

Using visual programming kit and Lego Mindstorms: An introduction to embedded system

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Abstract-Easier programming environment for novice users has always been matter of consideration throughout the development of programming kits. Text based programming kits have been dominant in programming world for decades, but without popularity from novice users. Human-being is more likely to be interested in graphics instead of characters. Numerous approaches to graphical programming environment have been introduced, and they are actively being used to educate young programmers. Although graphical programming relatively easy comparing with text based programming environment, it is still not an easy or interesting environment for novice users. Most programming is educated with a computer system, where executed program results are usually through the display devices like monitor. When result of a programming can be expressed by robot instead of display devices, it is more attractive and efficient. LEGO Company has been developing cheap and powerful programmable robot set named Mindstorms. Robot made from Mindstorms can be programmed with various language kits and it itself is provided with a graphical programming kit. Combining the robot with visual programming environment will provide efficiency in learning embedded system. Mindstorms robot is programmed with a few visual programming kits and it is compared with other visual programming for evaluation.

I. INTRODUCTION

Technology is rapidly developing, and so as the computer. One of the results of rapid development is hybrid computers, which is also known as embedded system, with smaller size and designated purpose. People walk down the street while talking with a friend through their mobile phone, and they listen to their favorite music through a digital music player while jogging in the park. It is also possible to watch a movie or a television show by using a portable media player while sitting in a train. Although most people possess an embedded system, they don't know how it is works. Assume every program used in the system had to be developed individually; rapid development of computer must have been delayed.

Computer is a machine which manipulates data according to a list of instructions and an embedded system is a special-purpose computer system designed to execute designated tasks. Since computer and embedded system market is growing

rapidly and more engineering students are demanded. Engineering students learn how to use a programming language while their freshmen period. Afterwards, they learn various theories and algorithms. Many algorithms and theories are implemented with programs written with programming languages. Engineering students have to accord with programming languages in order to extend their knowledge. However, although programming languages are much easier to use than before, programming still requires acknowledgeable dedication to be professional.

Recently, numbers of visual programming languages are being developed to replace the old-fashioned text-based programming languages. Visual programming languages can directly represent the program. Traditional programming languages are in one-dimensional strings commands, and user has to understand the actual meaning of the syntax. Visual programming environment can remove these abstractions by allowing the programmers to manipulate the structures by observing graphics like the blocks and the lines [1]. Visual programming languages are easily understood and they are assumed to be more independent when compared with text-based programming languages [2]. Since codes in visual programming directly communicate with physical system, reusability increases. For example, a block which will print welcome message on the screen is written in the first program and this block can be used again without modification by the second program when it is necessary. Compiling errors caused by typos and spelling mistakes always happen when writing a program with a text-based programming language, but these kinds of errors are remarkably reduced in visual programming environments [3].

Many of programming courses are based on computer system. Programmers write a program through a personal computer and execute it after compiling the source code. The result of program is appeared on the monitor. Education on programming language using only a computer system with text-based programming language and evaluating the result through monitor is not effective. Robotics always has been an issue to be used as a class material in engineering field. Because robotics is touchable, it is obviously effective when being used as a class material. However, robotics is considered

to be expensive and large-scale to be used as a class material [4]. Recently robotics technology has improved while the cost of it has decreased; it became easier to use a robotics as a class material. LEGO Company has been releasing a cheap and powerful robotic system series called the Mindstorms. The first version, version 1.0, was released in year 1998. Recently, in year 2006, NXT version was released. Mindstorms contains a small programmable brick containing micro-processors which is programmable through various programming languages. This programmable brick is named Intelligent Brick (I-Brick). I-Brick can communicate with personal computer through Universal Serial Bus (USB) interface or Bluetooth communication. Three output ports and four input ports are available on I-Brick to connect with motors and sensors. A graphical display panel is located in the front above four buttons. I-Brick also contains a speaker to output sounds [5]. Most robotic systems are almost impossible to change its shape. Fig. 1 shows Aibo which is a puppy-like entertainment robot released by Sony Company. Because I-Brick is another typical bricks of LEGO, it can be easily attached with other LEGO parts to become other thing. Humanoid robot, machine-like robot, animal type robot, and car type robot can be built with one set of Mindstorms NXT. Fig. 2 shows a humanoid robot named AlphaRex which is made with LEGO Mindstorms. Robotarm T56 is another kind of robot that can be made with one set of LEGO Mindstorms and this is shown in Fig. 3. With LEGO Mindstorms, it will be efficient to educate a computer system using various visual programming environment and different types of robots.

