A Survey on Commercial Starter Kits for Building Real Robots

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Many starter kits are commercially available now to assist robots' hobbyists in designing, building, and programming working robots. This paper serves as a critical survey paper that describes the available robotics kits. This survey addresses issues such as modularity, reusability of the building blocks, versatility, price, etc. The paper pretends to shed some light to researchers and hobbyist on the possibility of building real robots with low-cost market available starter kits.

Keywords: **Biologically-inspired robots, Education, Industrial robots, Mobile robots, Starter kits.**

1. Introduction

Nowadays, robots have started a new era and entered new fields of application, including reaching our homes to perform many tasks in the human society. These tasks may include, but not limited to, handling various house duties, providing medical care for elderly people, assisting people with motor or cognitive disabilities, educational entertainment (edutainment), personal assistance, giving directions at information points in public places, etc. These developments were achieved owing to the recent advances in other technologies such as sensors, actuators, materials, new communications, and multimedia technologies. Microsoft Chairman Bill Gates lays out this robotic future in [1] and summarized the challenging problems of this field in lacking of standardization, high cost of hardware components such as sensors, and concurrency of the parallel processors the robot may have.

In recent years, robotics has attracted considerable attention by the academic and the research communities. Robots has also become of greater interest to people with minimal technical skills so there is a need for easier to use and more flexible robot building kits systems.

Due to this increased interest in robotics in the recent years, many kits have emerged in response to the market needs. Numerous companies have been formed that offer a large number of robotics products aiming at fulfilling the market need for such kits. Such wide variety of products needs to be sorted and categorized to allow their users to choose which best fits their application needs.

The remainder of the paper is structured as follows: section 2 addresses the importance of robotics in education. Section 3 presents the categorization scheme of the available starter kits for building real robots followed by describing some commonly used starter kits in section 4. A comparative study between these kits is presented in section 5. Finally conclusions and future work are summarized in section 6.

2. Robotics in Education:

Robotics challenges traditional engineering disciplines because the integrated approach in the selection of means to the intended functional ends must involve, by nature, a team activity, and crossing the boundaries between conventional engineering disciplines [2]. Unlike traditional fields, robotics is still an emerging area that combines the essential elements of mechanical engineering, electrical engineering, and computer science. This synergistic combination of traditional engineering disciplines makes robots good platforms that can be used to provide theoretical basis and hands-on experience in different areas of technology such as drives and actuation systems, sensors, and measurement systems, control systems, microprocessor systems, and systems integration and analysis.

Relatively few robotics education programs exist at the graduate level, and even fewer exist at the undergraduate level. The courses in existence are still new and are open to rapid change and new approaches. Course goals can change from year to year as new technologies and theories are introduced into the field at large. In these courses, the real interaction with the robot is unquestionable to give the students hands-on robotics experience and to help them to understand real-world problems and to be able to identify these problems and formulate cost-effective applicable solutions.

Recently, robotics has started to become more and more popular as an educational tool, from secondary education, through undergraduate courses, to graduate education. Not only do engineering departments use robots in education but also a variety of arts and sciences courses use it as well. This is an indication of the success of robots in education, which is the result of the unique learning experience provided by robots, the cost of robots that dropped exponentially in addition to the plug and play feel of new robot platforms [3]. Robotics provides students with needed experience dealing with integrated systems building, real world issues, teamwork, multidiscipline information, and critical thinking [4]. Many researches aimed to achieve educational and research objectives through the use of small, low cost and configurable mobile robots kits. Universities and high schools are employing these kits in artificial intelligence, computer science, engineering, and physics courses where they provide students with a new perspective on building integrated systems allowing hands-on education and low-cost experimentation [3].

For example, the fields of robotics and computer science have been highly correlated for many years now. Numerous works have studied the impact of using robotics in education [2,3,4,5,6]. It was proven that the motivation to learn principles increases significantly when students have opportunities to apply those principles in constructing robots and designing problem-solving code. Robotics-inspired projects could help students at undergrad level understand core computing concepts better by exploring them in a setting, unlike desktop computing.

In the last decade many manufacturers have released numerous standardized low cost platforms. Most of these platforms were developed for the toy market where they made great success but quickly found their way into education setting. These platforms could be pushed beyond their early use and transitioned towards achieving substantial educational and research goals.

