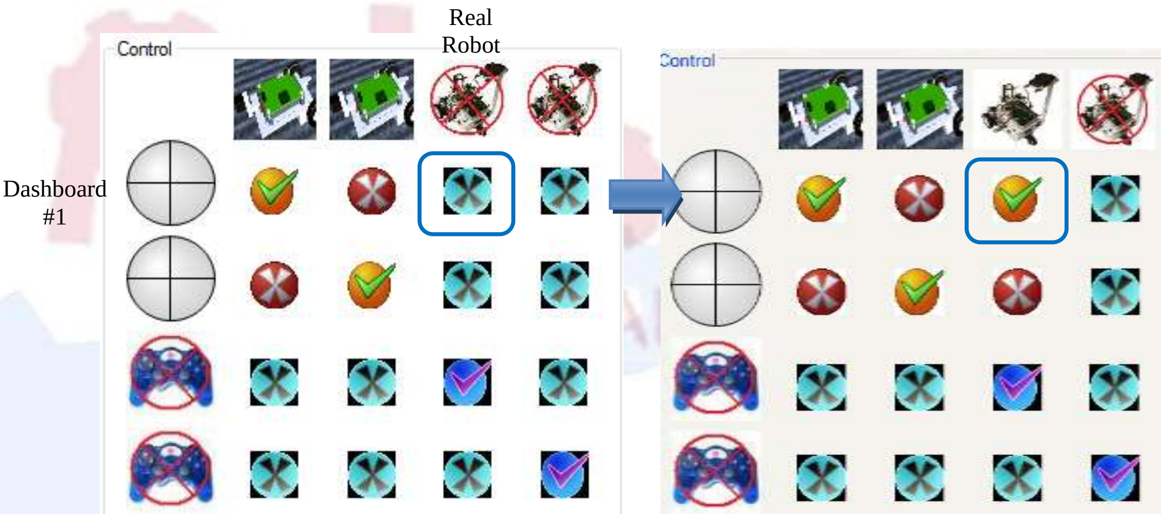


Fig. 10 – 3: Manual control of a real robot

Step 2: Move the dashboard to control the real robot. The real robot will move accordingly.

10.3 Fully Autonomous Robot

10.3.1 Connecingt the real robot

Repeat the steps stated in 10.2.1 to establish the communication via ZigBee.

10.3.2 Download the Program into the Real Robot

Step 1: Copy the folder RealAI from the CD or from the following website to your own PC.

Step 2: Substitute the file "ai.c" in the RealAI folder with the new "ai.c" generated. The same file name must be retained. As the lighting condition in real environment varies and it is certainly different from the virtual world, the sensor readings will change. Therefore, it is important to do a sensor calibration and make necessary changes in the program before downloading it onto the real robot.

Step 3: Launch the MPLAB workspace and open a project called RE2009PIC.mcp.

Step 4: In order to receive the real-time feedback from all sensors during the navigation controlled by a program, it is compulsory to change the robot ID in the "ai.c" file.

```
////////////////////////////

//The ID : It must be three digital number. Value is
from "001" to "999".  "000" is reserved.

char AI_MyID[3] = "002";    ← Assign the correct robotID

///////////////////////////////////

#define true 1

#define false 0

int AI_MotorType = 0;

int Duration = 0;

int SuperDuration = 0;
```

Step 5: Build the project. The message "Build Succeeded" will appear upon successful building. The compiled file will have an extension ".HEX".

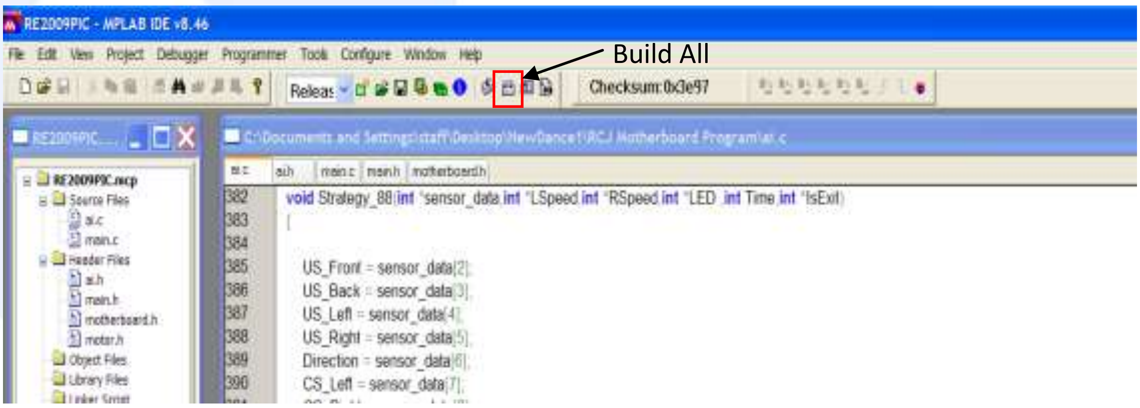


Fig. 10 – 4: Build a project

Step 6: Power off the robot and Connect the PKCKIT2 to controller board.

Fig. 10 – 5: PICKit 2 connection

Step 7: Launch the PICkit 2 programmer by clicking the "PICkit 2.exe".

Step 8: Choose "Tool – Check Communication" from the menu bar. The message "PICkit 2 found and connected" will be displayed in the status bar as shown in Fig. 10 – 6.

