Robot kits from Japan: new frontiers in education

Fransiska Basoeki[1], Fabio Dalla Libera[2], Emanuele Menegatti[2], Michele Moro[2]
[1] Dept. of System Innovation, Osaka University,
Suita, Osaka, 565-0871 Japan
[2] Dept. of Information Engineering, University of Padova
Via Gradenigo 6/A-B - I35131 Padova - Italy
{fabio.dallalibera, emg, mike}@dei.unipd.it

Abstract. The paper introduces and compares the use of current robotics kits developed by different companies in Japan for education purposes. These kits are targeted to a large audience: from primary school students, to university students and also up to adult continuous education. Unfortunately, most information regarding the technical specifications, the practical usages, and the actual educational activities carried out with these kits are currently available in Japanese only. The main motivation beyond this paper is to give non-Japanese speakers interested in educational robotics an overview of the use of educational kits in Japan. The paper is completed by a short description of a proposal for effectively programming one of the shown robots, an educational humanoid, by means of a pseudo-natural language.

Keywords: education, educational robot kits, Japan, humanoid robots, wheeled robots.

1 Introduction

With the advance of technology, robotics have been successfully used and integrated into different sectors of our life. Industrial robot arms almost completely replaced the manual workload. Service robots, such as Roomba, serve as home helpers in the households, dusting the house automatically. Also in the field of entertainment, many robots have also been developed, AIBO provides a successful example of this. Recently, the development of robots also puts focus on edutainment purposes [1]. Not only one is able to learn how to build a robot system, but also to have fun competing with others. Tournaments, such as Robocup and First Lego League, have gained attention as events able to provide both education and entertainment at the same time.

Robotics offers a new way of teaching sciences to students [2], especially when integrating it into standard class curricula. Robotics can also foster the interest for scientific and technical disciplines. In Japan particularly, there is a downtrend of interest in technologies and sciences among the youngers [3]. This could create a problem to a country where development of technologies and manufacturing industries play such an important role. Robotics is hoped to rise up appreciation in technologies and sciences and also enthusiasm in “making-artifacts” for the youngers.

As introducing robotics in schools becomes popular nowadays, there is a large variety of commercial edutainment robots available in the market. These robots can

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be mainly divided into three groups. The first is reconfigurable robotics construction kits, like the Lego Mindstorms NXT, which is widely used for education. The second group is wheeled robots. Finally, the last group is humanoid robots, which is still the less common type due to its cost and availability. The products of three Japanese companies will be discussed in this paper. Vstone [4], ZMP [5], and Elekit [6] develop a range of both wheeled and humanoid robots. Vstone, which is well-known worldwide because of its VisiON robot series which was five times the Robocup World Championship, develops several low cost educational robot kits aimed at students as early as primary school. ZMP provides a series of educational robots called e-nuvo, ranging from a basic kit to learn motor control, upto a full-sized car, mainly aimed at university students. Elekit developed several low cost wheeled robot kits and also a simple humanoid. This paper will discuss wheeled robots and humanoids separately.

2 Wheeled Robots

Wheeled robots refer to a car like robot with wheels; they often provide only 2 controls, left and right. Their main application is for line tracing race as an introduction of control systems. Some products offer the study of control system of balancing an inverted pendulum. These robots are provided as kits, so the students are able to gain experience in building robots, including tightening screws, fitting gears, and also soldering.

2.1 Vstone's Beauto Series

This section will discuss the three of the current model of Vstone's wheeled robots, which are Beauto Racer, Beauto Chaser, and Beauto Balancer, their summary is shown in table 1 [4]. Beauto series (as shown in Fig. 1) offers learning of programming from basic until using C programming on microcontrollers [7].

Beauto Racer and *Beauto Chaser* share similar hardware specifications, with the main difference on the CPU. *Beauto Chaser* and *Beauto Balancer* offer the ability to program the microcontroller (Renesas H8) on the board directly using C programming language in *HEW*, a development environment for microcontrollers produced by *Renesas*, while *Beauto Racer* is only programmable using the bundled software, *Beauto Builder R* (Fig. 2).. The blocks used for the flowchart are 10 for beginners and 4 extra for advanced users. These blocks allow the user to stop, make the robot turn or go straight, timing the instructions, turning on the LEDs, creating conditional and loop commands. The speed of the motor can also be set. Advanced users may use the memory map allocation to set variables such as the motor output.