3. Categorization Schema

Hundreds of robotics kits are now commercially available for building real robots. A real robot is a machine that imitates the actions and/or appearance of an intelligent creature, usually a human. This machine must be able to perceive its surroundings and takes actions based on environment perception.

This paper divides the available commercial kits into five main categories according to the components available in the kits and its completeness in building a robot as shown in Figure 1.

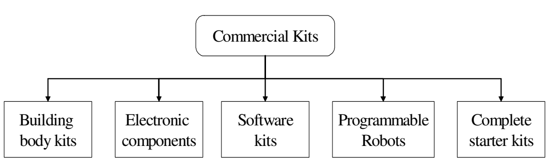

Figure 1- Categories of Commercial robotics kits

The building body kits are kits that consist of only different body building blocks that are used in building the skeleton of the robot like LEGO Technic, fischertechnik and Meccano. The Electronic kits consist of the microcontroller that serves as the brain, different electro-mechanical components, sensors, and actuators that bring the life to the robot skeleton. While the programming kits like Microsoft Robot Studio are software simulated environments to allow programming and emulating the robots. While these previous categories need to be merged to deliver one complete robot, there are robot kits that include all these items. First of which is the programmable robots which has no flexibility in the body or electronic design as it is delivered by the manufacturer already assembled, but can be reprogrammed to deliver different functionalities using the supported software tools. The second of which are the complete starter kits that allow different levels of flexibility in the body design, the electronic and mechanical design, and software functionality. The next section describes some of complete starter kits that are commonly used to build real robots with different configurations.

4. Complete starter kits

Based on the degree of versatileness, commercially available starter kits can be classified into two basic subclasses: versatile and non-versatile kits as shown in figure 2.

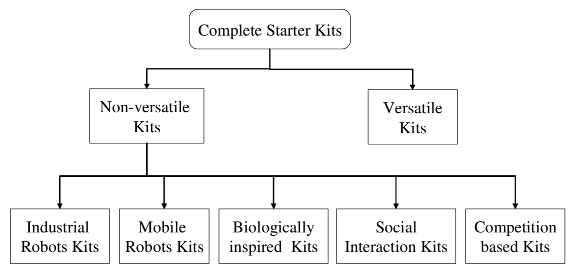

Figure 2: Categories of starter kits.

Versatile starter kits provide generic building blocks that can be used to build robot with different morphologies. Non-versatile starter kits facilitate building robot with specific morphology such as industrial robots, mobile robots, biologically-inspired robots, social robot and competition-oriented robots.

4.1 Non-Versatile Complete Starter Kits

4.1.1 Industrial Robot Kits

These kits facilitate constructing multipurpose, reprogrammable industrial manipulators with different degrees of freedom (DOF). Many kits are available nowadays for beginners as well as advanced hobbyists to build robotic arms as shown in the following subsections.

4.1.1.1 RA-01 Robotic Arm Kit

The RA-01 Robotic arm unassembled kit costs around $350 while the assembled kit is also available for an extra $100 [7]. The kit comes with 5 servo motors, arm base, body parts, instructions manual, the controller board PCB, and components which have to be soldered. The control software is also available with the kit and is connected to the RA-01 via a serial cable. The Windows program has a script writing feature that allows the user to program the robotic arm with thousands of movements with full, precise, and repeatable control of each movement. Scripts may hold a maximum of 10,000 movements (including pauses) with a maximum repetition of 10,000.

4.1.1.2 Robotic Arm Trainer

The Robotic Arm Trainer [8] is built to teach the basic robotic sensing and locomotion principles while testing the hobbyist motor skills as he/she builds and controls the arm. This unit can be controlled with its five switch-wired controllers with lights to grab, release, lift, lower, rotate wrist, and pivot sideways 350 degrees. An IBM PC computer optional kit can be used with this robotic arm. The computer interface allows for dual (computer and manual) control of the Robotic Arm. It features programming; saving, editing, and downloading capabilities using one PC parallel port. The computer interface includes an assembled interface card, parallel port cable, two 3.5 inch diskettes, cable connector, and operating instructions

4.1.1.3 Lynx

Lynx robotic arm kits [9] uses ultra-tough laser-cut Lexan structural components, black anodized aluminium servo brackets, custom molded components, and the servo motors for its motion. Lynx offers three robotic arm kits, two of which are more popular, the lynx 5 series and the lynx 6 series kits. The lynx 5 series has 4 Degrees of Freedom (DOF) while the 6 series has an additional DOF (5 DOF total) for wrist rotation. Also the 6 series has more powerful servo motors to compensate for its longer arm.

