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FACULTY OF MECHANICAL ENGINEERING
INSTITUTE OF AUTOMATION AND COMPUTER SCIENCE

IMPLEMENTACE SYSTÉMU VIDĚNÍ PRO ROBOTA BIOLOID

VISION SYSTEM IMPLEMENTATION ON BIOLOID ROBOT

BAKALÁŘSKÁ PRÁCE
BACHELOR´S THESIS

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ZADÁNÍ BAKALÁŘSKÉ PRÁCE

student(ka): József Ropog

který/která studuje v **bakalářském studijním programu**

obor: **Aplikovaná informatika a řízení (3902R001)**

Ředitel ústavu Vám v souladu se zákonem č.111/1998 o vysokých školách a se Studijním a zkušebním řádem VUT v Brně určuje následující téma bakalářské práce:

Implementace systému vidění pro robota Bioloid

v anglickém jazyce:

Vision system implementation on Bioloid robot

Stručná charakteristika problematiky úkolu:
Implementujte systém vidění na robotu ze stavebnice Bioloid. Systém vidění bude založen na bezdrátovém přenosu informací mezi použitou kamerou a řidicím počítačem. Robot bude sloužit jako mobilní platforma předávající bezdrátově informace o svém okolí do řidicí jednotky. Bezdrátová kamera má rozšířit navigační schopnosti robotu. Hlavním cílem této práce je vytvoření testovacího robota se systémem vidění, který poslouží pro následné ověřovací experimenty.

Cíle bakalářské práce:

Prozkoumejte běžně dostupné robotické stavebnice.
Zjistěte možnosti dostupných stavebnic ve spojitosti s využitím systému vidění.
Vyberte nejvhodnější stavebnici a implementujte systém vidění.
Navržený systém prakticky realizujte a otestujte.

Seznam odborné literatury:

www.megarobot.net
www.robotika.cz

Vedoucí bakalářské práce: Ing. Stanislav Věchet, Ph.D.

Termín odevzdání bakalářské práce je stanoven časovým plánem akademického roku 2010/2011.

V Brně, dne

L.S.

Ing. Jan Roupec, Ph.D. Ředitel ústavu	prof. RNDr. Miroslav Doupovec, CSc. Děkan fakulty

LICENČNÍ SMLOUVA

ABSTRAKT

Tato bakalářská práce se zabývá implementací systému vidění na dvounohý humanoid robot ze stavebnice Bioloid. Systém vidění je složen z bezdrátové kamery, která je namontovaná na robotovi a z řídícího počítače.

Cílem této práce bylo zkonstruovat a oživit humanoidního robota, vytvořit systém vidění a bezdrátový komunikační systém. V centru je robot, který pomocí bezdrátové komunikace současně odesílá i přijímá údaje. Tento systém nabízí skvělé schopnosti na další rozšíření.

ABSTRACT

This bachelor's thesis deals with vision system implementation on bipedal humanoid robot made of the Bioloid assembly kit. The vision system is composed of a wireless camera, mounted on the robot and the controlling computer.

The goal of this work was to construct and vitalize the humanoid robot, to establish the vision system and to create a wireless communication system. The center of this system is the robot, which wirelessly sends and receives data simultaneously. This system offers great capabilities for further expansions.

Klíčová slova: humanoid robot, Bioloid stavebnice, systém vidění, dálkové ovládání, bezdrátová komunikace

Keywords: humanoid robot, Bioloid kit, vision system, remote control, wireless communication

PODĚKOVÁNÍ

Děkuji vedoucímu bakalářské práce Ing. Stanislavu Věchetovi, Ph. D. za účinnou metodickou, pedagogickou a odbornou pomoc a další cenné rady při zpracování mé bakalářské práce.

Contents:

1. INTRODUCTION

In our time, the new science of robotics is growing more and more important and for the ordinary people more accessible. Scientists talk about a future, where intelligent robots will control and help our life by accomplishing things, what a human being would only do with difficulties. They talk about a humanoid robot with artificial intelligence, what will win the olympics or a team of humanoid robots will win the world championships of football. These robots are the "Androids", which is the male form, and "Gynoids", which is the female form of these robots. Until recently, androids and gynoids have largely remained within the domain of science-fiction, frequently seen in film and television. These movies are usually about artificial intelligence, what changes the world in unimaginable measures, mainly destroying our world and making us slaves. Sure, these stories are just creatures of the wide imagination of the human brain, and we will talk about more actual problematics of robot science.

The vision system is built on wireless communication between the camera and the controlling computer. The Bioloid robot will function as a mobile platform reporting information of its surroundings to the computer. The wireless camera should extend navigational skills of the robot, what is the center of a wirelessly communicating system. The remote controller sends data and commands to the robot's controlling unit wirelessly, as well as the camera mounted on the Bioloid sends data back to the controlling computer, of course wirelessly. The goal of this work is to establish a test robot with vision system, which will in the future serve as a great start for further experiments.

In the future, this work will be upgraded to a state, where the robot will navigate by the applied wireless camera and will avoid obstacles autonomously. The application written for this work will not only view the picture of the camera and log the seen pictures, but it will do a serious picture processing with image recognition and obstacle judgment. The processed data will be sent to the robots controller unit, which by the received data will control the robot.

2. HARDWARE

Hardware is a definition of physical matters of a technology. We have used different types of hardware for this work. First of all, we had to build up the mobile platform, the **bipedal Bioloid robot**. The robot is built up of servo actuators, sensors and controlling units. These pieces programmed together by a software give the bipedal Bioloid robot.

The **vision system** is combined of the second hardware set of this work. It is a combination of a wireless router (the transmitter) and a wireless camera (the receiver).

Under the name "**remote control**" is the last set of our hardware. It is composed of a CM-5, a CM-510 and a set of Zig-100 and Zig-110. The Zig-100 and the Zig-110 uses the ZigBee wireless networking standard. Detailed information about these hardwares are below.

2.1 The bipedal Bioloid robot

The bipedal Bioloid robot is named by its shape. It has a head (the AX-S1 sensor), a body with two arms and two legs. So, bipedal means two legs, and as it is written in the Bioloid User's Guide, this bipedal robot is a "humanoid". In this chapter we will talk about the parts of the humanoid Bioloid robot.

2.1.1 What is the Bioloid?

Bioloid is an all-around robot kit that can be assembled in any way the user wants and it has four versions. The Bioloid is similar to a block toy, but, whereas the user of an ordinary block toy is only free to set the physical appearance of the toy, the user of a Bioloid can not only manipulate the physical appearance but also set a certain behavior patterns. The CM-5 is the CPU, which acts as the brain of the robot. This version of Bioloid needs AX-S1s so that the robot can "hear", "see" and make noises. The AX-S1 is the sensor of the robot. The AX-12+s act as the "musculature" of the robot. These servo motors realize the movements, which were programmed before in the RoboPlus software. The name 'Bioloid' is a compound word of bio + all + droid and means that all life may be embodied in the shape of a robot through this Bioloid. [1]

For this work we have used a mixture of the Bioloid Comprehensive Kit and the Premium Kit. We have also used some official accessories, for instance the wireless camera kit and the ZigBee set. We will talk about these accessories later.

Bioloid reads various information from sensors and joints and then moves by itself using these informations. For example, you can make a puppy robot that stands up when you clap once and sits down when you clap twice; a robot that greets when people approach; a robot that steers by itself through obstacles; and a robot that plays with a ball. In addition, you can control the robot wirelessly. Even users without expert knowledge about robots can easily program motions using an attached software. [1]

Here is a list of used hardware and software from the Bioloid Comprehensive Kit, the Bioloid Premium Kit and the accessories. [2]
The comprehensive kit allows to build 26 different robots. As an upgrade over the beginner kit, it contains a different frame set (which lets you build more robots) and 18 servos instead of 4.

- 1 Bioloid CM-5 mcu (Atmel ATMega128) controller
- 18 Dynamixel AX-12+ serially controlled servos
- 1 Dynamixel AX-S1 sensor module (3 IR sensors, microphone, piezo speaker, IR data transmitter)
- 1 Rechargeable NiMh battery pack (9.6V)
- RoboPlus software (freeware)
- 2 Switch Mode Power Supplies
- Serial Cable (9pin D-type)
- 1 Bioloid Comprehensive Frame Set
- Quick Start Manual, User's Guide
- CD with Software (allows visual programming of the robot)

+ 1 Bioloid CM-510 mcu (ATmega 256) controller from the Bioloid Premium Kit
+ Wireless Camera Kit - official ROBOTIS Bioloid accessory
+ ZigBee communication module - a set of a Zig-100 and a Zig-110 - official ROBOTIS Bioloid accessory.