The feature of *Beauto Chaser* is the ability to learn how to program a microcontroller. It is also possible to add an extra board, VS-WRC004, on top of VS-WRC003, so that it is able to control up to 4 different motors. The main application of the robot is obstacle avoidance utilizing its infrared distance sensor. Further use also includes following the light, and also following a path line, which is possible by facing the sensor downwards. By using C programming, the user can also program the buzzer to play different music notes. With an additional extra kit, the user will be able

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to program the robot to be a remote controlled toy car. With creativity, there are many different possible applications of the robot obtained just by adding extra kits.

The bundled software (*Beauto Builder NEO*) [7] shares similar block flowchart interface as *Beauto Builder R*. In additional, it is also possible to command the robot to move backwards, turn around, move slightly diagonal forward or backward, or turning on the buzzer. If the robot is connected to the computer, it is also possible to view the sensor's value in real time.

Table 1. Wheeled educational robot series developed by Vstone.

Categories	Beauto Racer	Beauto Chaser	Beauto Balancer
Price	¥2,940 (€ 26)	¥5,985 (€ 53)	¥9,975 (€ 87)
Aimed users	primary - junior high	junior high - university	senior high - university
Size (mm)	81 × 77 × 23	175 × 125 × 55	110 x 45 x 210
Weight	81g (battery on)	194g (battery off)	175g (battery on)
Motor	2 DC motors	2 DC motors	1 DC motor
Sensors	2 infrared sensors	1 infrared distance sensor	gyro board
CPU	VS-LT001	VS-WRC003	
	control 2 DC motors		control 2 DC motors
Software	Beauto Builder R	Beauto Builder NEO	Balancer programmer
Battery	1 AA battery	4 AA batteries	

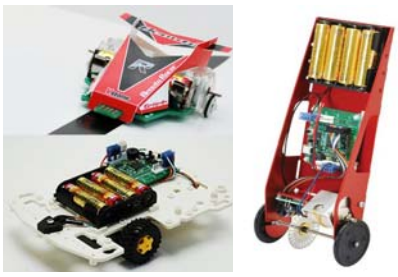

Fig. 1. (from top left clockwise) Beauto Racer, Beauto Balancer, Beauto Chaser.

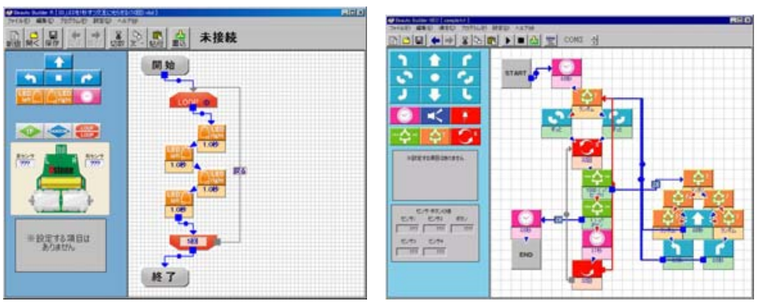

Fig. 2. Vstone bundled software, *Beauto Builder R* (left) and *Beauto Builder NEO* (right).

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Beauto Balancer enables students to learn about how inverse pendulum works and control system for self-balancing. The famous product of similar concept is Segway. A single DC motor is used to make it go forward or backwards and to balance itself according to the info gained from the sensor. The assembly is simple as it does not have many parts and can be done in less than one hour. Once the robot is built, the user can directly test the balancing program already inserted into the board. If the robot is well balanced, it is even safe to put things on top of it [8]. Similar as *Beauto Chaser*, it is possible to add extra sensors for more capability, or additional boards for controlling more motors and wireless controller kit. By using a simple Windows GUI provided by Vstone, the user is able to change the integral and differential gain for gyro and encoder without the need of use of code programming. The user is able to change between 2 modes, still mode or moving mode. The speed and acceleration can also be set from the program. It is easy to use for beginners, but also offers flexibility for advanced users by providing the ability to program the microcontroller. The unique and simple design of the low cost *Beauto Balancer* allows the use of it as a learning kit to study control system in Mechatronics course [9]. By using the kit, it is hoped that the students are able to grasp the concept of why things can be controlled using classical control theory and modern control theory.