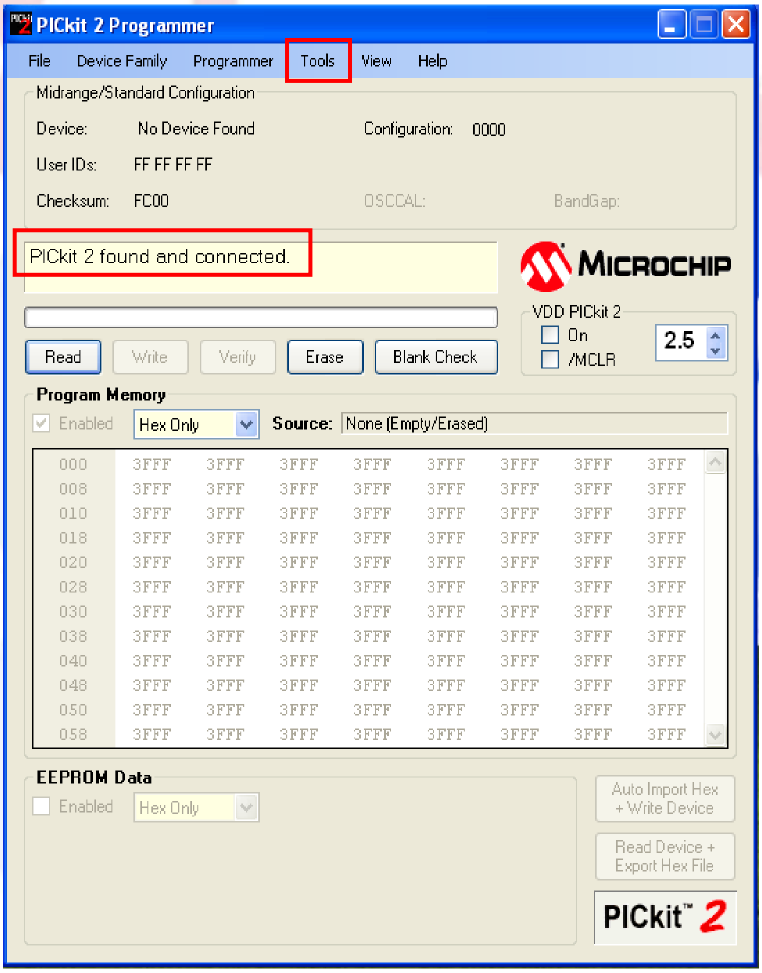


Fig. 10 – 6: PICkit 2 Communication

Step 9: Click on "" button to erase the memory. This is to erase the program memory, data EEPROM memory, ID and configuration bits.

Step 10: Import the correct ".HEX" file built in step 5 by choosing "File – Import HEX file" function. The message "Hex file successfully imported" will be displayed in the status bar.

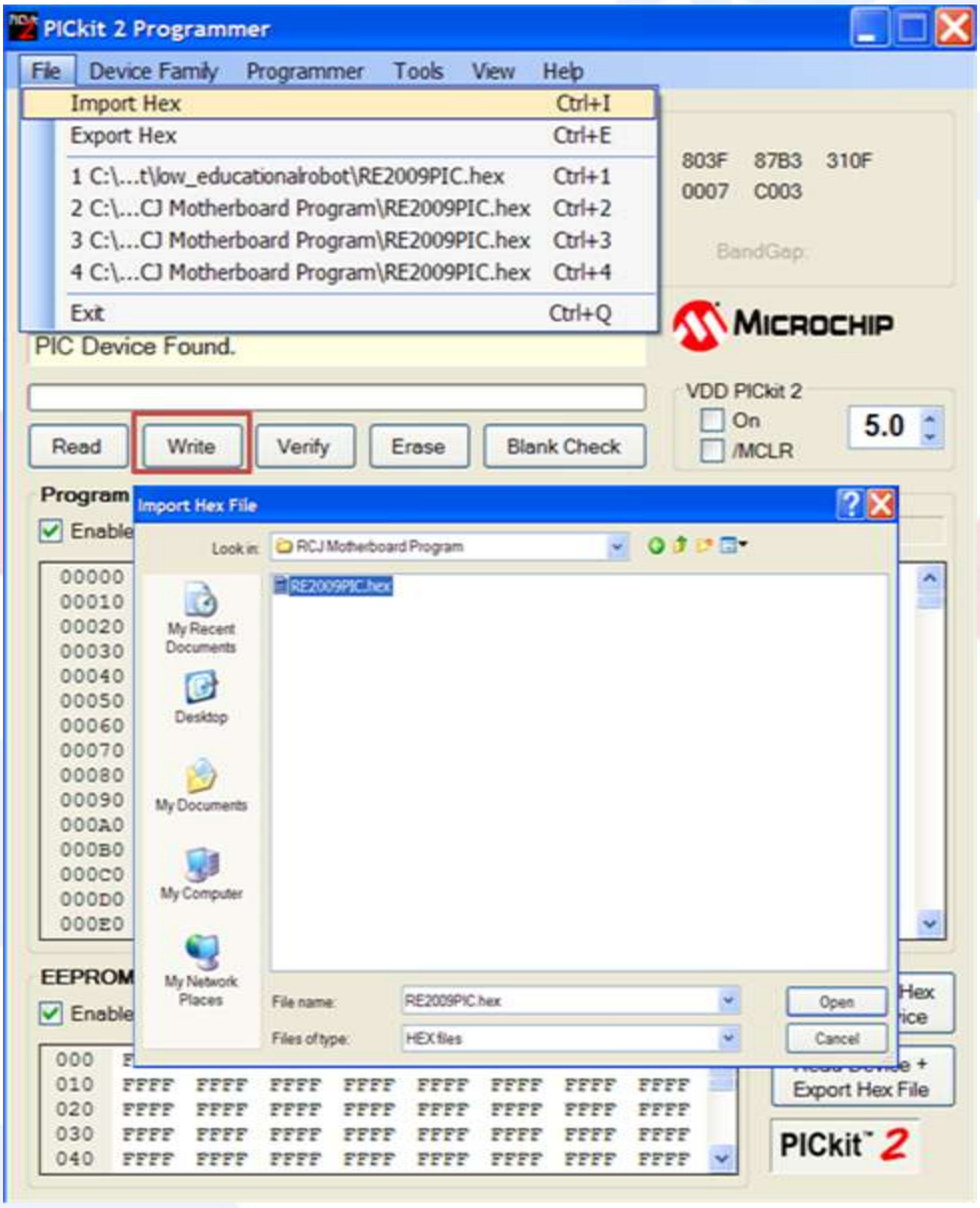


Fig. 10 – 7: Import ".HEX" file

Step 11: Download the program to real robot by clicking the "Write" button. The message "Programming Successful" will be displayed upon successful downloading.