Pic. 2: The full Comprehensive Kit [3]

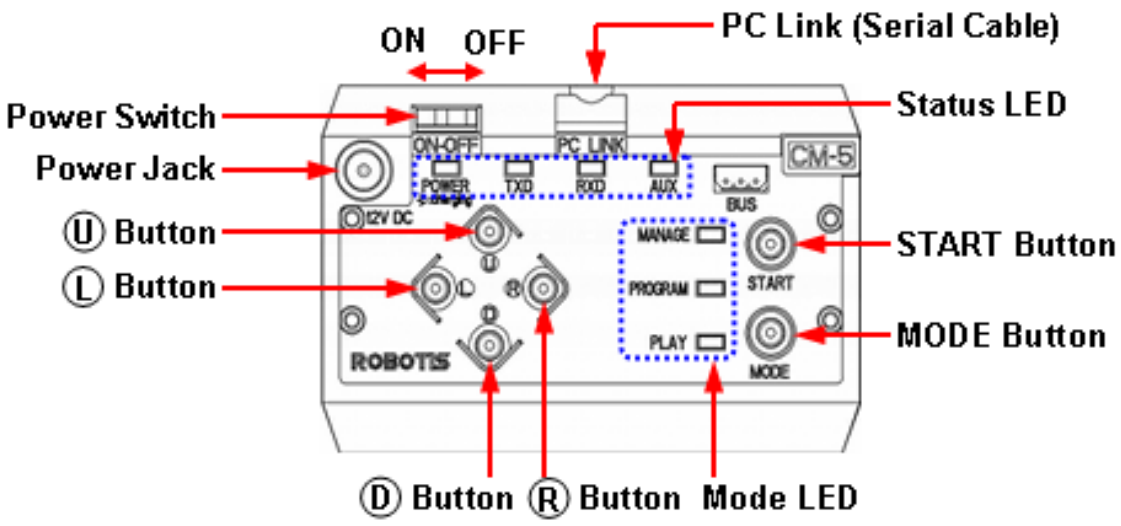
2.1.2 CM-5

CM-5 is the CPU of Bioloid which acts as the brain of the robot and uses an Atmel ATMega128 processor. It can control 28 AX-12+s and 10 AX-S1s simultaneously. Buttons are mounted inside to be used as an input device and can function as a remote control. Rechargeable batteries are also mounted. [1]

In this work, the CM-5 not acts as the controller unit, so the brain of the robot. In our case the CM-5 is just a remote controller programmed in included software to send data to the another controller unit and act as the transmitter. The data transfer is implemented by a paired Zig-100 and Zig-110 hardware and the ZigBee module. The CM-5 is connected with the controlling computer by serial RS-232 connection.

Pic. 3: The CM-5 controller [4]

Pic. 4: The CM-5 on the humanoid robot



Pic. 5: Parts of the CM-5 [4]

- Detailed information about the parts, shown on Pic. 5: [4]

- **Power Switch :** The switch to connect the power.
- **Power Jack** : The socket to connect the power jack of SMPS.
- **Start Button :** The button to select the mode.
- **Mode Button** : The button to change the operation mode of CM-5.
- **PC Link(Serial Cable) :** The port to connect the serial port of CM-510 and PC using serial cable; It is used for task code download or communication with PC.
- **U / L / D / R Button** : The assigned buttons used for entering purpose during the program operation; commands to robots are transmitted by these buttons.
- **Mode Display LED** : LED to display current operation mode of CM-5; Detailed descriptions are provided as below.

[MANAGE]
- It displays Dynamixel Management Mode is in progress.
- It is used to set or test the operations of CM-5, AX-12, and AX-S1 using RoboPlus Manager.
- It is automatically executed when RoboPlus Manager and CM-5 are connected.

[PROGRAM]
- It displays the motion edit mode is in progress.
- It is used when the motions are editted with RoboPlus Motion.
- It is automatically executed when RoboPlus Motion and CM-5 are connected.

[PLAY]
- It displays the task code mode is in progress.
- It is used after downloading the written code to CM-5 with RoboPlus Task.
- The Start button must be pressed directly by the user to execute when PLAY LED flickers.
- **Status Display LED** : The LED represents the current status of CM-5. Detailed descriptions are provided as below.
- **POWER** : Turned on if the power is ON; flickers if it is being charged.
- **TXD** : Turned on while CM-5 is transmitting the data to the outside.
- **RXD** : Turned on while CM-5 is receiving the data from the outside.
- **AUX** : Assigned LED to be used by the user in the program. It can be turned on or off using task code.

2.1.3 CM-510

This is our second controller, just like the CM-5, but the newest version of it. It is smaller in shape, because the CM-5 has space for the included battery, but the buttons are very similar. It has more functions than its predecessor, more connectors, improved memory size and improved abilities. The basic Bioloid Comprehensive Kit contains the CM-5, which acts as the brain of the robot. But in our case we need improved connectibility, so we used the CM-510 to act as the controller unit of the bipedal Bioloid robot. Because of this we had to change the shape of the humanoid robot a little bit, what made it a bit instable. We had to modify the controller unit area, because the older version humanoid robots shape is not compatible with the newer controller unit, the CM-510.

The CM-510 is coming with the Bioloid Premium Kit, like it has been said before and instead of using an ATmega-128 processor, it uses an ATmega-2561 processor, which enables to use twice as much memory as the CM-5 and enables the declaration of 50 variables. The CM-510 is connected to the controlling computer by RS-232 serial cable and the servos are connected to the controller unit by TTL serial connection.

Pic. 6: The modified controller unit area

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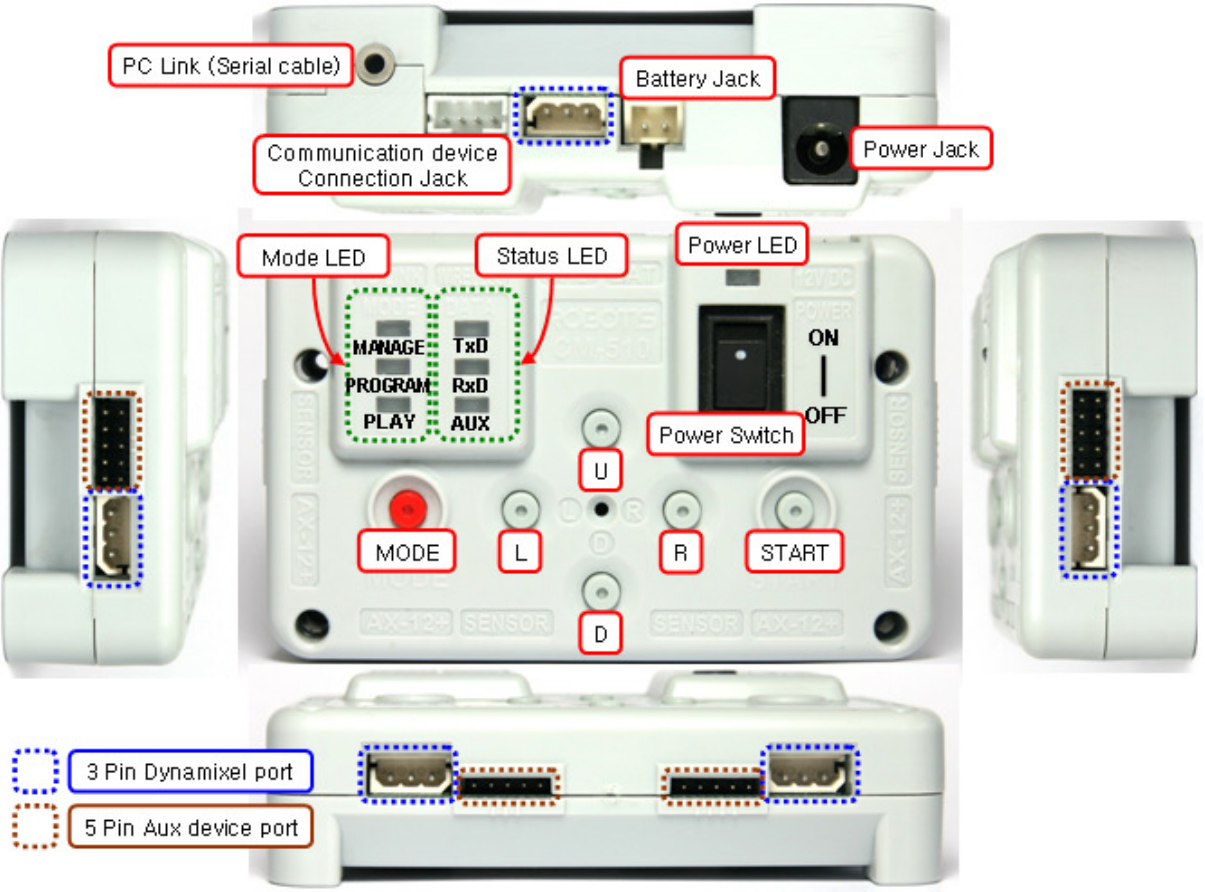
Pic. 7: The CM-510 controller [4]



Pic. 8: Parts of the CM-510 [4]

- Detailed information about the parts, shown on Pic. 8: [4]

- **PC Link (Serial Cable)** : Used to connect the serial cable to the CM-510 and PC via serial port. Used for communication with other PC or downloading task code.
- **Communication Device Connection Jack** : Used for wireless communicate with ZIG-110, IR receiver modules or other boards
- **Battery Jack** : Used to connect with the battery.
- **Power Jack** : Used to connect the SMPS power supply
- **Power LED** : ON and OFF LED status for the power
- **Power Switch** : Used to turn the robot ON / OFF.
- **MODE Button** : Used to change the operation mode of CM-510. Please read below for more information.
- **START Button** : Used to START selected mode. Please read below for more information.
- **U / L / D / R Button** : Used for input purposes when a program is playing. These buttons can be used to send commands to the robot.
- **AX-12+ BUS Port** : Used to connect the AX12+ Dynamixel in a daisy chain method.
- **Peripheral Devices Connection Port** : Used to connect Distance Measurement Sensor, Touch Sensor, IR Sensor, and peripheral devices. The port numbers for each port are represented in bars such as I , II , III, IIII , IIIII , and IIIIII.
- **Mode Display LED** : LED to display current operation mode of CM-510; Detailed descriptions are provided as below.