The software used for control is called RIOS, which is a Windows program that works for both, the L5 and L6 Robotic Arms. With RIOS, the robot can be taught sequences of motion via the mouse or joystick. The inverse kinematics engine makes positioning the arm effortless. This program uses external digital and analog inputs to affect the robot's motion for closed loop projects. The kit can also be connected to an external circuit without being connected to a PC; the software (RIOS) can create the BASIC code to control the arm from Basic Atom or Basic Stamp 2. The external microcontroller circuit is not provided with the kit but can be bought separately.

4.1.2 Mobile Robots kits

A mobile robot is a machine that can move in the real world and can be completely autonomous. Many starter kits are currently available to build reprogrammable mobile robot that is able to navigate autonomously through indoor/outdoor environments.

4.1.2.1 ActivMedia's Pioneer Robot

Pioneer-DX is a general purpose mobile robotic platform manufactured by ActivMedia [10]. It is more robust than most hobby kits and offers an embedded computer option, opening the way for onboard vision processing, Ethernet-based communications, laser, DGPS, and other autonomous functions. It arrives with a ring of 8 forward sonar and with an optional rear sonar ring. DX's powerful motors and wheels can reach speeds of 1.6 meters per second and carry a payload of up to 23 kg. In order to maintain accurate dead reckoning data at these speeds, the Pioneer uses 500 tick encoders. It is equipped with laser-based navigation system, bumpers, gripper, vision, stereo rangefinders, compass and more modules are still under development.

The software used with DX is called ARIA and it provides several functions such as wander randomly, control by keys or joystick, plan paths with gradient navigation, display a map of its sonar and/or laser readings, localize using sonar (with optional laser upgrade), communicate sonar & control information relating sonar, motor encoder, motor controls, user I/O, and battery charge data, run C/C++ programs and simulate behavior offline with the simulator.

Pioneer DX comes with an aluminum base, 2 wheels, 1 battery, motors, encoders, front sonar ring, microcontroller, ARCOS microcontroller server software, ARIA Robotics API for developers and an operations manual. Communication with a PC client is available via wireless modem, robot to laptop or desktop connection or a connection to an embedded computer. Accessories are also available for Pioneer DX robot that include stereo range finding camera, 360 Omni-cam, colour tracking, compasses & tilt-position sensor, gripper and a docking station.

4.1.2.2 K-Team's Khepera Robot

Khepera III [11] is based on many years of experience in miniature robotics. It features multiple sensor arrays for both long range and short range object detection. For optimal autonomy is has a swappable battery pack system. The Khepera III robot is able to move on a tabletop but it is also designed to move on a lab floor. Rough floor surfaces, carpets, and doorsteps are not a problem for the Khepera III.

Khepera III can be controlled by KoreBot which fits the needs of OEM developers of handheld devices. At the size of a credit card, KoreBot is a powerful embedded platform based on XScale. KoreBot extends the same type of functionality and performance found in the latest generation consumer PDA devices to the industrial market. It is ready-to-run, extremely compact, but flexible for expansion and customization for customer application needs; KoreBot provides the starting point for new designs and comes complete with all the hardware and software needed to start development including its Linux operating system. It is an internet-ready appliance with web browser and server built-in when using pre-configured Linux operating system. Equipped with several I/O functions the XScale can be rapidly configured to be a data entry terminal, video player, or control system. Applications range from environmental monitoring to factory automation. KoreBot allows you to quickly and easily develop advanced applications using the GNU/Linux programming tools and the SysQuake. SysQuake provides optimized numerical computation and interactive scientific visualization to enable the design robot control and robot vision software rapidlly. Remote operation programs can be written with Matlab, LabView, or with any programming language supporting serial port communication.

4.1.3 Biologically Inspired Kits

Apart from traditional mobile vehicles that use wheels and tracks as locomotion systems, there is widespread activity in introducing inspiration from biology to produce novel types of robots with adaptive locomotion systems [12]. The following subsections describe some starter kits that can be used to construct biologically-inspired robots.