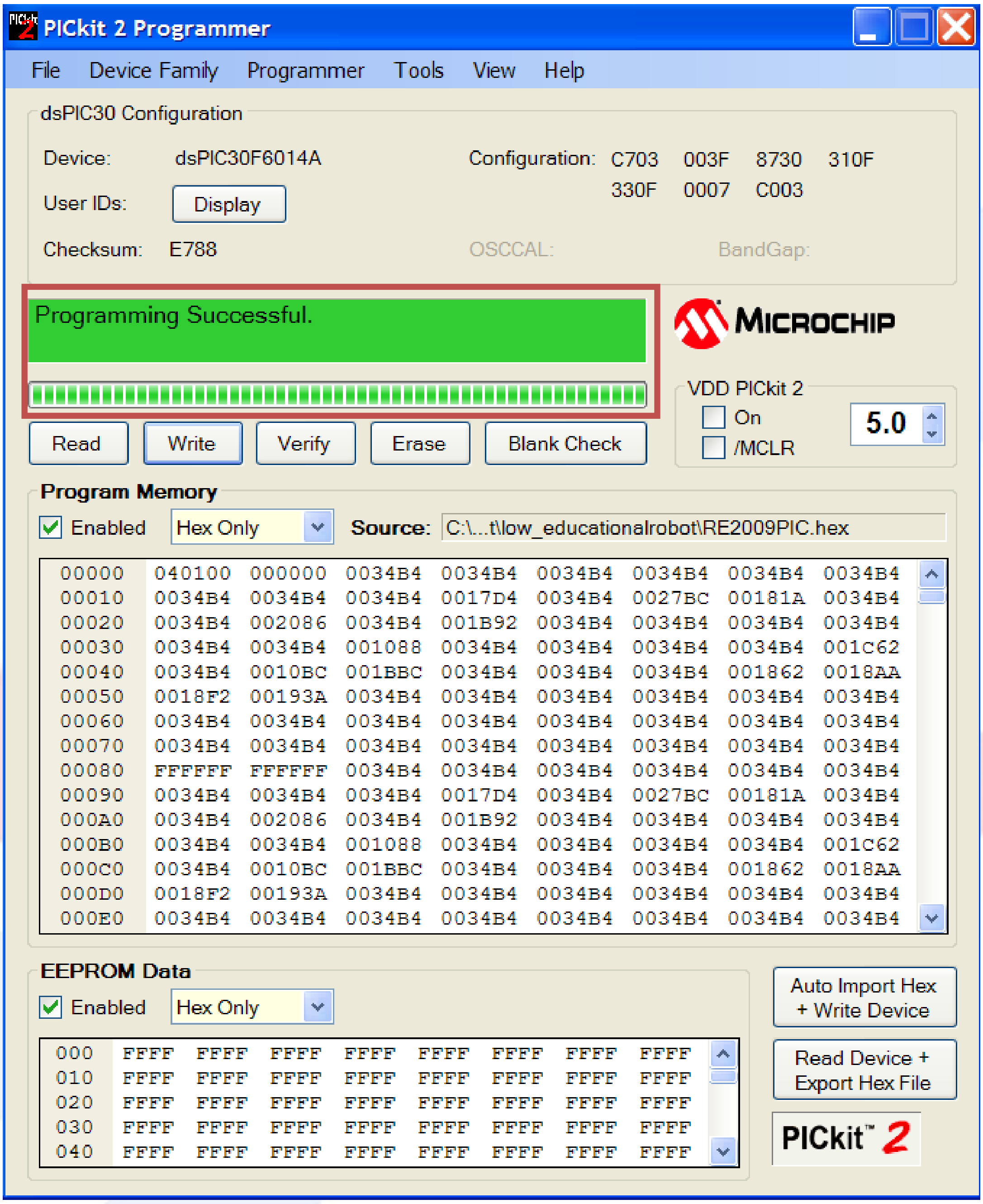


Fig. 10 – 8: Downloading program to Real Robot

Step 12: Remove the PICKit 2 and test the program.

10.3.3 Testing

Step 1: Power on the robot.

Step 2: Select the real robot from the “Robot Section” segment in the Robo Control Panel. The real-time sensor readings will be displayed.

Step 3: You can also control the robot in the competition panel.

Fig. 10 – 9: Real-time control of real robot

The sensor reading are displayed on the LCD panel attached on the controller board. The two rows display segments shows eight readings.

	Left colour sensor	Right colour sensor	Compass sensor	Front ultrasonic sensor
Row 1	0	0	0	0
	Front ultrasonic sensor	Back ultrasonic sensor	Left ultrasonic sensor	Right ultrasonic sensor
Row 2	10	32	9	526

Appendix A. User Guide of Virtual Simulation Environment

A1. Starting Visual Simulation Environment

The Visual Simulation Environment (VSE) provides simulates physical objects and their interactions including collisions, friction and gravity. It requires a reasonably powerful graphics card. Please check the requirements below and ensure that your computer satisfies them.

For best performance hide or close all pop-up windows that may appear on top of the simulation window.

Microsoft Visual Simulation Environment Graphics Card Requirements

- *Minimal Requirements*

  Graphics card supporting DirectX 9.0c (or later) and Shader Model 2.0+ with 64MB of video memory or greater. Examples include, ATI Radeon 9800+ or NVIDIA FX series or later.

- *Recommended Requirements*

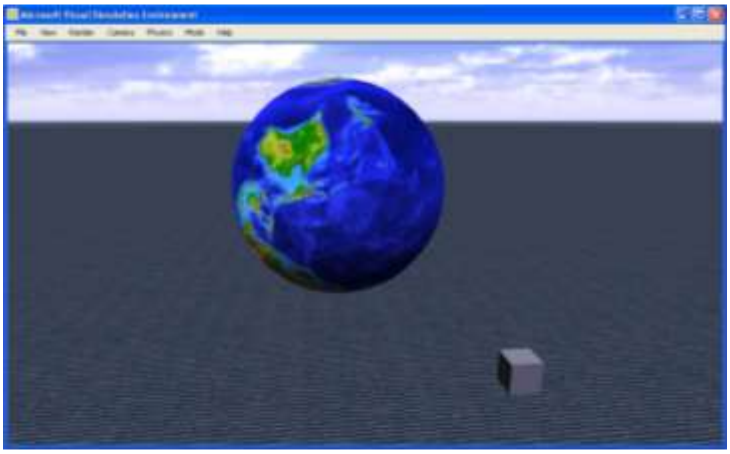
  Graphics card supporting DirectX 9.0c (or later) and Shader Model 3.0+ with 128MB of video memory or greater. Examples include, ATI Radeon x1300 or NVIDIA 6 series or later.