[MANAGE]

- It displays Dynamixel management mode is in progress.
- It is used to set or test the operations of CM-510 and AX-12 using RoboPlus Manager.
- It is automatically executed when RoboPlus Manager and CM-510 are connected.

[PROGRAM]

- It displays the motion edit mode is in progress.
- It is used when the motions are editted with RoboPlus Motion.
- It is automatically executed when RoboPlus Motion and CM-510 are connected.

[PLAY]

- It displays the task code mode is in progress.
- It is used after downloading the written code to CM-510 with RoboPlus Task. The Start button must be pressed directly by the user to execute When PLAY LED flickers.
- **Status Display LED** : The LED represents the current status of CM-510. Detailed discriptions are provided as below.
- **TxD :** Turned on while CM-510 is transmitting the data to the outside.
- **RxD :** Turned on while CM-510 is receiving the data from the outside.
- **AUX :** Assigned LED to be used by the user in the program. It can be turned on or off using task code.

2.1.4 AX-12+

The AX-12+ is a robot exclusive servo actuator which acts as the joints of the robot. AX-12+ controls speed, monitors location and senses both temperature and load using an openly published instruction/status packet protocol. It can also be used as a wheel when set to endless turn mode. The servo shuts down in the event of overheating, out of range voltage, or several other user configurable alerts. [1]

The bipedal humanoid robot is built up of 18 AX-12+ servo actuators. The servos realize the movements programmed in attached software. These software can be the older editions coming with the Comprehensive Kit - the Behavior Control Programmer, the Motion Editor or the Robot Terminal. We have used though the newer edition of software set in this work, the RoboPlus, which contains all the necessary software: the RoboPlus Task, the RoboPlus Manager, the RoboPlus Motion, the RoboPlus Terminal and the Dynamixel Wizard.

Pic. 9: The AX-12+ servo actuator [5]

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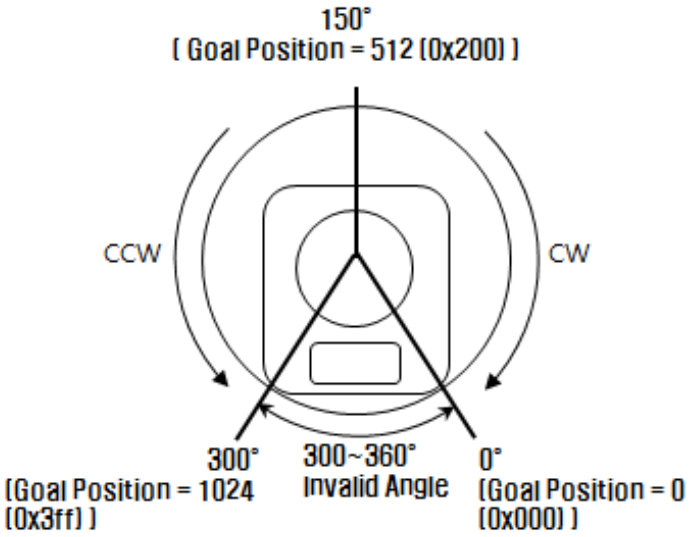
These servo motors are connected to the controller unit with TTL serial cables. These cables can communicate with the controller unit with the speed of 1Mb/s. Every motor has its own identification number (ID). By the received ID the servo motor knows whether the instruction sent by the controller is for itself, or not.

Every servo motor has 1024 possible positions. Like the picture shows below (pic. 10), the possible positions are split into 300°, the remaining 60° is invalid range. The only case when these angles are not forbidden is when the motor is set to endless turn mode - wheel function. [6]

AX-12+ servo actuator parameters: [7]
Reduction ration: 1/254
Operating voltage: 10.0 V
Holding torque: 16,5kg . cm
No-load speed: 0,196 sec/60°



Pic. 10: Goal position [4]

2.1.5 AX-S1

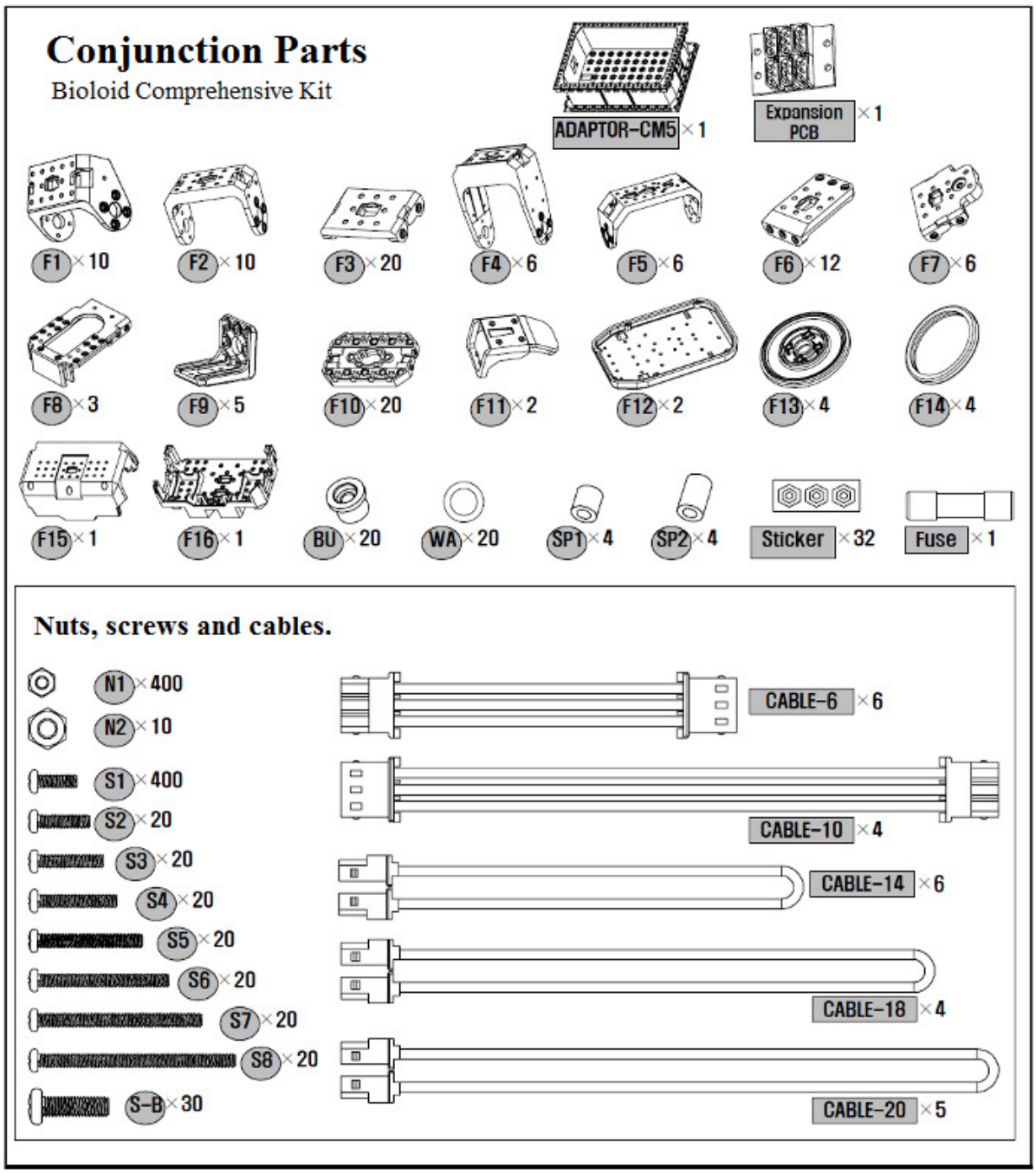
Dynamixel Sensor Module ‘AX-S1’ is a Smart Sensor Module that integrates the functions of sound sensor, infrared remote control receiver, infrared distance sensor, light sensor, buzzer, as well as the driver, control unit and network, in other words it acts as the "eye", "ear" and mouth of the robot. Compact in size, AX-S1 has various functions and it is made up of special materials that can withstand even the extreme external force. In addition, it can readily recognize subtle changes such as internal temperature, service voltage and other internal conditions and has built-in capability to resolve the situations at hand. [8]

This sensor is the main sensing module of the Comprehensive Kit, what makes this module very important. This little sensor makes the robot intelligent. The newer version of Bioloid kits, the Premium Kit solves the sensor problem with more, separate sensors, which are connected to the CM-510 controller unit. In our special case, the AX-S1 is a little less important, because here we do not really need sensors. The orientation of the robot will be done in the future with the help of the vision system - the wireless camera kit. Sure, if we want the robot to use the AX-S1 module, we can easily connect the sensor to the CM-510 and program it to work just as fine as it works with the CM-5.