2.2 e-nuvo WHEEL

ZMP offers wheeled robots and the basic kit starts from a price of ¥140,900 (€ 1,258). This robot is upgradable with option packs, which lead to possibility of higher steps in learning. With the simple design of the robot, the students can understand modern control system better and also learns how to utilize gyro sensor and encoder. It can be simulated through MATLAB, so the user can gain experience in simulating robots on computers. Aimed mainly at university students, they can learn programming, motor control such as PWM and H-bridge, line tracing experiment, classical control system (PID), modern control system, and model based design. It is controllable through wireless network (optional pack) and also through MATLAB, making it convenient to use as a tool to learn various algorithms such as avoiding obstacles and behavior planning. As mentioned above and shown in Fig. 3, the robot basic kit comes as a 4-wheeled robot, where the students learn basic microcontroller programming (on H8 microprocessor) and basic motor control system. When the optional packs are applied, the robot can imitate an inversed pendulum and also be a 2-wheeled robot, where the students learn balancing control system.

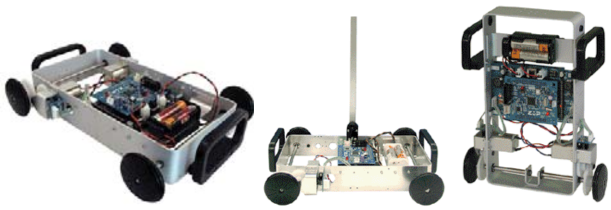

Fig. 3. Variations of e-nuvo WHEELS, from left to right, line tracing, inverted pendulum, and two wheels balancing.

2.3 Elekit MR Series

Elekit develops two types of wheeled robots (see Fig. 4). The lower cost one, MR-005, which is only equipped with 1 light sensor, requires soldering to assemble and costs ¥2,940 (€ 26). The KIROBO MR-9132, which does not require soldering and takes less time to assemble, is equipped with 2 light sensors and 2 touch sensors and obtainable at ¥5,775 (€ 51). Both are aimed at users older than 12 and programmable using the bundled software, IconWorks. Like Vstone's one, also Elekit's software uses mainly an iconic interface to enable beginner users to program the robot with a flowchart-like form. The functionality is also similar: it allows the user to make the robot move, read sensor info, incorporating timings, and basic programming instructions.

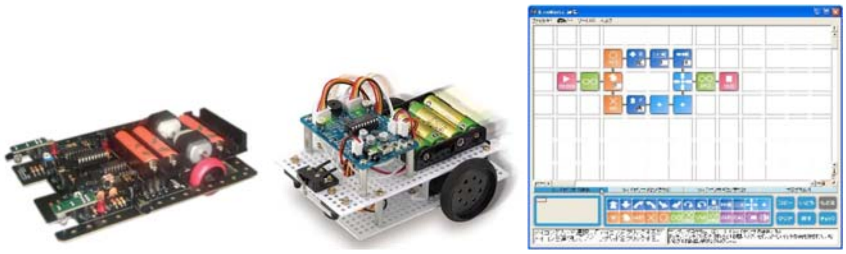

Fig. 4. Elekit MR-005, KIROBO MR-9132, and the software IconWorks.

3 Humanoid Robots

Two-legged humanoid robots are particularly popular for the use in Robocup soccer and Robo-one competitions. Combining soccer and humanoid robots create an interesting combination that grasps the students' attention and creates motivation, and thus represents both a great education tool and a way to stimulate development of new technologies by young people.

3.1 e-nuvo WALK

The humanoid robot offered by ZMP at ¥560,000 (€ 5,000) has 12 degrees of freedom and is equipped with Intelligent Servo Module (Fig. 5). This robot provides a further study of control system, which concept can be learned from e-nuvo WHEEL. The board has 2 analog ports and 4 digital ports, allowing extension of the robot's ability by adding USB cameras or sensors such as pose or range finder sensors. The control system of the robot is applied through CAN (Controller Area Network), which is a system widely used in commercial cars. This allows the usage of the robot as a tool of product development in companies.

e-nuvo WALK utilizes distributed control system, by dividing the control system to higher rank (on PC), and joint control system (on the robot). Both development of real and virtual robot is performed through Microsoft Robotics Developer Studio, which is an efficient robot control system development environment. Developing the

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motions of the robot is made easier by having a 3D image of the robot so that the user can check footsteps of the robot. So, even if there is no hardware, virtual development is made possible since it is equipped with a 3D simulator. Since this software uses .NET Framework, various programming language, such as Visual C# and Visual C++, can be used. Visual Programming Language is also available, making it easy to program, for example, using XBOX 360's controller to control the real or virtual robot.