- *Minimal Requirements to use GPU Accelerated Physics*

  NVIDIA GeForce 8, GeForce 9, or GTX 200 series GPU or later, 256MB of video memory or more required.

Starting Simulations

To start VSE, select one of the entries in the VSE folder under Microsoft Robotics Developer Studio in the **Start** menu. (All of the different simulation environments are listed in there as well as samples for each of the simulated robots.) This will display the VSE window and load the relevant simulation. The Simulation Tutorials provide examples of simulated environments.



When the simulator is running, you can move the camera viewpoint by dragging the mouse pointer across the screen. It does not change the camera position but it changes the point that the camera is looking at.

To move the camera, you can use the keyboard as follows

Key	Action
w or Up Arrow	moves forward
s or Down Arrow	moves backward
a or Left Arrow	moves left
d or Right Arrow	moves right
q	moves up
e	moves down

If you hold down the Shift key while you hold one of the keys listed above, the camera moves much faster. You can also use the mouse at the same time as you hold down a key. This allows you to "fly" around by changing direction with the mouse and moving with the keyboard.

A2. Visual Simulation Environment Menus

The following commands are provided on the Microsoft Visual Simulation Environment (VSE) window.

The File Menu

- *Open Scene* - Loads a scene.
- *Save Scene As* - Saves a scene. When you save a scene, the simulator saves the simulator state along with the state for every entity in the scene. It also saves a manifest which can be used to re-initialize the scene and any services associated with the entities.
- *Save Material Changes* - Saves changes made to materials in Edit mode.
- *Open Manifest* - Load a service manifest.
- *Create Embedded Resources* - Creates a single saved file containing all effects, textures, meshes, etc.
- *Capture Image As* - Save the current view of the simulation to a file.

- *Exit* - Exits the simulation and shutdown its Decentralized Software Services (DSS) node. The Simulator will remember the window size and position for the next time it is started.

The Entity Menu

The Entity Menu is only visible when you select Edit from the Mode menu.

- *Undo* - Undoes the previous change.
- *Redo* - Repeats the last change that was undone.
- *Cut* - Removes the currently checked entities.
- *Copy* - Copies the currently checked entities.
- *Paste* - Adds the last cut or copied entities back into the scene.
- *Paste As Child* - Pastes the last cut or copied entities as a child of the currently checked entity.
- *New* - Displays a dialog that enables you to create a new entity.
- *Load Entities* - Loads entities from a file.
- *Save Entities As* - Saves the currently checked entities to a file.

The View Menu

- *Playback bar* - Displays the playback bar for recording and playing back recorded sequences.
- *Status bar* - Displays or hides the status bar. The status bar shows you the current frame rate in frames-per-second, the simulation time, as well as the current camera position and look at point.
- *Profiler* - Brings up the Profiler UI dialog.
- *Look Along* - Sets the camera view to a specific viewing axis. Useful for accurately re-orienting the camera after you have moved it around a lot.

The Render Menu

The first four entries in this menu enables you to change how entities in the simulation are rendered. You can toggle between these modes using the **F2** key.

- *Visual* - Renders a full 3D view. Meshes associated with each entity in the scene are rendered with realistic lighting and shading.

- *Wireframe* - Renders the scene as a wireframe view. This mode enables you to get a rough idea of how many polygons make up each mesh and where the polygon edges are.

- *Physics* - Renders the scene showing physics outlines. This mode enables you to see how each entity is modeled in the physics engine. The scene is not rendered completely if the physics engine is disabled.

- *Combined* - Renders the full 3D view with physics. This mode makes it easy for you to determine how well the physics shapes match the visual mesh for each entity. The physics part of this scene is not rendered completely if the physics engine is disabled.

- *No Rendering* - This option turns off the rendering to economize on CPU time. The simulator continues to run.

- *Graphics Settings* - Enables you to change settings that control how the scene is rendered.

- *Physics View Settings* - Allows you to select the items that are shown in Physics View.

The Camera Menu

The **Camera** menu allows you to easily switch between cameras if you have more than one in the scene. You can press **F8** to quickly switch between cameras.

- *Main Camera* - Sets the view from the simulated camera provided by default.

- *Other cameras* - Sets the view from other cameras defined in the current scene. Note that there are also options to display cameras in separate windows. This allows you to have, for example, a view from a camera mounted on a robot at the same time as the main view so that you can see not only what the robot sees but also what it is doing. This is very useful for diagnosing computer vision programs.

The Physics Menu

- *Enabled* - Enables, or disables, physics forces in the simulation. You can also use the **F3** key to toggle physics on/off.

- *Settings* - Enables you to control whether default camera is treated as a rigid body and the gravity setting. If the camera option is set, you can use the camera to bump objects in the scene. You can also adjust the simulation speed.

The Mode Menu

- The settings on the **Mode** menu enable you to change how you can interact with entities in the scene. Pressing **F5** toggles between the options.

- *Run* - The normal operation mode for running your simulation.
- *Edit* - The mode that enables you to edit state of entities in the simulation. This mode automatically disables Physics.

The Help Menu

- *Contents* - Shows web pages that provide more information about how to use the various features and controls of the VSE.
- *About* - Shows a dialog that displays information about the version of the VSE and also information about the current graphics hardware.

A3. Visual Simulation Environment Keyboard and Mouse

The Visual Simulation Environment (VSE) simulation window provides keyboard and mouse operations that can be used to control the view and elements in the simulation environment.

Using the Keyboard

The following keys control the movement and orientation of the camera in the simulation environment when the **Simulation** pane has input focus. When the **Simulation** pane has input focus, it is surrounded by a blue border. Click inside the pane or press the **Tab** key until the blue border appears.

Key	**Action**
w or Up Arrow	Move forward
s or Down Arrow	Move backward
a or Left Arrow	Move to the left (slide sideways)
d or Right Arrow	Move to the right (slide sideways)
q or Page Up	Move up
e or Page Down	Move down
Home	Reset to initial position

Note that you can also use the numeric keypad, as long as it is not in numeric mode. In this case the numeric keys 2, 4, 6 and 8 act as arrow keys.

If you press the **Shift** key with these keys, the movement keys move 20 times faster.