Pic. 11: The AX-S1 sensor [9]

2.1.6 Conjunction Parts

There are frames, cables, and wheels serving as conjunction parts. CM-5, AX-12+ and AX-S1 can be connected and combined together using these conjunction parts. They can be combined together using attached bolts and nuts. These conjunction parts are responsible of the physical appearance of the robot. The Quick Start Guide shows the user how to assembly easily robots by the examples. Or the user can make his own construction, everything is on the user's imagination. [1]

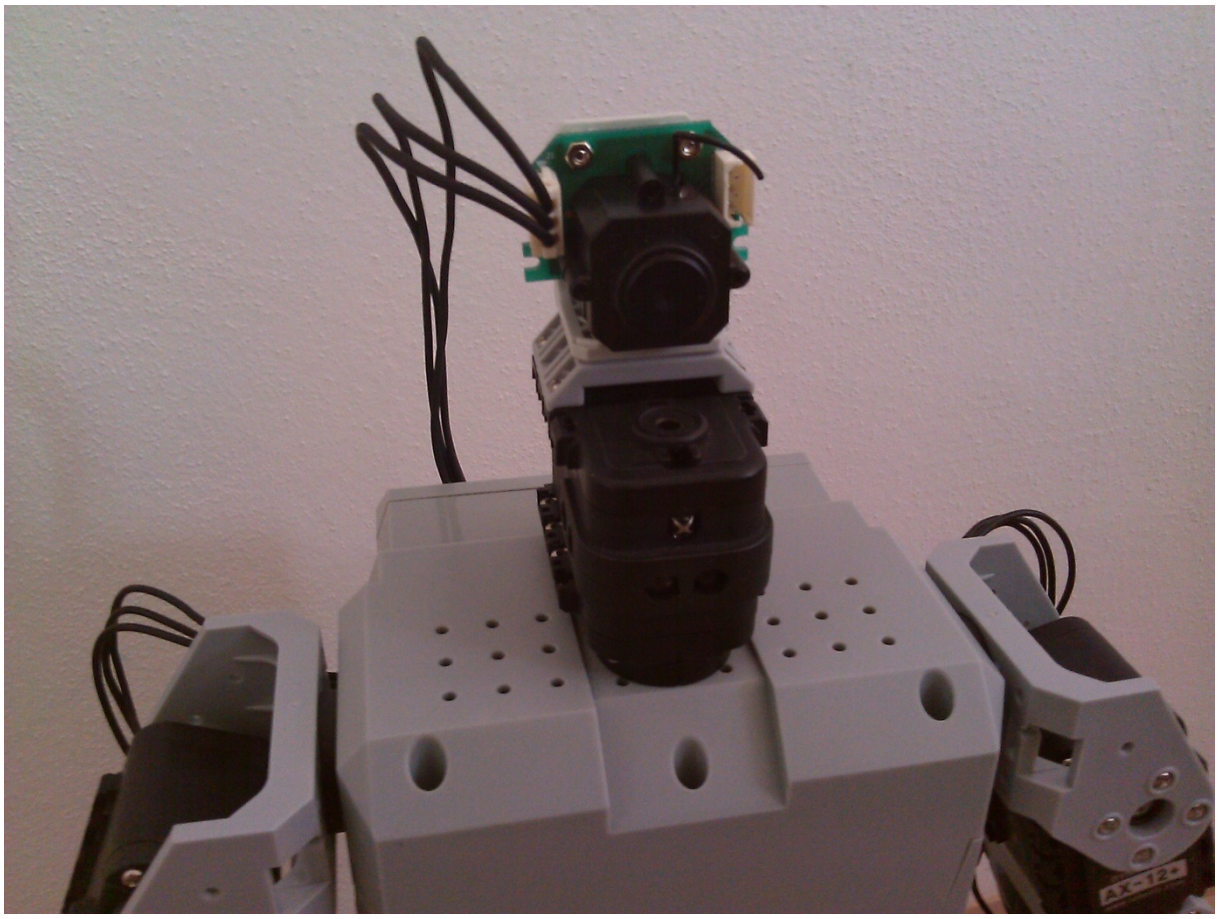


Pic. 12: The conjunction parts of the Bioloid Comprehensive Kit [4]

2.2 The vision system

This wireless camera set is not part of the Bioloid Comprehensive Kit. This set is an official ROBOTIS Bioloid accessory, although you can find the set in the Bioloid Expert Kit too. The wireless camera set is composed of a wireless image transmitter (wireless camera) and a receiver (wireless router). By receiving an image from the transmitter that is embedded in Bioloid robot, the receiver connected to the PC via USB port can process the image. [10]

In the "Wireless Camera Kit (EU)" box you can find the receiver (a wireless router), the transmitter (the wireless camera), an adapter, which is used to connect the receiver to the power supply, and a USB cable to connect the receiver to the computer.
However, if you want to fully use the camera kit, you will have to apply power supply for the camera. The camera needs to be connected to a Bioloid controller (CM-5 or a CM-510) with a special TTL serial cable, what can be easily found among the conjunction parts.



Pic. 13: The wireless camera mounted on the robot.

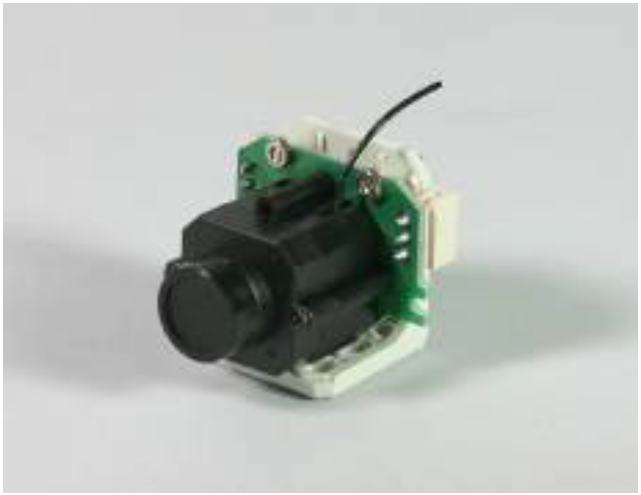
2.2.2. The receiver - wireless router

The wireless router is the pair of the wireless camera and acts as the receiver. It has several inputs and outputs. In its box is an attachable antenna, which can be attached on the front of the receiver, where the user can choose from four channels too, which one is wanted to be used. On the back of the receiver is the 12V DC power input, the USB port, one Audio and one Video RCA Cinch cable output slot. The last two slots are used if the user wants to connect the receiver to the TV. Additionally the user can restrict the use of certain channels with little switches. For instance, if the user wants to use only channel 1, physically turns on channel 1 (presses down the first little switch) whereby restricts the use of the other three channels.

Pic. 15: The receiver [10]

2.2.1 The transmitter - wireless camera

Usually the wireless camera is connected to a CM-5 since they come together in the Bioloid Expert Kit. In our modified case though the wireless camera is connected to the newer version of Bioloid controllers, the CM-510. Both controllers are compatible with the camera and easily connectible. The wireless camera is recognized by the Windows like USB 2860 Device. The camera is an eMPIA Technology product, the company is focusing on manufacturing video and audio interfaces.



Pic. 14: The wireless camera [10]

2.3 Remote control

A remote control is a component of an electronic device used for operating the device wirelessly from a short line-of-sight distance. [11]

We have used the Zig-100/Zig-110 modules, to solve the question of the remote control. These modules are using the ZigBee standard, which is a wireless networking standard.