4.1.3.1 Toddler

Walking robots are relatively unexplored in the area of hobby and education. The reason for this is that they have inherent design limitations such as their ability to handle diverse terrain including stairs; they require more complex programming algorithms and sensor-based feedback; and interdependency between software and hardware requires some critical thinking to obtain the desired actions. This may be one of the reasons most of our robots have wheels. However, people have a natural tendency to appreciate a walking robot: they seem more like human beings; they offer more entertainment value because they are fun to watch; and to make a biped robot walk successfully is a challenge worthy enough to pursue the concept.

Costing almost $250, the Toddler robot [13] is a high quality robot CNC-machined from aluminium and brass. The aluminium parts are brushed, anodized, and acid-etched to make the perfect finish. The package includes body parts, legs, ankles, control linkages, screws/nuts/standoffs, etc. The Toddler robot requires 2-3 hours to assemble and tune. The aluminium parts have holes, slots, and configurable mounting angles for your own customization. The Toddler robot is controlled by a surface mounted BASIC Stamp® 2 module. Four infrared sensors and receivers, LEDs, servos for tilt and stride, resistors/capacitors, speakers, and photo-resistors complete the control system.

4.1.3.2 Crawlers

The Parallax robotics team are continually developing new interesting projects. Parallex introduced two highly advanced new robots, Quad-crawler [13] and Hex-crawler [13] robots. The Crawler hexapod is an advanced robotic kit that consists of a walking platform. The crawler robots are built on a high-quality aluminium chassis that provides a sleek platform for the servo motors and BS2/BOE based control system. The kits include the BS2-IC microcontroller, Board of Education carrier board, 12 Hitec servos, and 1 Parallax Servo Controller. The crawler circuits are built on the Board of Education carrier board. The crawler kits contain electronic parts, aluminium parts, nuts, bolts, washers, and screws.

The Qaud-Crawler costs approximately $500 and consists of 8 servo motors to operate the 8 legs. The Hex-crawler is for almost $650 and consists of 12 servo motors to operate the 12 legs. With additional accessories, the crawler robot may be programmed to perform all sorts of neat movements. The length of the Quad-crawler is 3.5 inches to 4 inches while the length of the Hex-Crawler is 19.56 inches to ensure maximum physical leg clearance. This enhancement will allow the Hex-Crawler to walk with a maximum walking stride without the legs physically touching. The Hex-Crawler can have more than one sensor pointing straight in front of the hexapod.

Hexapod walker robot kit [7] from Image SI Inc. has plastic base and legs, using three servomotors for motion. The kit includes two switch sensors & whiskers used for obstacle avoidance. The Hexpod kit also has a pc board, microcontroller, mounting hardware, and booklet. It uses PIC as its microcontroller, and can be programmed in PICBasicPro (a samle program is available for download via their website). The kit costs 190$ unassembled and 290$ assembled.

4.1.4 Social Interaction Kits

Most of the new robotic trends are in their nature designed to interact more with the human being, whether for the purpose of entertainment or transmission of information for the benefit of performing given tasks or services [14,15]. This new reality entails the opening of a new field of work to deal with issues concerned with the human-robot social interaction. The following subsections highlight some starter kits that are now commercially available and can be used as a platform to study human-robot social interaction.

4.1.4.1 Alex Animated Head

Alex [16] is a working animated head built from a complete kit of pre-cut pieces. The head turns and nods, eyes swivel, and lips move. Alex is a great starter kit to study the human robot interaction and ideal for displaying messages and educational purposes. The kit includes the building pre-cut pieces, hardware, servos, and ready assembled fully featured animation controller board.

Alex Animated Head is a little above $100 and consists of a 16 seconds digital speech recorder with electric microphones with 16 ohm speakers and up to 4 servo tracks capability. The controller provides recording and playback capabilities with flashing blue eyes and sound. The main processing unit is a PIC16C72 microcontroller. It also supports other features like loop play and auto start-up.

4.1.4.2 Trekker-R robot kit

SuperDroid Trekker [17] is available in many configurations that have different difficulty levels. Each equipped with different kind of sensors. The robot uses modified 360 rotation servos and has aluminium chassis. The chassis is designed in such a way that additional accessories can be added to enhance the robot building experience.

Trekker uses OOPIC as its processor and can be programmed using C, BASIC, or Java. The OOPIC microcontroller has the advantage of being an object oriented PIC which allows multitasking. The add-on features of the Ultrasonic sensors, IR detectors, LCD, electronic compass, line following sensors, flame detectors, a large selection of wheels, and bumper switches make the Trekker very versatile.