In section II, more specific structure of LEGO Mindstorms will be explained. The visual programming environments will be introduced in section III. Section IV will be evaluating the visual programming environments. Final section, section V is the conclusion.



Fig. 1 Aibo Robot



Fig. 2 AlphaRex



Fig. 3 Robotarm T56

II. LEGO MINDSTORMS NXT

LEGO Mindstorms are provided with beams, gears, and blocks. All this components are called as LEGO parts. LEGO parts are geometrically designed, and they can be linked with other parts to be constructed. Mindstorms NXT also provides software which can be installed in to the computer. This software provides the construction guides for different types of robot. User can also write a visual program for the constructed robot [6].

I-Brick is the name of the programmable brick of NXT. Fig. 4 shows the block diagram of I-Brick. I-Brick has two processors installed into it. 32-bit Atmel ARM7 processor with 256 KB Flash memory and 64 KB random access memory (RAM) is the main processor and it handles the display module, sound module, Bluetooth communication, and USB communication. Atmel 8-bit AVR processor is a co-processor which handles the buttons installed in the front. These two processors communicate with each other through Inter Integrated Circuit (I2C). I-Brick can download programs from personal computers through USB communication or the Bluetooth communication. A dot matrix display supporting 100

x 64 pixels is located on the front of I-Brick. This display module can show numbers, text, figures and bitmap image file. With the three output ports on I-Brick, provided interactive servo motors can be connected. The Mindstorms NXT provides touch sensor, sound sensor, light sensor, and ultrasonic sensor, and they can be connected to the any of the four input ports available on the I-Brick. Fig. 2 shows how the I-Brick looks like.

A Tribot was constructed with Mindstorms NXT for experiment. I-Brick is constructed as the driving base of the Tribot. This driving base can be connected with other devices like bumper, grabber, and detector. Each device is constructed based on the sensors provided by the Mindstorms NXT. Tribot is connected with a touch sensor which is constructed as a front bumper. The touch sensor is pressed when the front bumper hits an obstacle in the front. The touch sensor will return the binary value according to the position of the orange lever. When the lever is pressed, the current will flow and the circuit is complete. Therefore, the return value will be true and this value is initiated by the I-Brick as 1 meaning true. Two interactive servo motors are connected on left and right side of the driving base. The motor on left side is connected to output port B and the other motor is connected to output port C. Each motor is connected to a wheel and a tire. Tribot is a 3-wheel robot, and the third wheel without any power is located at the center rear part of the driving base. The motors can rotated with synchronization so that the Tribot can move in straight line. It is also possible to make the Tribot to spin in one position by rotating the motors in the opposite direction.



Fig.7 A robot made with LEGO NXT

III. VISUAL PROGRAMMING ENVIRONMENT

Robots constructed with I-Brick can be programmed with visual programming environment. In this section, 3 programs will be written using different visual programming environment. The written program will make the Tribot move forward until the bumper is pressed. When the bumper is pressed, the Tribot will move backward for certain distance and then turn left to change the direction. Finally, it will move forward again until the bumper is pressed. The Tribot will continue above actions until the program is terminated by user.

A. LEGO Software

LEGO Mindstorms NXT comes with a visual programming environment. This software is very easy to use. Fig. 8 shows the interface of the software. This program will be called as Lego Software (Lsoft). In the Lsoft, there are several menus on the left side of the screen for users to choose. After user decides the blocks to be used, user just has to drag it to the programming board and drop it. When a block is dropped on the programming board, description of the block will appear and users just have to pull down the menu or check the boxes to decide the action.