Key	Action
F2	Change the render mode
F3	Toggle the physics engine enable
F5	Toggle between Edit Mode and Run Mode
F8	Change the active camera

When the simulator is in **Edit** mode the navigation keys work the same but some additional options are available when the left **Ctrl** key is held down. When the left **Ctrl** key is pressed, the currently selected entity will be highlighted if it has a valid bounding sphere associated with it. While the **Ctrl** key is pressed, the following additional keys are available:

Key	Action
Up Arrow	View the selected object from above (a positive Y distance from the object)
Shift+Up Arrow	View the selected object from below (a negative Y distance from the object)
Left Arrow	View the selected object from a positive X distance from the object
Shift+Left Arrow	View the selected object from a negative X distance from the object
Right Arrow	View the selected object from a positive Z distance from the object
Shift+Right Arrow	View the selected object from a negative Z distance from the object

Using the Mouse

In most cases, dragging the mouse cursor through the **Graphics** pane by holding down the left button and moving the mouse causes the camera viewpoint to change. In general, keyboard commands affect the position of the camera while mouse movement affects the orientation of the camera.

When the simulator is in Edit mode and the left control key is held down, the mouse behavior can be different. If an entity is selected and the Position property is selected in the **Property** window, the mouse movement affects the position of the entity. If any component of the position vector is selected, the entity is constrained to move only along that axis. Similarly, if the rotation property is selected in the **Property** window, the mouse movement affects the orientation of the entity. If any component of the rotation vector is selected, the entity is constrained to rotate only along that axis.

Using an Xbox Controller

If you have an Xbox Controller connected to your PC, you can use it to control the camera as well. The two thumbsticks on the controller can be used to move the camera around. Note that you must press and hold the Left Shoulder button (just above the left thumbstick) while you are moving the camera. This is not immediately obvious.

The movement of the camera is controlled using the left thumbstick and the right thumbstick is used to pan and tilt the camera as follows (with Left Shoulder held down):

Thumbstick	Direction	Action
Left	Up	Move forward
Left	Down	Move backward
Left	Left	Move to the left (slide sideways)
Left	Right	Move to the right (slide sideways)
Right	Up	Rotate (tilt) up
Right	Down	Rotate (tilt) down
Right	Left	Rotate (pan) left
Right	Right	Rotate (pan) right

IMPORTANT NOTE: If you are using another application that uses the Xbox Controller, such as the Simple Dashboard, you must make sure that the Simulation window has the input focus in order to use the controller to move the camera. Click inside the simulation window with the mouse to give it focus. A blue border appears around the simulation area when it has focus. If another application has the focus, then you cannot control the simulation camera using the Xbox Controller.

The simulation coordinate system

The simulator uses a right-handed coordinate system. The +Y axis represents elevation above the ground plane. The X and Z axes are parallel to the ground plane. When facing in the +X direction, the +Z axis is to the right. Some modeling tools use a different coordinate system and it is important to export the models rotated in such a way that they appear correct in the simulation environment.

Appendix B. ZigBee Communication Module Setup

Step 1: Launch the Control Panel (Start → Settings → Control panel)

Fig. B – 1: Launch the Control Panel

Step 2: Double click on the 

icon. The system properties window appears as shown in Fig. B – 2.

Fig. B – 2: System properties

Step 3: Select the *Hardware Tab* in the system property window.

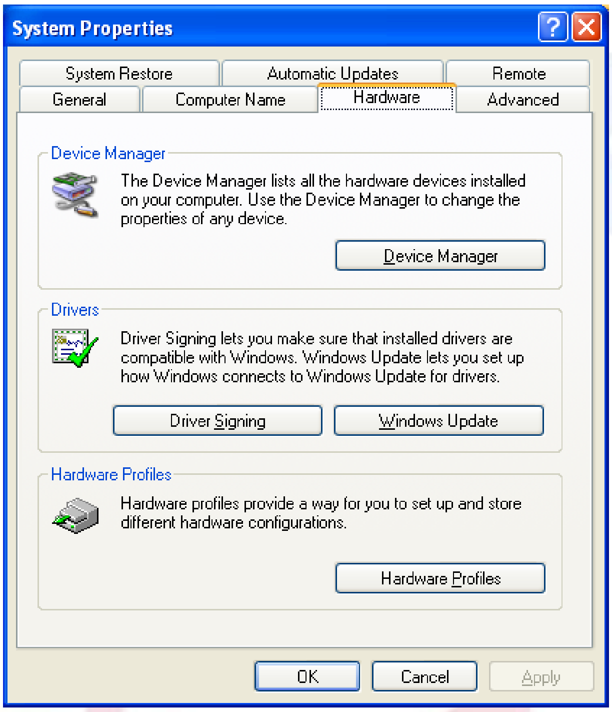


Fig. B – 3: System Properties

Step 4: Double click on the *Device Manager* button to explore the device manager.

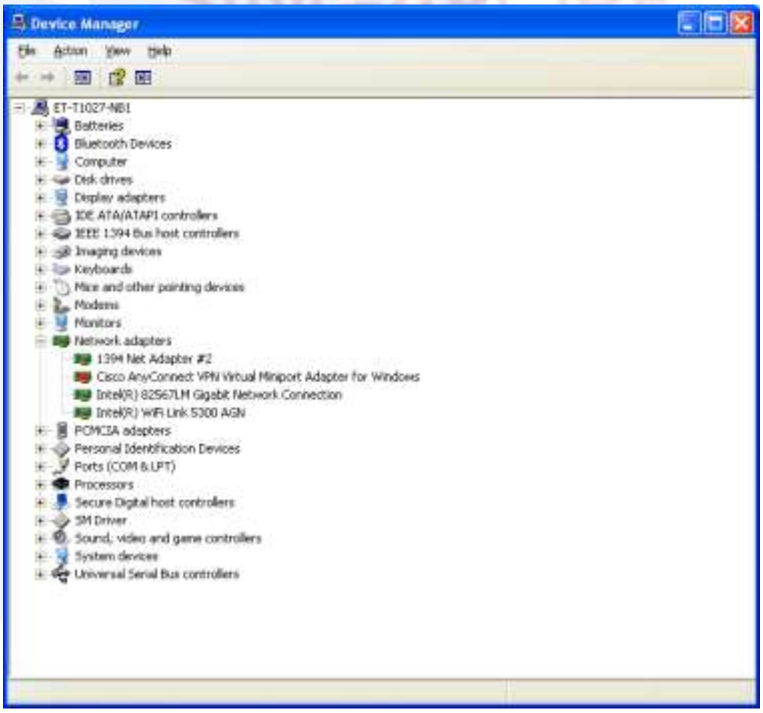


Fig. B – 4: Device Manager

Step 5: Double click on the Ports (COM & LPT) to identify the port which the Zigbee module is connected.