4.1.5 Competition Kits

Many starter kits have been inspired by robotic competitions that are regularly taken place in order to motivate people to work in robotic projects.

4.1.5.1 Sumo-Bot

The huge success of Boe-Bot made Parallex explore more interesting avenues to target the market needs. The Sumo-Bot robot [13] is a competition-ready robot designed within the Northwest Robot Mini-Sumo Tournament rules. It has the ability to locate and knock its opponent right out of the ring while detecting the outside circle.

For almost $200, the Sumo-Bot Robot Competition Kit includes approximately 170 pieces of two Sumo-Bot robots to assemble, including a development board, serial programming cable, and a screwdriver. The electronics consists of a surface-mounted BASIC Stamp 2 module, infrared sensors to detect your opponent and the edge of the Sumo Ring. The hardware package includes the black anodized aluminium chassis and scoop, servo motors, wheels, and 4AA power pack mounting standoffs.

The Sumo-Bot performs several activities which include friction analysis, self-calibrating sensors, memory optimization with multipurpose variables and a sensor flags register, and state-machine diagrams for sensor-based navigation. The Brain of the Sumo-Bot is the BASIC Stamp microcontroller. The Sumo-Bot faces the same limitations of his sibling the Boe-Bot in the programming language of the Basic Stamp and the absence of floating point arithmetic.

4.2 Versatile Complete Starter Kits:

4.2.1 LEGO MIND STORM

LEGO Mindstorm [18] was developed as a toy to address the market increasing obsession of robotics since the mid 80s. Since then, large number of studies were directed to explore the applicability of LEGO Mindstorm in education and research [4]. It has been demonstrated that LEGO Mindstorm has become a suitable platform for college students and researchers. In the last decade, many academics as well as hobbyist have been pushing the limits through reverse-engineering its firmware, hacking together new programming environments, and sharing recipes for unanticipated ways of connecting it to the outside world.

The basic LEGO Mindstorm kits costs about US$200 and contains 750 building block pieces. The core of the kit is the programmable control unit RCX. RCX stands for robotic command explorer. It consists of a 10MHz Hitachi H8 microcontroller with 32KB of RAM, space for batteries, and an infrared transmitter and receiver, which communicates with a base station plugged into a PC port. It also contains a five digit liquid-crystal display (LCD), four control buttons, and six wiring connectors. Three of the external wiring connectors are outputs, each supplying a user-controlled voltage to a motor, a lamp, or anything else that will run off half a dozen AA batteries. The remaining connectors can read data from a variety of sensors (one light and two touch sensors, all housed in Lego-style bricks, are included with the basic kit, along with two stepper motors). The LCD can display motor settings, sensor readings, or diagnostic information about the status of the RCX and its software

The latest product in the Mindstorms series is Mindstorms NXT, released in August 2006. The NXT is the brain of a MINDSTORMS robot. It's an intelligent, computer-controlled LEGO brick that lets a MINDSTORMS robot come alive and perform different operations. It has a 32-bit ARM7 microcontroller with 256 Kbytes FLASH, 64 Kbytes RAM, 8-bit AVR microcontroller with 4 Kbytes FLASH, 512 Byte RAM, Bluetooth wireless communication, USB full speed port, 4 input ports, 6-wire cable digital platform, 3 output ports, 6-wire cable digital platform, 100 x 64 pixel LCD graphical display, Loudspeaker - 8 kHz sound quality and a Sound channel with 8-bit resolution and 2-16 KHz sample rate.

The LEGO MINDSTORMS NXT software enables you to program your NXT robotic invention and upload your programs to the NXT via USB or Bluetooth connectivity. The intuitive Mac and PC compatible drag and drop software, powered by National Instruments LabVIEW, comes with building instructions and programming guides to easily begin constructing and programming with MINDSTORMS NXT.

4.2.2 The Boe-Bot:

In the early 90s, the BASIC Stamp microcontroller was envisioned by Parallax founders to bring the power of microcontrollers to ordinary people. Since then, Parallex has offered many products to provide robotics hobbyist with what they need. The Boe-Bot Robot Full Kit is Parallex most complete reprogrammable robot kit. With no previous robotics, electronics, or programming experience needed and with a cost of $149.95, Boe-Bot made its way to be one of the most popular hobby kits. Customers quickly learnt that the Boe-Bot is expandable for many different robotic projects. Since then hobby became business and Boe-Bot took its place as an education and research kit.