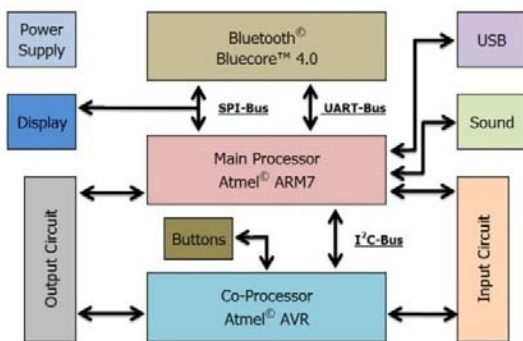


Fig. 5 Hardware block diagram of I-Brick

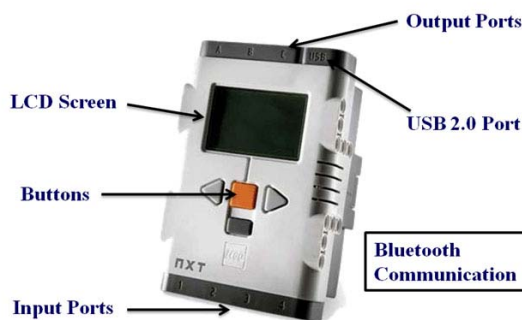


Fig.6 Structure of I-Brick

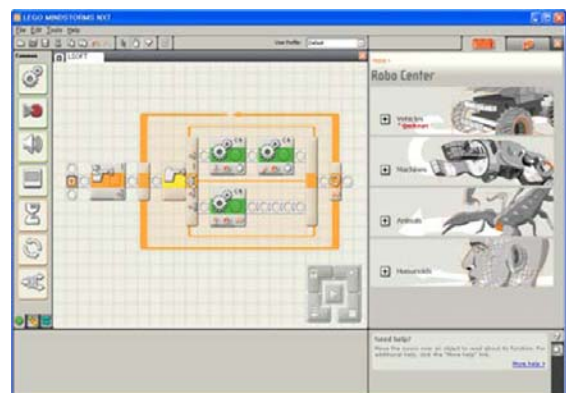


Fig.8 LEGO software interface

Fig. 9 shows enlarged diagram of Lsoft program. Each block in the program represents designated command for I-Brick. The block with green highlight is used for motor. Fig. 10 shows the description of the motor block. Users can decide port, direction, steering, power, duration, and next action. In order to move the Tribot in straight line in forward direction, 'B' and 'C' have to be checked, direction should be check at 'upward arrow', gage on steering should remain in the 'middle', the power could be set any value between 40 ~ 100; where 100 is maximum power, and duration should be set to 'unlimited' as it is shown in Fig. 10.

Program in Fig. 9 is written for the Tribot. The entire program is grouped by a loop which is repeated until the program is terminated by user. Within the loop, a switch statement block is located. This switch statement will run different action according to the status of the touch sensor. When the touch sensor is pressed, the upper body will be executed. The two green highlighted blocks will rotate the motors in backward direction for half second, and then rotate the motors in opposite direction to make Tribot rotate to change the heading direction. When the touch sensor is not pressed, the Tribot will move in straight forward by rotating two motors identically. Fig. 11 shows the description of switch statement block. The control mode is set to sensor, and sensor mode is set to touch sensor. The port and the status of the lever are also decided.

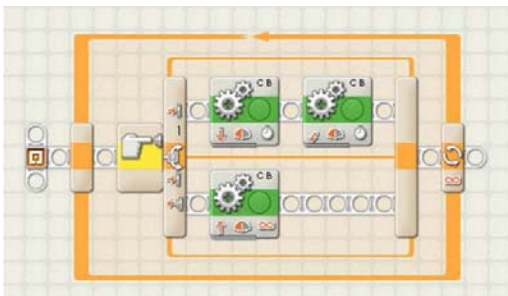


Fig.9 LEGO software program

The LSOFT is easily used by drag-and-drop interface. Each block can be directly mapped to each devices of LEGO NXT. Furthermore, step by step instruction for programming is available by the provided software.

B. Microsoft Robotics Studio

Recently, Microsoft Company published a software environment named Microsoft Robotics Studio (MSRS) for robotics. MSRS is aimed to work with all kinds of robotics. MSRS supports extensible runtime architecture for all types of robot. Therefore robotics using 8-bit, 16-bit, or 32-bit processors and even for robots using multi-processors can be programmed with MSRS. MSRS also provides set of useful tools for programming and debugging in simulation environment. Robotics can be programmed by using visual programming environment which supports drag-and-drop interface. MSRS named this their visual programming environment as Microsoft Visual Programming Language (MVPL). MVPL has similar structure with Lsoft, as it is also in drag-and-drop interface. MVPL is not easy as the LSOFT but it is more flexible in a way because it can be used with various types of robotics. MSRS is provided with many resources and tutorials and LEGO Mindstorms is one of the robotics system has been chosen.