Fig. 5. e-nuvo WALK (left), simulation environment, and motion editor (right).

3.2 Gogic Player

Elekit offers a simple humanoid robot kit that is equipped with 5 servo motors, and allows a variety of motion programming and exposure to a control system. Due to the few number of degrees of freedom, it is relatively simple and requires no complex setting. The kit can be assembled in 2-3 hours.

The bundled software, Gogic Works, comes with two different skins, for beginner and advance users. The robot is controllable with a general TV remote control; mobile phones that have this function can also be used to control the robot.

With the equipped distance sensor, the robot can be programmed to move independently, with functions such as searching for people. With extra optional packs, the robot can be made into a transformer robot (see Fig. 6), allowing the robot to change from a humanoid form to a car form and vice versa.

Fig. 6. Gogic Player and its transformation (left) and the bundled software (right).

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3.3 Robovie

Robovie-i. This type provides a low cost 2-legged robot (shown in Fig. 7). The “i” in its name corresponds to “introduction”, as assumed to be easily handled by beginners, even primary school students. The robot can be easily assembled using just a screwdriver. The robot has 3 degrees of freedom, 2 for the legs and 1 for the waist. The CPU used is VS-RC003, which can be used to control 30 channel servomotors. Decoration stickers such as eyes and mouths are also included in the kit to add fun for the users. It is compatible with additional kits such as a wireless controller and a speaker for making it talk and it can also connect with sensor kits such as a gyro sensor. The software used to operate this kit is *RobovieMaker* (shown in Fig. 7).

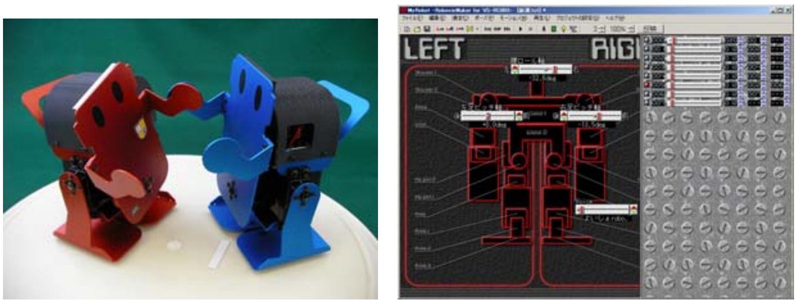

Fig. 7. Robovie-i (left), and the bundled software RobovieMaker (right).

The kit is interesting for beginners in robotics, not only because it can be easily assembled, but because it is easy to make motions such as walking. After the student finishes studying *Robovie-i*, the kit is also upgradeable to *RB2000*, a real 2-legged robot with 13 degrees of freedom. Basic robotics knowledge, such as walking motion and the notion of center of mass, learned using *Robovie-i* could be applied on *RB2000* making it easier to learn to control a more complex robot.

By incorporating simple sensors, the robot can be programmed to react to sensory information. Some applications include sumo competition, or dancing synchronously with music.

RobovieMaker. The robot motions can be developed with the bundled software RobovieMaker by connecting the robot via USB. The motion is created by moving each joint by a slider interface to create poses, and these several poses are then put into a sequence, like an animation, to form a motion. Since only moving sliders are needed, no programming skill is needed. The users may use the included default motion as a base to create their own motion.

Robovie-nano. This model is a low cost entry level robot kit. It is only 23 cm high and weighs 575g (see Fig. 8 left). The CPU is VS-RC003HV and it has 15 degrees of freedom. Its legs exploit parallel links, allowing more stable motions. Even in the basic version, it is equipped with speakers. Additional available sensor kits include a gyro sensor and extra motors to extend the degrees of freedom of the robot.

RobovieMaker2. This software, bundled with *Robovie-nano*, is an improvement of *RobovieMaker*: it enables the user to incorporate the integrated gyro sensor info and LED into the motion. The motion is made by inserting instructions in a flowchart form, allowing the user to make a more complex program for the robot such as having

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feedback of the sensor info to make the robot stable, rather than just simple sequential movements. The input from a game controller, which can be used to control the robot, can also be incorporated into the flowchart program.