The Boe-Bot Full kit [13] consists of approximately 90 pieces, containing BASIC Stamp microcontroller module, passive components (wires, resistors, capacitors), sensors (photo resistors, bumpers, infrared sensors), and hardware (chassis, wheels, servos, whiskers). The Boe-Bot robot is built on a high-quality brushed aluminium chassis that provides a sturdy platform for the servo motors and printed circuit board. It consists of mounting holes and slots that may be used to add custom robotic equipment. Wheels are machined to fit precisely on the servo spline and held in place with a small screw. The Boe-Bot robot's flexibility stems from the fact that it is a rolling Board of Education carrier board. All I/O projects are built on the breadboard. The Board of Education programming boards may be removed to be used as your platform for the Stamps.

The Boe-Bot robot takes about 1-2 hours to be put together. After mastering the basics, Boe-Bot add-ons let you branch out into new activities, such as making your Boe-Bot talk with a speech board, adding infrared remote control, maze contests, line following, interfacing direction sensors, and using RF modules and video/camera equipment to build a Video-Bot.

4.2.3 VEX

The VEX Robotics Design System [19] was inspired by the FIRST (For Inspiration & Recognition of Science & Technology) Robotics competition. This not-profit organization was founded to inspire young people's interest and participation in science and technology. It was developed by RadioShack in collaboration with Carnegie Mellon University Robotics Institute, in Pittsburgh.

The VEX starter kit costs $299 and comes with over 500 parts that includes configurable chassis, programmable micro-controller, three variable speed motors, one servo motor, multiple gears, two bumper sensors, two limit switches, various wheel types, and a radio controller for wireless control.

Although the kit has enough parts to build various robot structures and provide several motor kinds, you can also buy better quality motors, sensors, and wheels that will all fit very well in the chassis plates that are pre-drilled so that no machining is required. The VEX processor can be programmed using the easyC Programming kit and transferred to the micro-controller via serial cable. The VEX kit relies on the PIC18F8520 microchip as its processor, which has a program space of 32K and a memory of 1800 bytes + 1024 bytes of EE2PROM. This means that this kit can also be programmed with Microchip MPLAB IDE. The kit has 16 analog and/or digital pins (shared) and 8 PWM outputs for motor control.

With all this integrated in the VEX Starter Kit, and with the help of the step-by-step user guide instructions, hobbyists can build different robot structures with many different functions. The versatility of this kit adds a complexity for beginners, the kit is therefore recommended for high-school ages or above.

4.2.4 Microbric VIPER Robot Kit

The VIPER robot development kit [20] has a unique feature of having absolutely no wires involved for the assembly of this robot. The kit comes with two motors, two wheels, control board, battery holders, remote control, and the software CD. The VIPER uses the BASIC language to program its ATOM microcontroller board via the ATOM BASIC IDE and a serial cable.

The kit comes with a range of modules which are little circuit boards that hold several electromechanical devices, each having a different function. Among the modules included are a LED module, switch, buzzer, button, bump sensor, and an infra-red module for remote control. The modules are then connected to the main control board by tiny building blocks that hold the motherboard and the modules together. Add on sets are also available for the VIPER kit, including an extra wheel and motor pack, a sumo robot pack, and a line following sensor pack.

4.2.5 Qfix

In Qfix [21], the mechanical parts are made of aluminium. Mechanical elements include bars and plates, holders for motors and sensors, axes, and wheels. The Qfix starter kit is called “crash-bobby” and uses the Atmel ATmega32 microcontroller, which has a program space of 32K and a memory of 2KB + 1KB EPROM; the electronics are modular and can be connected via I^2C bus.

The kit includes a controller board (Bobbyboard), base plate, two motors, two wheels, three infrared distance sensors (by SHARP), CD with manual and software, and a download cable. Crash-bobby can be programmed via a parallel or a USB cable; it uses GNU C/C++ for programming. The kit does not come with batteries included, although, a rechargeable battery as well as a charger can be bought from the Qfix website. The controller board allows for digital and analog inputs, 2 motor outputs, 4 push buttons, programming socket, and an I^2C socket for connection with other electronic modules. Expansion sets are available for this kit; which may be connected via the I^2C bus. Available expansion sets include line sensor set, LCD display, wheel encoder set, bumper set, metal building blocks, and a soccer platform with omni drive wheels. The Qfix robots are often found in RoboCup junior competition.