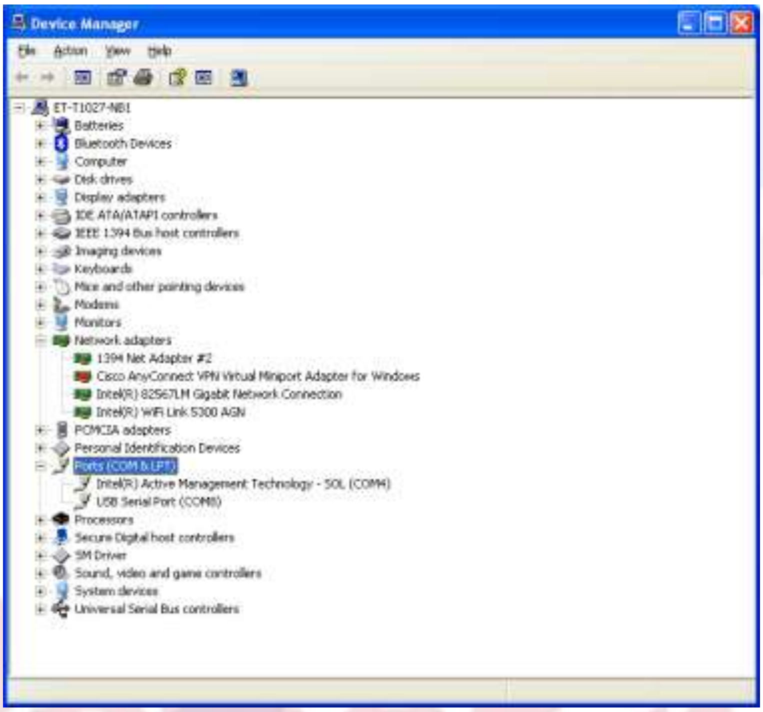


Fig. B – 5: Device Manager

Step 6: Check the com port assigned to the USB Serial Port. The COM Port 8 is used in this example.

Note: The com port assigned for ZigBee module is automatically generated by computer. It is not the same for different computers. Users have to identify the com port connected with Zigbee module.

Appendix C. RE – VSS – CSR Directory Structure

The files, such as entity property, wheeled robot programming, humanoid robot gait tuning data, performance file etc. are automatically organized by default, if you do not change the file location manually. All files are stored in the Microsoft Robotics Developer Studio 2008 R3 directory.

To access it,

1. Click on Start → All Programs → Microsoft Robotics Dev Studio 2008 R3→ Robotics Developer Studio,
2. Expend the Microsoft Robotics Developer Studio 2008 R3 directory; you will be able to see the CoSpace file directory where the user guide, icon, all files associated with the virtual environment, virtual robot, and manifest files, etc. for CoSpace Dance are located as shown in Fig. C – 1.

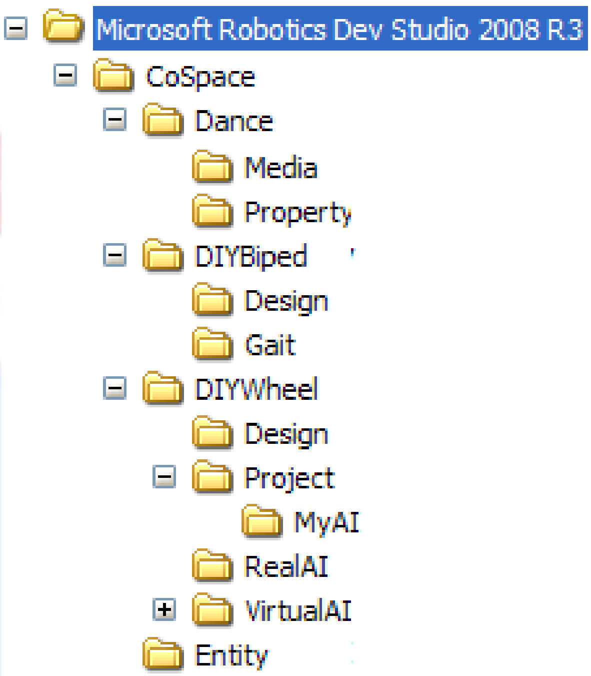


Fig. C – 1: The structure of CoSpace Directory

The CoSpace directory contains four subdirectories: Dance, DIYBiped, DIYWheel and Entity.

Directory	Subdirectory	Files stored
Dance	Media	Not applicable for RE – VSS - CSR
	Property	Not applicable for RE – VSS - CSR
DIYBiped	Design	Not applicable for RE – VSS - CSR
	Gait	Not applicable for RE – VSS - CSR
DIYWheel	Design	Robot design interface (rdi) files for wheeled robots
	Project	AI strategies (programing) Each project will have its own folder. There are 4 files in each project folder. There are ai.cs – C# source code generated based on the graphical programing developed in the AI development panel. ai.cs is for virtual wheeled robot. ai.c – C source code generated based on the graphical programing developed in the AI development panel. ai.c is for real wheeled robot. MyAI.smp – Ai strategy file. It can be loaded for editing in AI development panel. MyAI.DLL – the dynamic link library file of the AI strategy. It can be loaded to control a virtual/real wheeled robot.
	RealAI	Real robot AI strategy files.
	VirtualAI	Virtual robot AI strategy files.
Entity		Not applicable for RE – VSS - CSR

Appendix D. How to Control the Real and Virtual Robots Using Your Own C Code

The RE – VSS – CSR provides a C programming interface which enables professional programmers to test the AI strategy using the CoSpace platform. Following are the steps of creating your own AI strategy for both virtual and real robots.

AI strategy for virtual robot

If you like to write your own AI strategy in Visual C# or modify the ai.cs generated from graphical programming, you need to

1. Install Visual C# compiler.
2. Copy ai.cs from the project directory to ..\VirtualAI\VirtualAI\ directory and replace the existing ai.cs file.
3. Launch the visual C# project by double clicking VirtualAI.csproj. The ai.cs will be the part of the project.
4. Edit the necessary C# code.
5. Build solution to generate the DLL file. The “virtualAI.dll” is created in \VirtualAI\VirtualAI\bin\Release folder.
6. The “virtual.dll” file can be loaded.