2.3.1 ZigBee standard

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios. ZigBee is a low-cost, low-power, wireless mesh networking standard. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other WPANs, such as Bluetooth. ZigBee is targeted at radio-frequency applications that require a low data rate, long battery life, and secure networking. [12]

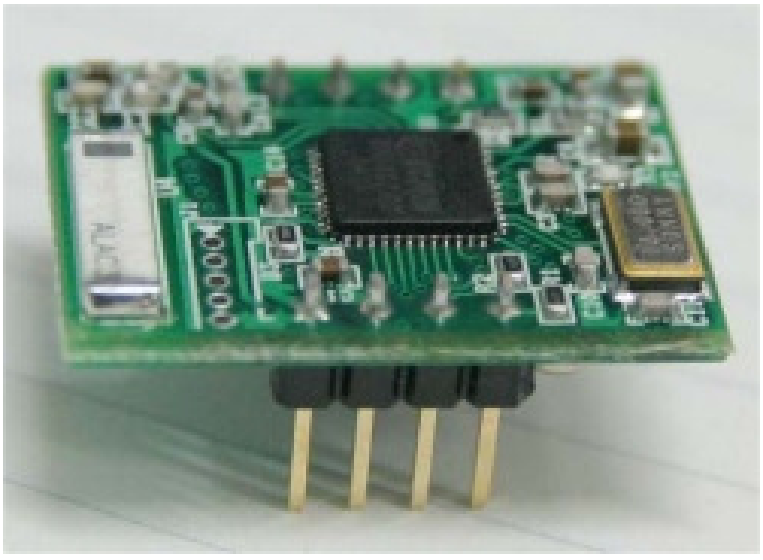
2.3.1.1 The Zig-100 and the Zig-110

The Zig-100 and Zig-110 use ZigBee connection and provide equal functions; the only difference is the interface with the parts to be installed. One set is composed of two units of Zig-100/110 for sale, and it can be used immediately without setting separate ID since the ID of other module has been already set from the beginning of purchase.[4]

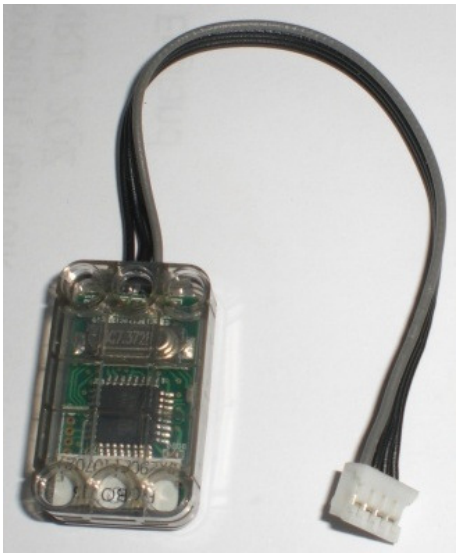
The connectable parts are as follows: [4]

- ZIG-100 : CM-5, ZIG2Serial, RC-100
- ZIG-110 : CM-100, CM-510, CM-700

We have used the Zig-100 + CM-5 and the Zig-110 + CM-510 combinations in this work. The Zig-100 + CM-5 combination is the transmitter and the Zig-110 + CM-510 is the receiver. We will talk about these combinations below.



Pic. 15: The Zig-100 module [4]

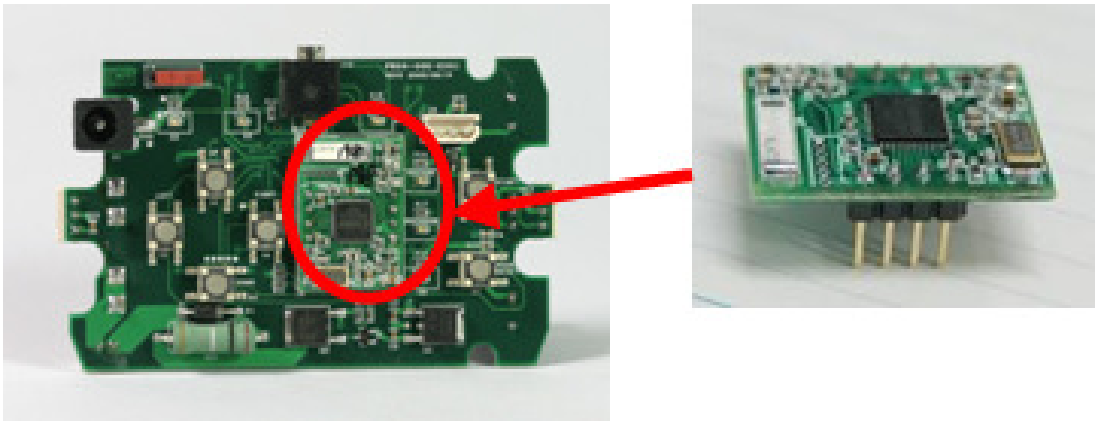


Pic. 16: The Zig-110 module [4]

2.3.2 The transmitter (Zig-100 + CM-5)

In electronics a transmitter or radio transmitter is an electronic device which produces radio waves. Tansmitters are necessary component parts of many electronic devices that communicate by radio, such as cell phones, WiFi and Bluetooth enabled devices, garage door openers, two-way radios in aircraft, etc. A transmitter can be a separate piece of electronic equipment, or an electrical circuit within another electronic device. [13]

Our transmitter is composed of a Zig-100 ZigBee aided module and a CM-5 controller unit. The Zig-100 is embedded inside the CM-5 controller, shown on Pic. 17. The CM-5 does not come with this interface installed. The Zig-100 and Zig-110 modules are not part of the Bioloid Comprehensive Kit, they have to be bought separately. The CM-5 is programmed in RoboPlus to transmit data via the embedded Zig-100 to the paired Zig-110, which is connected to the CM-510 and forwards the received data to the CM-510.



Pic. 17: Zig-100 Wireless Communication Module can be connected to CM-5[4]

2.3.3 The receiver (Zig-110 + CM-510)

A receiver is an electronic circuit that receives its input from an antenna, uses electronic filters to separate a wanted radio signal from all other signals picked up by this antenna, amplifies it to a level suitable for further processing, and finally converts through demodulation and decoding the signal into a form usable for the consumer, such as sound, pictures, digital data, measurement values, navigational positions, etc. [14]

The receiver is composed of a Zig-110 wireless communication module and a CM-510 controller unit. Thanks to the configuration of the CM-510 the Zig-110 module is easily connectable to the CM-510s "wireless" port. The Zig-100 and Zig-110 modules can be paired together easily through the RoboPlus Manager software. The CM-510 is programmed in the RoboPlus software to receive transmitted data by the CM-5 and the Zig-100 and force the robot to act by the received instructions.

Pic. 18: Zig-110 Wireless Communication Module connected to the CM-510 [4]

3. SOFTWARE

Software, is a collection of computer programs and related data that provide the instructions for telling a computer what to do and how to do it. In other words, software is a conceptual entity which is a set of computer programs, procedures, and associated documentation concerned with the operation of a data processing system. [15]

A software offered by Bioloid Comprehensive Kit contains the following three programs. With proper use of these programs, the user can easily operate the robot even if the user is a beginner. By combining the Behavior Control Programmer and the Motion Editor will our robot function properly. An advanced user can program functions which are not offered in the menu by properly using the scalability of these programs.

In the introduction of this chapter we will talk about the software offered by the Bioloid Comprehensive Kit for a little while. We will just introduce these software, because in this work we mostly used newer versions of these software, the RoboPlus software set. We will talk about the RoboPlus software in detail later.

Behavior Control Programmer

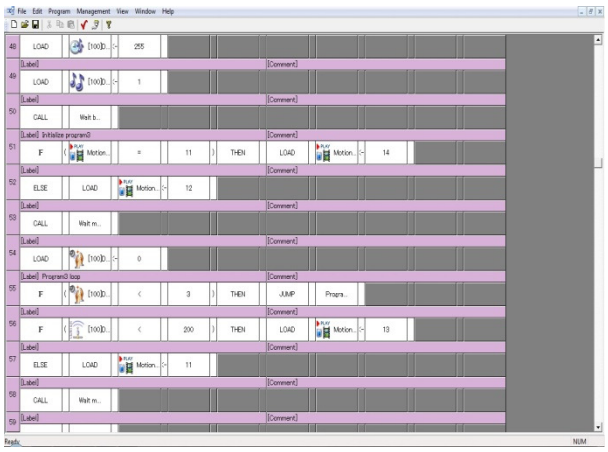
Behavior control programmer is a software that sets rules for the robot on situation recognition, situation judgment and behavior. For instance, with this main software can the user tell the AX-12+ servo actuators how many degrees they have to turn or set the sensing distance of an AX-S1 sensor. [1]

Motion Editor

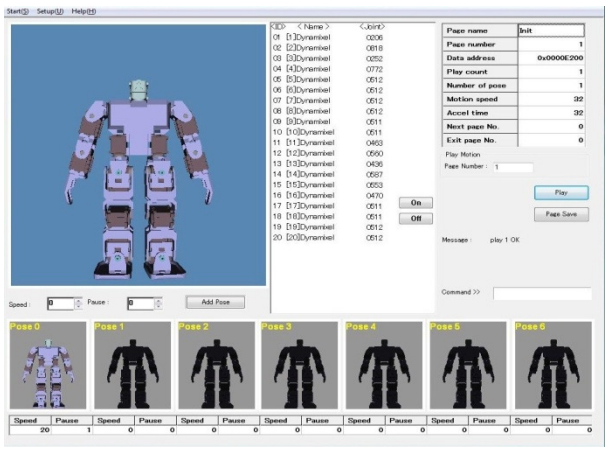
Motion editor is a software that helps the user program complicated robot motions. Motions created in this program can be called and used by the behavior control program. Our robot works if these software are tuned together. [1]

Robot Terminal

Robot terminal is a software that is used for robot management, mostly used by advanced users. It is kind of a serial communication terminal that can be used when the user wants to send data to and from the robot. [1]