Robovie-X. The Robovie-X (see Fig. 8 right) is the biggest model and comes with seventeen degrees of freedom, with dimensions 343×180×71mm (H×W×D) and weight 1.3kg. It features VS-S092J servos which have 9.2kg/cm of torque. The VS-RC003HV onboard controller features a built-in audio system and an IXBUS connector which allows optional expansion boards to be incorporated into the robot to expand it's functionality. This robot has high motion performances, capable of fast walking, dancing, flip, side-flip, standing-up, fighting, playing soccer, etc.

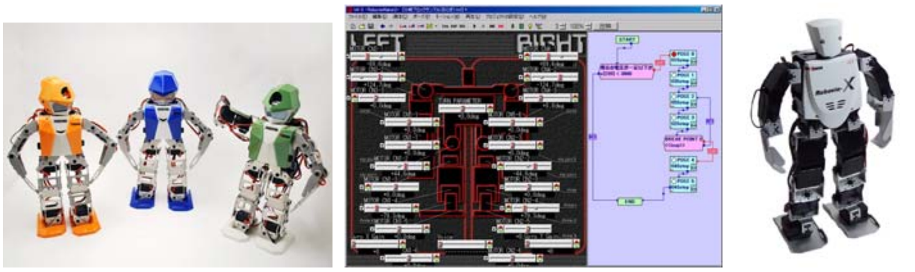

Fig. 8. Robovie-nano (left), the bundled software RobovieMaker2 (middle), Robovie-X (right).

4 Educational humanoids: a new challenge

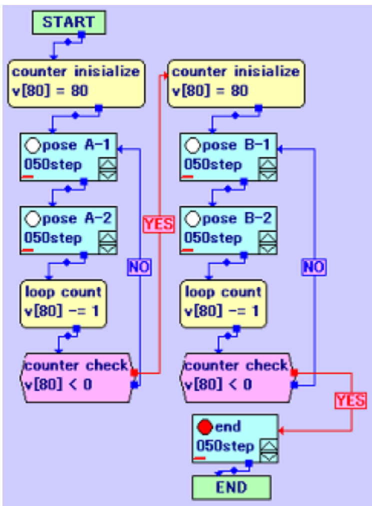

Fig. 9. An example of a program sequence

Comparing with simple, wheel equipped vehicles, educational humanoids offer new questions on how using them in an effective didactical way. One of the most relevant challenges is related to the relatively low level of abstraction their programming environments provide. This is essentially due to the complexity of the robotic structure: the relatively great number of degrees of freedom does not permit to maintain easily accessible the level of programming you can usually find in simpler types of robots like LEGO Mindstorms. We will show this using the Robovie-X humanoid and then proposing a higher level of abstraction through a natural language programming interface.

This robot may be programmed using the *RomovieMaler2* GUI presented in section 3.3.

When you have defined a pose on the left side

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of the interface (see Fig. 8 middle), you can add it into the Motion Area on the right side where poses are connected into a sequence that forms the program (Fig. 9). In the motion sequence the programmer defines also the duration of the transition from one pose to the following one, fixing the global motion speed. The sequence may also include conditional controls commands, cycles and calculations on global variables.

The programming environment compiles the program sequence into a textual, low-level command file, which is downloaded onto the controlling card and there executed. Despite the graphical interface provided, programming the robot in this way is a rather complex task and it requires a significant degree of expertise in order to produce stable poses and reasonable behaviors for the humanoid. This difficulty suggested us to experiment a higher level approach based on a pseudo-natural command language whose keywords should have been not ambiguous, self-explaining and related to the robot capabilities. Moreover, the language should have given the possibility to easily define high-level actions.

The first step was to assign names, defined as language keywords, to all the joints of the robot. The 17 joints have been divided into one single joint on the head and 8 couples of joints for each side. So we identified these names: *head*, *shoulder*, *arm*, *elbow*, *hip*, *thigh*, *knee*, *calf*, *ankle* and the sides *left* and *right*. Then we identified some basic actions like: *move* (equivalent to *turn*), *increase*, *decrease*, *set*. In general the motion specifies a direction, described by: *inside*, *inward*, *outside*, *outward*, *front*, *forward*, *back*, *backward*, *right*, *rightward*, *left*, *leftward*.