AI strategy for real robot

If you like to write your own AI strategy in C or modify the ai.c generated from graphical programming (only Game0), you need to

1. Install MPLAB and PICKit 2 downloader. Please refer to session 9 and 10.
2. Copy ai.c from the project directory to realAI directory and replace the existing ai.c file.
3. Launch the real robot project by double clicking RE2009PIC.mcp. The ai.c will be the part of the project.
4. Edit the necessary C code.
5. Build ALL to generate/update the RE2009PIC.hex. The “RE2009PIC.hex” is the AI strategy in the machine language.
6. Download the “RE2009PIC.hex” to the real robot (Session 10 shows the details).
7. Observe the real robot performance.

Appendix E. Hardware Connection for CoSpace Robot

The RE – VSS – CSR platform provides the same graphical programming interface for the virtual robots and the real robots. It enables the communication between the real robots and the CoSpace server. The synchronization of the real robots and the virtual environment/virtual robots can be realized using the patform. Fig. E – 1 shows the connection and communication of the CoSpace system.

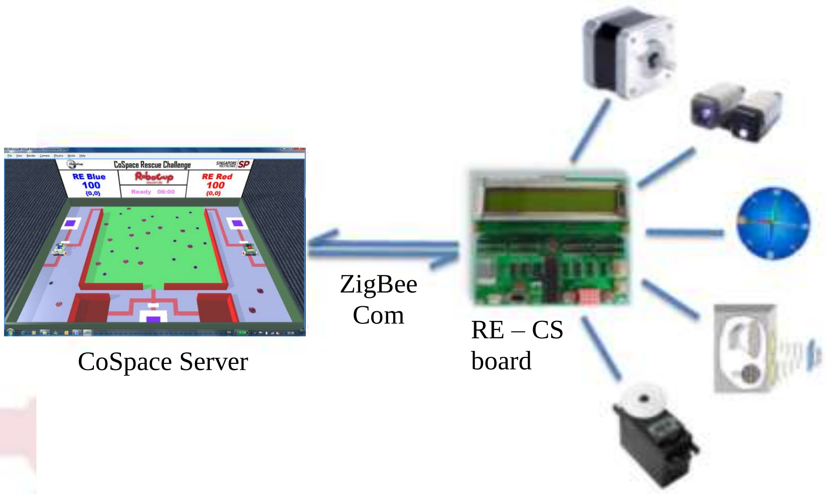


Fig E – 1: CoSpace System

In order to program the real robot using the same AI development panel as for the virtual robot, all sensors, motors and other hardware components must be connected to the controller board (RE – CS01 or RE – CS02) according to the connection stated in table E – 1.

Table E – 1: The Connection of all Components of a CoSpace Rescue Robot

Component		**PIN**		**Unit**
		RE-CS01	**RE-CS02 (LEGO)**	
Wheel	**Left**	Motor 1 [DUO]	Motor 1 [LEGO]	Speed scale [-5, +5]
	Right	Motor 2 [DUO]	Motor 3 [LEGO]	
Ultrasonic Sensor	**Front**	CCP1	CCP1	Distance in centimeter.
	Back	CCP2	CCP2	
	Left	CCP3	CCP3	
	Right	CCP4	CCP4	
Color Sensor	**Left**	ADC2	ADC2	Brightness value
	Right	ADC3	ADC3	
Compass	**Compass**	DI/01	I/01	Degree

In the AI development panel, a prompt message will show you again the correct pin connection when the mouse hover over a ComboBox, Slider or TextBox as shown in Fig. E – 2.

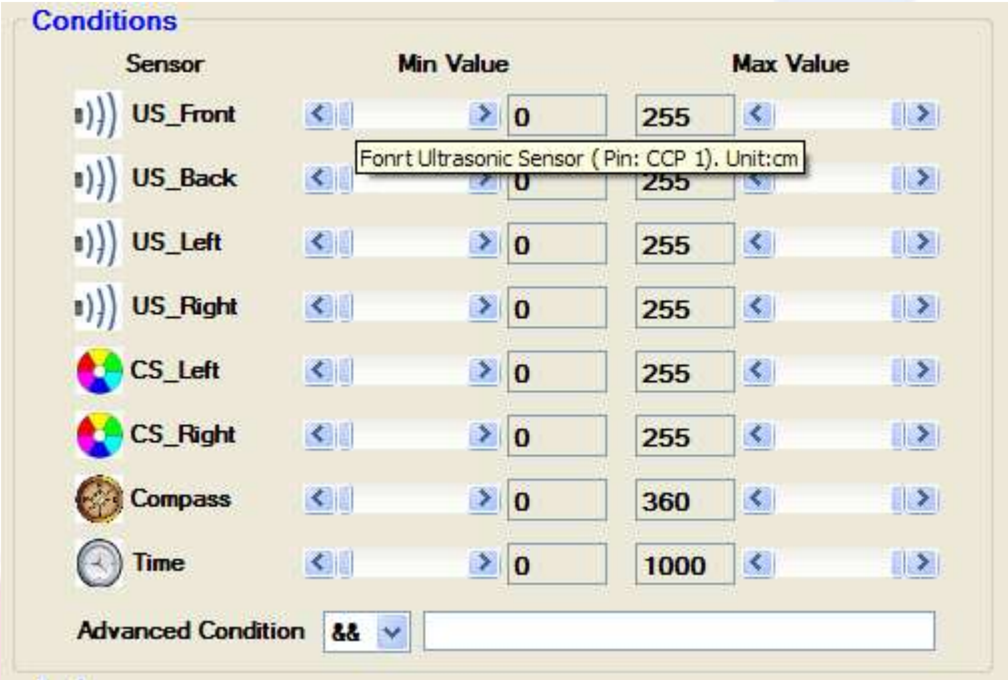


Fig. E – 2: The connection of each component.

Please refer to the RE – CS01 and RE – CS02 User Guide for the educational controller board.

Appendix F. Communication Protocol

One device is able to communicate with many devices via ZigBee communication. Hence, the CoSpace server equipped with ZigBee transceiver is able to communicate with many real robots with ZigBee module installed. In order to establish one-to-one communication, each robot has to assign a unique ID. The ID is made up of three integer numbers. It is defined at the end of main.h file of Real project. ZigBee utilizes Serial Port for communication. Fig. F – 1 shows the setting of serial port properties.