Pic. 19: The Behavior Control Programmer



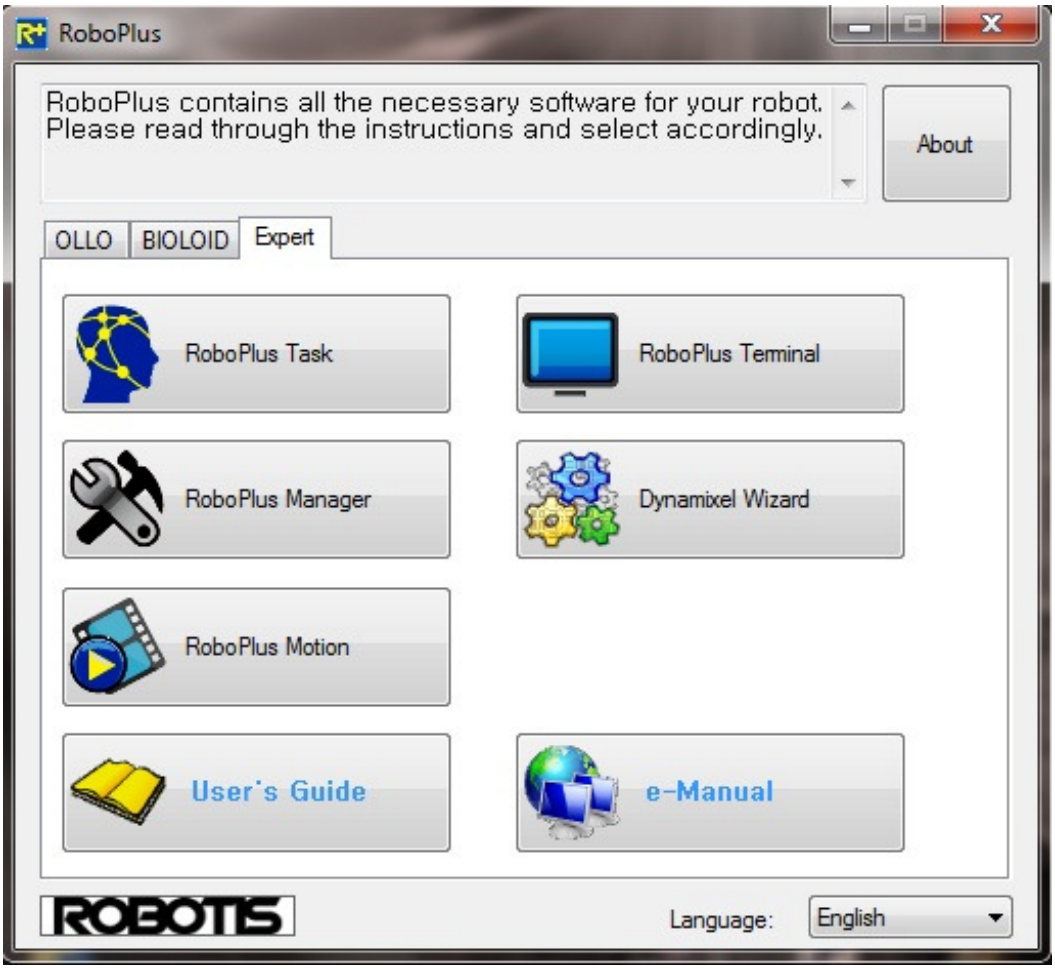
Pic. 20: The Motion Editor

3.1 Robot Motions

To vitalize a robot, the user needs to tell the robot, what to do, and how to do it. In detail, the user has to tell the robot exclusive servo actuators how to behave in certain situations. For these tasks the RoboPlus software is a vital option. The robot motions were programmed in the RoboPlus Motion software, but if the user wants to realize these motions, has to write a program in RoboPlus Task and then the robot will react to user-made instructions. In this chapter we will talk about programmed robot motions in detail too.

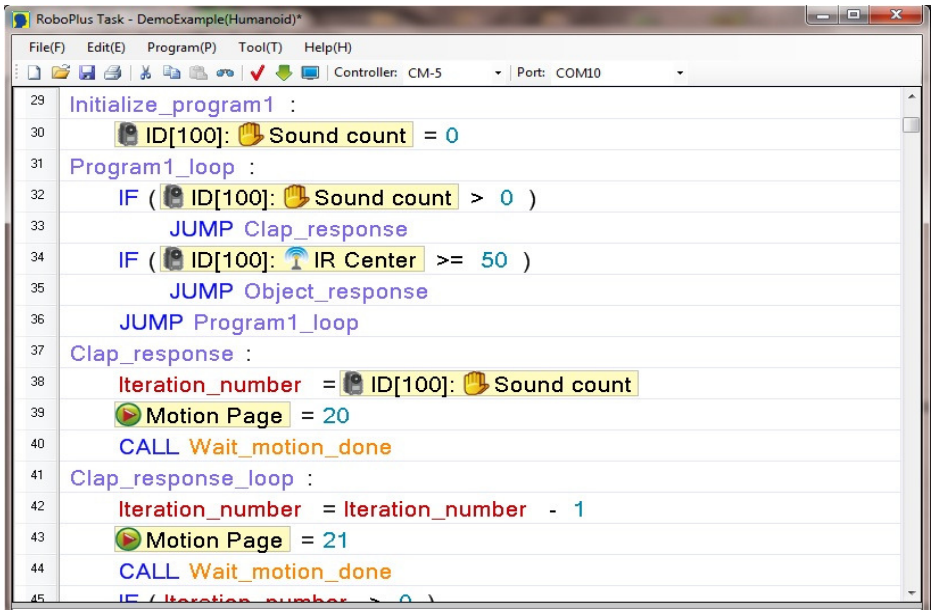
3.1.1 The RoboPlus software

RoboPlus is a software to create a customized program for every ROBOTIS product. This software offers solutions not only for Bioloid, but for an another ROBOTIS product, OLLO. The RoboPlus contains all the necessary software for the robot. The user can choose of five software which one wants to use.



Pic. 21: The RoboPlus software

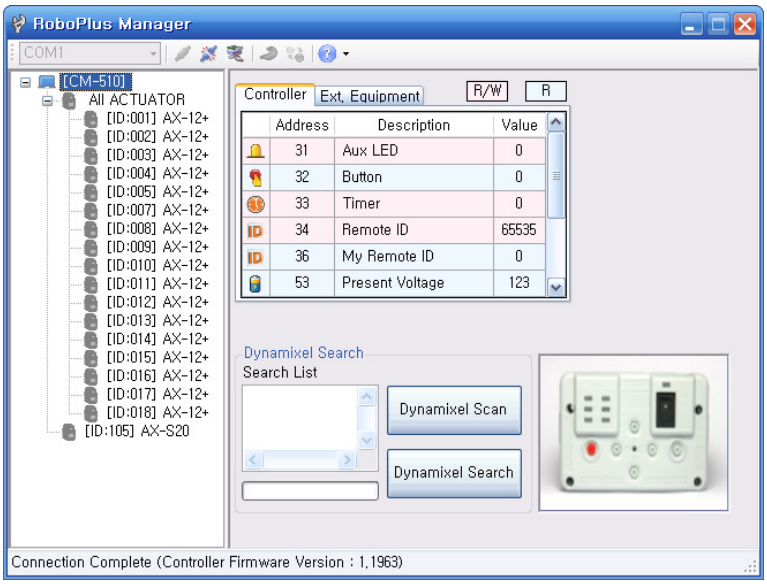
The **RoboPlus Task** software sets rules for the robot on situation recognition, situation judgment and behavior. A task is a set of motions to perform certain actions. RoboPlus refers to the source code that specifies tasks to be executed by the robot as "task code". The robot moves according to the user's task codes. RoboPlus Task is a software to make writing these task codes easier. [4]



Pic. 22: The RoboPlus Task software

The **RoboPlus Manager** software is used to handle devices used by a robot. Allows the user to manage and test robots components, such as controllers, actuators, sensors, etc. Major functions of this program are as follows: [4]