Fig. 12 shows the program written with MVPL. More blocks are used to program the identical for Tribot when it is compared with Lsoft. Blocks of MVPL have distinct functions as Lsoft. 'GenericContactSensors' block and 'RandomDrive' block. Shown in Fig. 12 are responsible for devices of LEGO. 'GenericContactSensors' block is pre-defined block containing the data for the bumper attached with a touch sensor. These blocks are originated from the Robotics Tutorial 3 which is provided on the MSRS webpage. In MVPL, blocks are also called as 'activity.' 'RandomDrive' is a user-defined block possessing the command to control two motors. In the program, the Tribot should move in forward direction, backward direction, or spin.



Fig.10 Description of move block



Fig.11 Description of switch statement block

All three movements require using two motors. Therefore, in the MVPL, three 'RandomDrive' blocks are used. This 'RandomDrive' block is set to three states and they are labeled as 'Backup', 'Turn', and 'Drive.' Fig. 13 shows the 'Turn' state of 'RandomDrive.' 'RandomDrive' block is organized with 'calculate' block, 'join' block, 'GenericDifferentialDrive' block, 'Data' block, and 'Timer' block. 'GenericDifferentialDrive' block contains the command which will rotate two motors. In MVPL program, 'Polarity' is defined as a variable with value of 0.35, which means 35%. This value is set as the output power of motors connected to I-Brick. The motor on each side is set to output power of 35% with different rotating direction. These values are combined into by 'Join' block to be transmitted to 'GenericDifferentialDrive' block. Then 'GenericDifferentialDrive' block is connected with 'Timer' block which will keep the state according to the set time. In this program, the 'Timer' block is connected to a block containing the value of 500. The 'Timer' block is in the unit of milli-seconds. The 'Turn' state of 'RandomDrive' will obtain the output power for the motor and rotate for the set time. With the combinations of all the activities and blocks, the program will run the robot exactly the same with the one written with LSOFT.

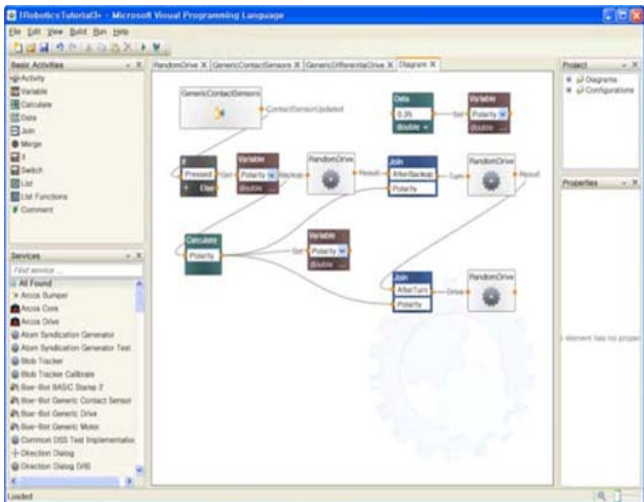


Fig.12 MSRS visual programming interface

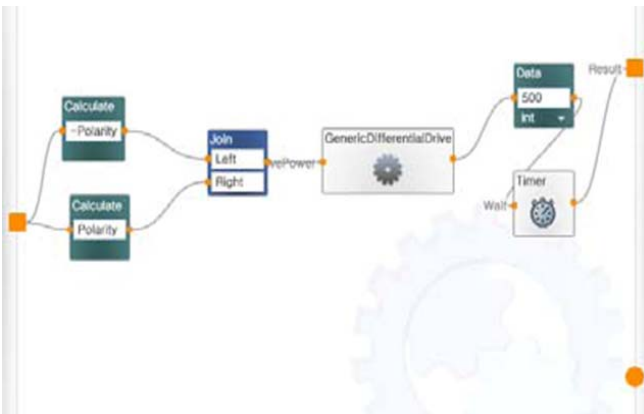


Fig.13 'Turn' state of 'RandomDrive.'