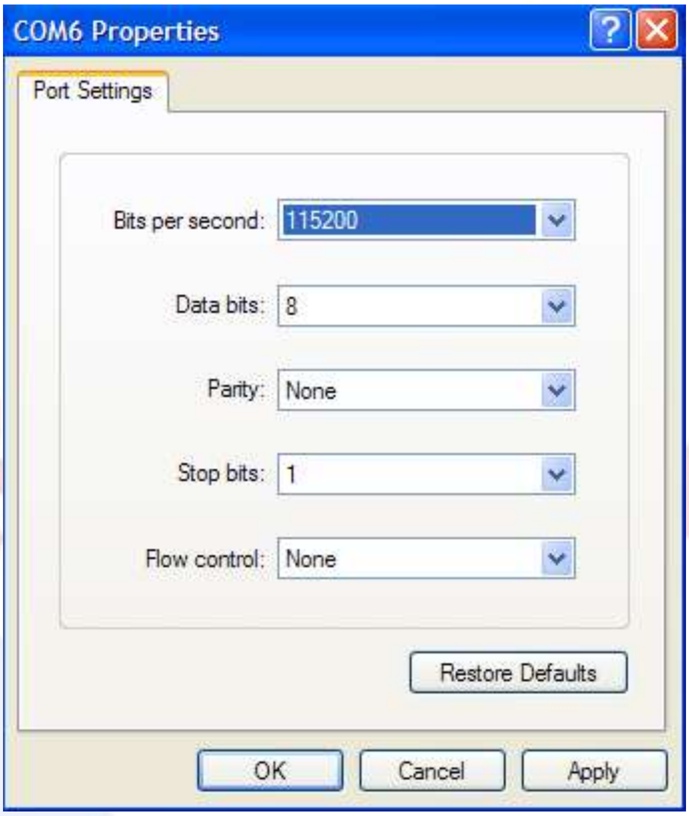


Fig.F – 1: Serial Port Properties

All packets follow the communication protocol in the following format:

"<!" `(start code)` , **three integer number** `(real robot ID)`, **a char** `(command)`, **data, "!>"** `(end code)`

The communication protocol is listed in Table F – 1.

Table F – 1: The Communication Protocol for CoSpace Platform

Sender	Command	Function	Packet	Remark
Robot	‘P’	Feedback Play State	<!006Pc!>	c is a char denoted Play State. 0: Normal Mode; 1: AI Mode.
	‘G’	Feedback Game ID	<!006Gc!>	c is a char denoted Game ID. Its value is [‘0’,’8’];
	‘Q’	Set Play State	<!006Qc!>	c is a char denoted Play State. 0: Normal Mode; 1: AI Mode. The Play state in Control center will set to this value.
	‘I’	Feedback MyID	<!006I!>	
	‘S’	Feedback Sensor Value	<!006Ss1, s2,s3,s4, s5,s6,s7, sum !>	S1 to s7 are sensor’s value of front, back, left and right ultrasonic sensor, left and right color sensor and compass sensor. Sum is the sum of all sensors value. All this value is in digital number, for example, if sensor value 123, it sents three chars, i.e. ‘1’, ‘2’ and ‘3’;
CoSpace Server	‘V’	Set Motor Speed	<!006Vv1v 2v3v4!>	V1 to v4 are four chars denoted speed of four wheels. Its value is [‘0’-5 , ‘0’+5];
	‘G’	Set Game ID	<!006Gc!>	c is a char denoted Game ID. Its value is [‘0’,’8’];
	‘L’	Set LED	<!006Lc!>	c is a char. 0:OFF; 1: TOGGLE; 2:ON
	‘H’	Request Game ID	<!006H!>	
	‘P’	Set Play State	<!006Pc!>	c is a char denoted Play State. 0: Normal Mode; 1: AI Mode.
	‘Q’	Request Play State	<!006Q!>	
	‘T’	Request Play time	<!006T!>	
	‘S’	Request Sensor Value	<!006S!>	

Appendix G. Action To Be Taken After the Treasures Found

When a robot detects a treasure, it must stop and flash the LEDs for 2 seconds. In fact, if the robot does not move away after 2 seconds, it will still sense the treasure. Hence, it will not move away. Therefore, in order to let the robot move forward after the treasure is detected, the following actions (or similar actions) are necessary.

1. If the “default” type condition is used, you need to write the following action in the statement.

Fig. G – 1: The action in the default statement

2. If the “super” type condition is used, you need to write the following action in the statement.

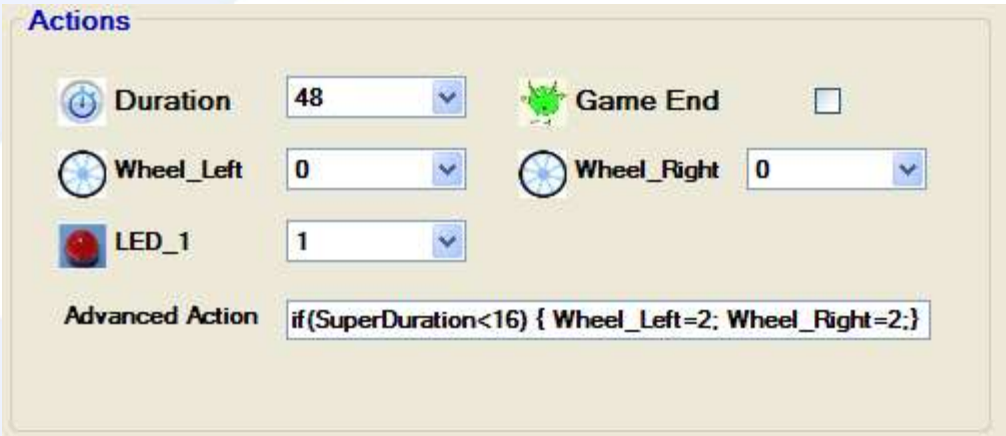


Fig. G – 2: The action in the super statement

Contact Us

Advanced Robotics and Intelligent Control Centre (ARICC)

Singapore Polytechnic,

500 Dover Road,

Singapore 139651

E-mail: CoSpace@robocupsingapore.org

http://www.robocupsingapore.org