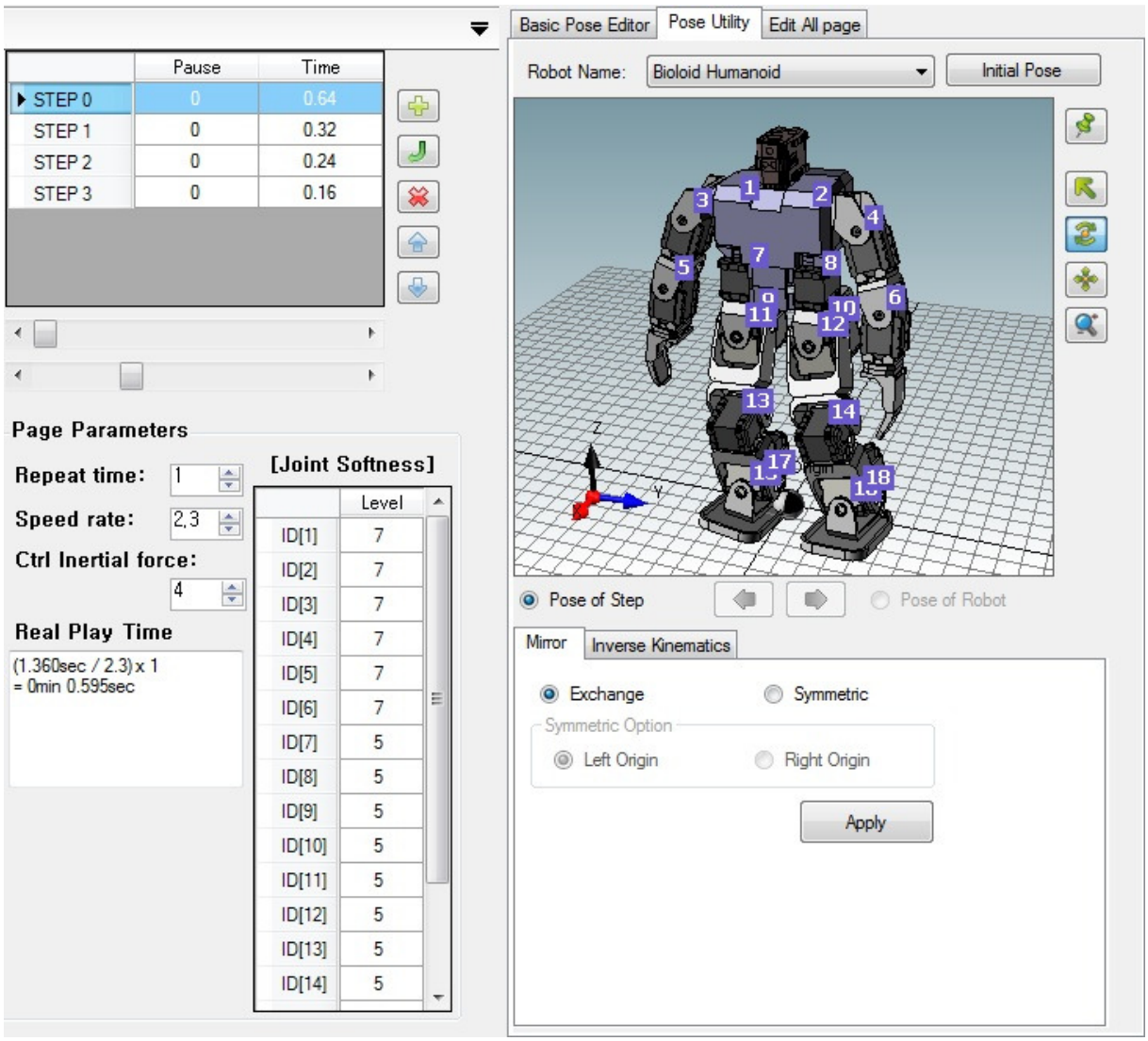
- Manage controller firmware. (Update and Restore)
- Inspect the status of the controller and peripheral devices. (Test)
- Set the required modes. (Settings)



Pic. 23: The RoboPlus Manager software [4]

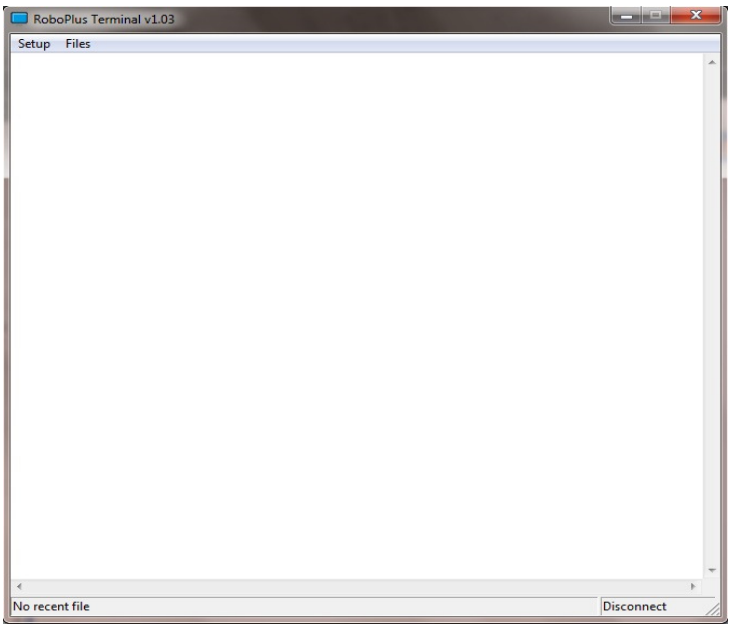
The **RoboPlus Motion** is a software, where the user can program robot motions. A motion is a set of actuator position and speed data necessary for robot movements. In order for the robot to move, a motion file is required. A suitable motion file must be downloaded for the assembled robot.

A task code file is a program while a motion file is data. For better understanding, let us think about MP3 players and MP3 files. If there were no MP3 players, you will not be able to listen to music because MP3 file could not be played. The result is the same when there is an MP3 player but no MP3 file. If you want to make your robot move, you need a task code file. If the task code downloaded into your robot uses motions, you must download the motion file as well. If no motions are used in the task code, you do not need the motion file.[4]



Pic. 24: The RoboPlus Motion software

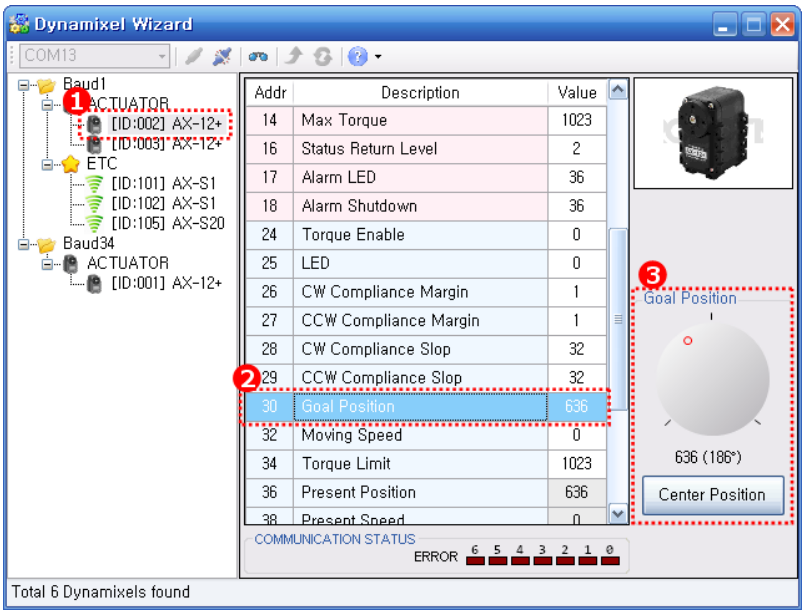
The **RoboPlus Terminal** is a tool to help users to manipulate the controller by themselves through text-baed User-Interface. The terminal program communicates with the controller in the basis of ASCII code, and it prints various information transmitted by the controller for users. [4]



Pic. 25: The RoboPlus Terminal software

The **Dynamixel Wizard** software helps the users manage Dynamixel more easily. The main roles of the program are as follows: [4]

- Manage Dynamixel's firmware.
- Check Dynamixel's status.
- Set up the necessary modes.