5. Comparative Study

Starter kits differ greatly in terms of modularity, reusability of the building blocks, versatility, and price. These differences need to be studied and highlighted to allow their users to choose which best fits their application needs.

We are going to compare these kits in terms of:

- *Modularity:* is a property that measures the extent to which a kit can be divided into separate independent usable components.
- *Reusability of the building blocks:* is a property that measures the ability of the kits to build robots of different shape and structure and fit different skeleton requirement.
- *Time required to assemble:* time needed to construct a complete robot out of the building blocks and electro-mechanical components available in the kit.
- *The availability of support accessories:* the property that indicates the availability of supporting modules and additional components in the market.
- *Spare parts*: it is a property that indicates the availability of spare parts in the market.

- *Sensors available*: it is a list of the sensors included within the kits or can be added to the robot.
- *Software*: the types of software used to program or even simulate the functions of the robot.
- *Microcontrollers*: the types of microcontrollers that are provided or used in building the robot.
- *Audience*: it is a property that indicates the level of expertise of the target user.
- *Multifunctional*: it is the property that indicates the flexibility of using the kits in constructing a high diversity of robots.

Price: the money value of the kit.

Table-1 provides a complete comparison between all starter kits included from the metrics we mentioned above. The cross (×) indicates that the property is unavailable, the tick (✓) indicates that the property is available while numerous ticks (✓✓✓) indicates the high availability level of the property.

Table 1- Comparison of all covered starter kits.

	Company	# of building blocks	Micro-controller	Software	T assemble	Spare parts	Sensors included	Accessories	Multifunc-	Reusability	Modularity	Price range	Audience
LEGO MINDSTORM	LEGO	750	RCX	Visual Basic	1h	✓	✓	✓	✓	✓	✓✓✓	$200	12 +
Boe-Bot	Parallex	90	BASIC Stamp	PBASIC	1h	✓	✓	✓	✓	✓	✓✓✓	$150	12 +
Sumo-Bot	Parallex		BASIC Stamp	PBASIC	1h	✓	×	✓	×	×	✓✓	$200	
Toddler	Parallex		BASIC Stamp	PBASIC	3h	✓	✓	✓	×	×	✓✓	$250	
Crawler	Parallex		BASIC Stamp	PBASIC	11h	✓	×	✓	×	×	✓✓	$500 $700	
Khepera III	K-Team		DsPIC 30F5011	MatLab / LabView / C / C++			✓	✓			✓✓✓	$2600	
VEX	VEX	500 +	PIC 18F8520	easyC		✓	✓	✓	✓	✓	✓✓✓	$299	15 +
Qfix	qfix		Atmel AT-mega32	Wi-nAVR/ GRAPE		✓	✓	✓	✓	✓	✓	$340	
Microbric VIPER Robot	Micro-bric	20+		BASIC			✓	✓	✓	✓	✓	$85	
Alex- Animated Head	iiRobot-ics		PIC16C 72		1h	×		×	×	×	×	$100	
ActivMedia's	Mo-						✓	✓	✓	✓	✓		

Pioneer Robot	bileRo-bots												
Trekker-R	Super-Droid		OOPIC II	OOPIC compiler		✓	✓	✓	✓	✓	✓	$200	
RA-01 arm	Images SI Inc.		None (PC con-trolled)	SMC-05			×	×	×	×	×	$349	
Robotic Arm Trainer	OWI		None (PC con-trolled)				×	×	×	×	×	$85	

6. Conclusions and Future Work

Increasing robot utilization may be viewed in terms of low cost design and operation, which are based on the use of products from the market for robot components [6]. The importance of low cost robots can be recognized by the fact that they can be available everywhere at different levels of cost and complexity. In this survey, building real robots from low cost toy like starter kits has been addressed. Features of these kits and the main use of these assembled robots have been investigated. This article has given a clear comparison of the commercially available robots, their features, the contents of their kits and their complexity aiming to shed some light to researchers and hobbyist.

As future work we intend to thoroughly study the remaining categories of the commercial kits. We will carry a complete study of all micro-controllers and all electro-mechanical components used in building robots. Also the body building kits and the programming kits will be covered to completely provide a guide on building a real robot.

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