The general structure of a motion command is:

<action> <side> <limb> <prep> <number> *degree* <direction>

<prep> is one of the two preposition *at* and *of* which respectively indicate the absolute and relative amount of degree specifying the angular position of the servomotor. <side> is not present in the case of the head joint. For the 2 LEDs, the command structure is slightly different:

<action> <side> *luminosity* <prep> <number> *%*

Every type of sensors is described by a specific keyword: *gyrox*, *gyroy*, *shootanalog*, *pitchmove*, *rolllstep*, *rollrstep*, *legpace*, *turnctr*. For controlling these elements in terms of *gain* or *control*, the command structure is:

<action> <side> <sensor> *gain/control* <prep> <number>

The previous commands can also be extended including the playing of a sound:

. . . *playing* <file pathname>

To set the transition time of a pose, it is sufficient to add the following suffix:

. . . *in* <integer value> *millisecond*

More than one action can be concurrently executed, separating two subsequent actions by a comma (,) or by the keyword *and*, and concluding the set of actions with a dot (.). Nestable cycles are easily programmed using this structure:

repeat <integer value> *times* . . . <actions> . . . *end*

As mentioned before, we tried also to include some higher level actions, that are sequences of predefined poses realizing useful behaviors. The complexity of the action, in terms of the number of parameters, depends on its type.

walk <integer value> *steps ahead*/*back*/*rightward*/*leftward*

dance

bow

yawn

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getting up from face up/down
front/back gambol

A complete example written in the proposed language, with some further not described but straightforward commands, follows.

```
turn right arm at 180 degrees outward playing
     Other\Hello
reset
repeat 3 times
move head at 45 degrees rightward in 1500 ms
turn head of 90 degrees leftward in 1500 ms
end
walk 10 steps back
repeat 2 times
bow
end
exit
```

We developed a compiler able to translate these natural language commands into the program text file expected by the robot controlling card. As you can realize, this language makes it possible to break down the complexity in the effective programming of a humanoid for educational purposes and opens also the possibility of implementing vocal commands.

Table 2. List of introduced robots (basic default kit) sorted by categories and cost ([A]Beauto Racer, [B]Elekit MR-005, [C]Elekit KIROBO, [D]Beauto Chaser, [E]Beauto Balancer, [F]e-nuvo WHEEL, [G]Robovie-i, [H]Gogic Player, [I]Robovie-nano, [J]e-nuvo WALK).

Category		**Wheeled Humanoid**									
		A	B	C	D	E	F	G	H	I	J
Motors	DOF	2	2	2	2	1	2	3	5	15	12
Sensors	Light		X	X			X				
	Infrared	X									
	Rangefinder				X			X			
	Touch			X							
	Gyro					X	X				
	Encoder					X	X				
Software	Flowchart	X	X	X	X			X			
	C				X	X					X
	Slider Interface							X	X	X	X
	MATLAB						X				
	Robot Studio										X
	Simulation						X				X
	Other					X					
CPU	PIC			X							
	Renesas H8				X	X	X				
	Renesas R8C										X
	Other	X	X					X	X	X	
Usage	Beginner	X	X	X	X	X		X	X		
	Advanced				X	X	X			X	X
	Research						X			X	X

4 Summary and Conclusion

A selection of current available educational robot kits by 3 different companies has been presented. The robot kits introduced in this paper are summarized in Table 2. Wheeled robots are mainly targeted towards younger students while humanoid robots are more suitable for mature users. Since the robots come in kits, the users learn how to build a robot and how to use various sensors to increase the robot's intelligence. The provided software of the robot kits are mostly aimed at beginners where they can begin learning programming by arranging instruction blocks in sequential, conditional, or repetition structures, in a flowchart like a graph. Some kits with an included microcontroller allow advanced users to learn microcontroller programming and also learn C language. e-nuvo series uses commercial programs such as MATLAB, enabling users to learn one of widely used engineering tools, and Microsoft Robotics Studio, which opens up the possibility of simulation of virtual robot. With additional kits or upgrades, there are more possibilities of usage of the robots. In the end, we highlighted how the use of humanoid robots need more advanced programming language and programming environment and we proposed a simple pseudo-natural language for humanoid robot programming. The development of these kits and their uses in different kind of competitions are hoped to bring up the youngers' interest in science and technology.

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