C. LabVIEW

Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) is visual programming environment developed by the National Instruments Company (NI). LabVIEW is widely used for data acquisition, instrument control, and industrial automation on various platforms [7]. Lsoft is also developed based on LabVIEW. NI released an 'add-on' program to program LEGO NXT platform through LabVIEW. The blocks that can be used with LEGO NXT is presented as 'Add-On' blocks.

Fig. 14 shows the program written with LabVIEW. In LabVIEW, block for each hardware device of LEGO Mindstorms are pre-defined. Each block has pre-defined parameter value. When user wants to change the value of the parameter, additional block having same type of value should be dragged to the program screen. After entering the value, the parameter block and hardware device block have to be linked with a wire. LabVIEW will show the available point that could be connected. As it is shown in Fig. 14, there are different colors of wires, and they indicate the type of data. Blue lines means the transferred data are variable. If users link the wire into different data type, cross will appeared on the wire to indicate that it is not valid. Advantages of using LabVIEW are noticeable because explanation pop-up menu will appear for all the blocks that can be used for programming.

IV. EVALUATION ON VISUAL PROGRAMMING ENVIRONMENTS

Robot made with LEGO Mindstorms NXT was programmed with three different visual programming environments. Each visual programming environment had different method to program. However, when all three visual programming environments are compared with each other, there are similarities between them. Visual programming environments are easily understood by programmer because it directly shows the structure of data flow which is in block.

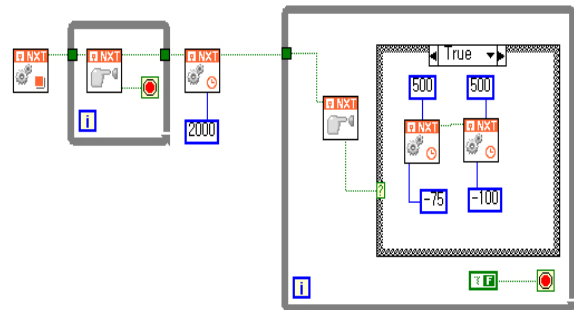


Fig.14 LabVIEW visual program

V. CONCLUSION

Lsoft is relatively easy to program when it is compared with other two environments. Blocks of Lsoft are stand-alone and independent. When user wants to control the motor, user can set all the parameter value in single block. In Lsoft, combination of independent blocks will result as a program. If many blocks are linked with each other, the program will be complicated. Therefore users can easily understand the Lsoft program structure because the parameters of each block are not linked but included in each block.

MVPL is more complicate to program when compared with Lsoft. In MVPL, users have to set all the necessary parameter to a block and link with the block responsible for hardware. For example, when user wants to rotate the motor in forward direction for 5 seconds, user has to use several blocks. First of all, activity block handling the motor rotation have to be used. Additional blocks to set the power and direction of motor have to be used, as well as timer blocks to maintain the rotation within the activity block. Which means, at least 5 blocks are used in MVPL to rotate the motor, which only one block is needed for same action in Lsoft. Although MVPL require more block usage to write a program, all parameter values are shown. Since all the information are shown, which include parameters and activity block, MVPL is more thorough for understanding the detailed information how the program flows.

LabVIEW included libraries with large number of functions. It is fully object-oriented and blocks can be reused without any modification if the data types are same. Programming Tribot with LabVIEW is very familiar with programming with Lsoft. As it is mentioned, Lsoft is originated from LabVIEW.

After programming Tribot with three different visual programming environments, it was noticed that visual programming environment is efficient to understand the data flow to control an embedded system. Although Tribot was a simple system with few hardware devices, it was enough to compare the thoroughness of each visual programming environment. In order to teach embedded system to novice programmer, visual programming environment will be efficient.

Robotics and embedded systems are developing rapidly. In order to educate engineering student to embedded system, sufficient programming skills are required. Therefore, most freshmen have to take programming course in advance. However, programming course with embedded system will give students to know the real-world problem heading in front.

Three visual programming environments to program LEGO Mindstorms NXT were evaluated in this paper. Visual programming environments are more efficient comparing with text-based programming environment to understand how commands are directly applied to hardware. Future research on using LabVIEW with other embedded system for education will be continued.

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