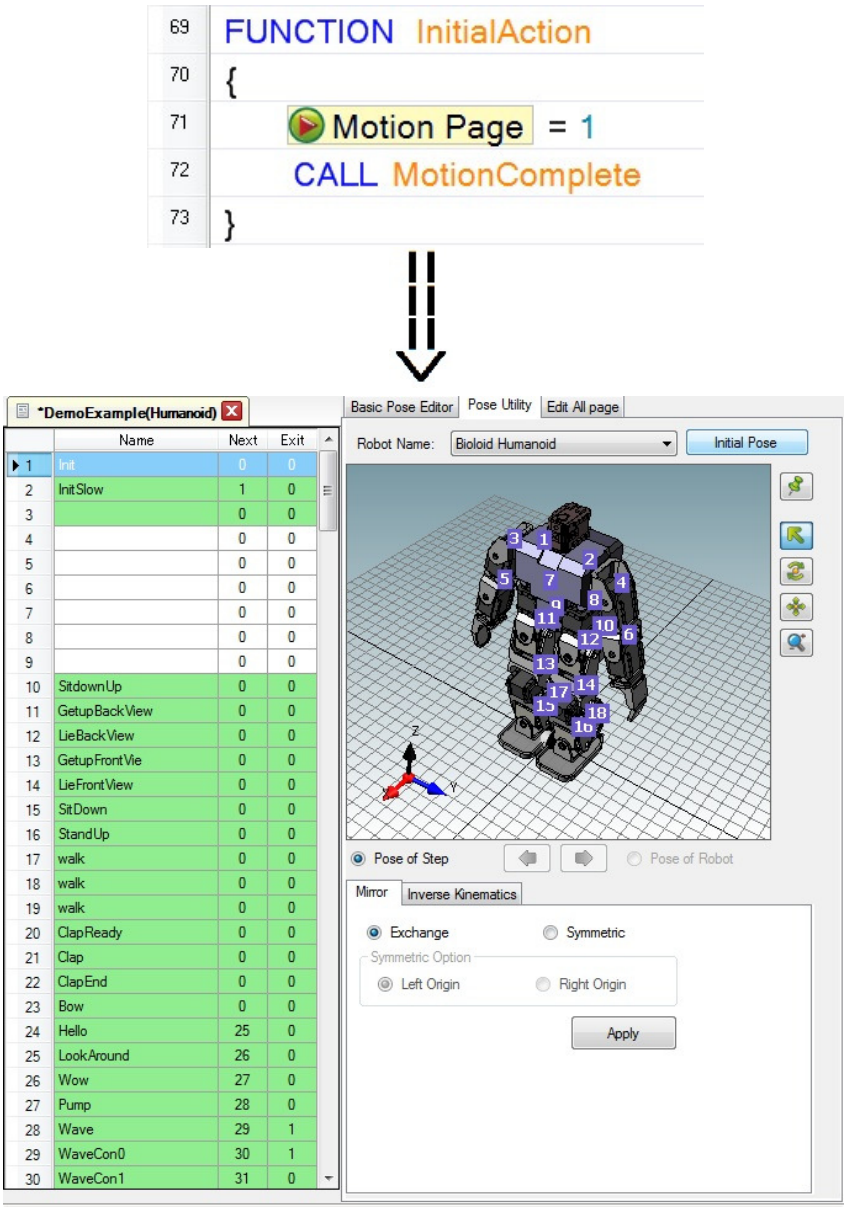


Pic. 26: The RoboPlus Dynamixel Wizard software [4]

3.1.2 Initial action command

Six functions were programmed and downloaded to the used humanoid robot. These six functions call forth five motions by pushing five buttons separately on the transmitter. The first motion is called after the "Start" button is pressed and that is the "Initial action". Like the function's name says the robot takes its initial position, which is an ideal position from which the robot can start its next movements. The robot gets to the initial pose state from any other pose.

The motions were programmed in the RoboPlus Motion software. The used motions were made by ROBOTIS and these motion files come with the attached software. Naturally the user can program own motions, although these pre-programmed motions are perfectly functional.



Pic. 27 + Pic. 28: The function programmed in RoboPlus Task calls the "Motion Page 1" programmed in RoboPlus Motion.

3.1.3 Go forward command

After the "Start" button is pressed on the transmitter and the initial pose has been taken, the user can control the robot with the four direction buttons on the CM-5. The "U" button calls forth the "Forward" function, which is paired with "Motion page 60" in the downloaded motion file. After pressing the "U" button the robot performs the instructions and starts to walk forward. This is an endless motion, which can be stopped by pressing again the "Start" button - this is the "Stop" function of which we will talk about in chapter "3.1.7 - Stop command".

3.1.4 Go backward command

If the "D" button is pressed on the CM-5, which is in our case the transmitter, the "Backward" function is called, which calls forth "Motion page 69" and the robot starts to walk backwards. This is an endless motion again, so it has to be stopped by the "Stop" function.

3.1.5 Turn left command

"Motion page 96" is called after pressing the "L" button on the transmitter. This motion page refers to a "Turn left" motion. After the CM-510 received the sent commands forces the robot to act by the received instructions, so turn left. Just like the forward and backward functions, this motion is endless so it has to be stopped by pressing the "Start" button on the CM-5.

3.1.6 Turn right command

The last motion is the "Turn right" motion. After pressing the "R" button on the transmitter, "Motion Page 87" is being executed and the robot starts to turn right. Again, this is an endless motion, so when the robot reaches the desired direction it has to be stopped to start an another motion.

3.1.7 Stop command

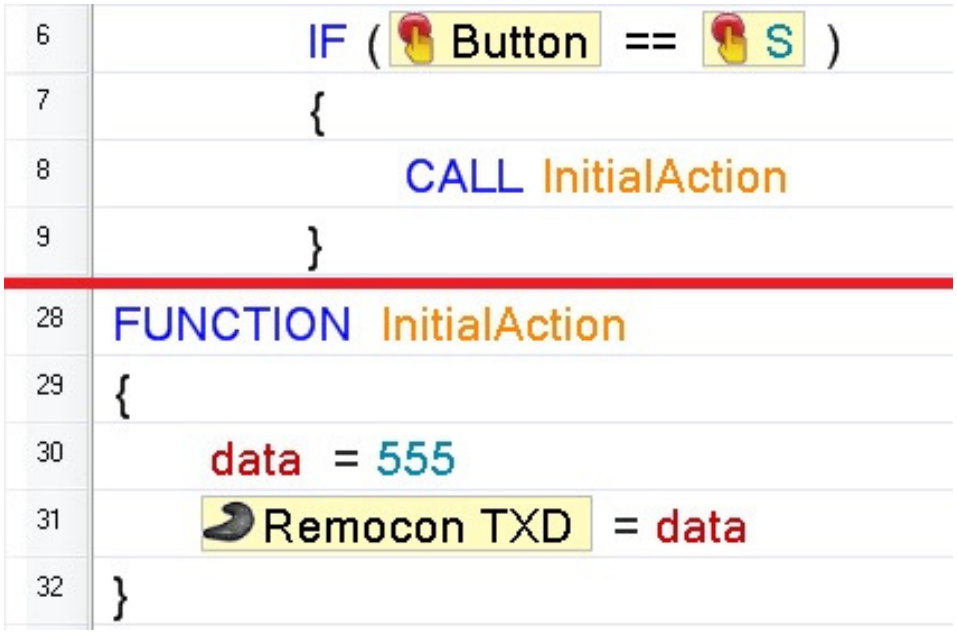
This command is very simple. It calls "Motion page 0", which is an "Exit page". It is designed to stop a motion in any time the user calls the "Motion page 0" almost immediately. After the initial pose has been taken the robot can start an another motion.

3.2 Remote control

The wireless communication between the transmitter and the receiver is established by the ZigBee standard. Both the CM-5 and the CM-510 were programmed in RoboPlus Task software to communicate with each other. The CM-5 sends instructions with the "Remocon TXD" command, which is used to transmit data via a wireless communication module. The CM-510 receives the sent instructions with the "Remocon RXD" command, which is used to read the data received via the wireless communication module.

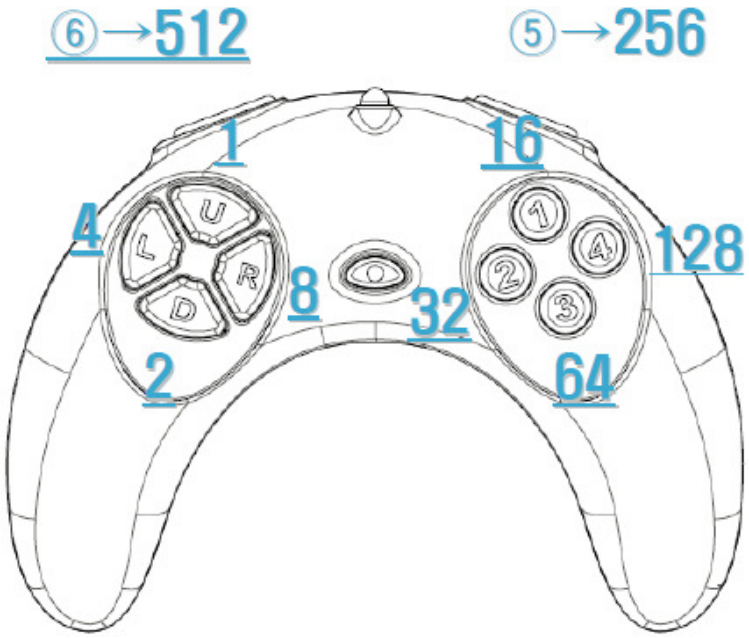
3.2.1 The transmitter program

The CM-5 is the remote controller in this system. When the "Start" button is pressed on the CM-5, data is sent to the CM-510. This action is implemented by the "Remocon TXD" command, a RoboPlus Task software command. Like the picture below shows (Pic. 29), the CM-5 sends a variable, named "data" with the value of "555" if the "Start" button is pressed. The "555" is an arbitrary number, what can be anything from 1 to 65535, except 1, 2, 4, 8, 16, 32, 64, 128, 256 and 512. These are in our case taken numbers, because the CM-5 uses these numbers for button identification. The CM-510 receives the sent number, and acts by the received data, which will be explained in the chapter "3.2.2 - The receiver program".



Pic. 29: If the "Start" button is pressed, "Initial action" is called, what sends data value "555" to the receiver.

If the "U" button is pressed on the transmitter it sends the data value "1" to the receiver. After the CM-510 receives the data, it performs the "Forward" function. This happens, because the number "1" is the code of the "U" button. The CM-5 transmitter acts just like the RC-100 transmitter, so the button codes are the same, like the picture shows below (Pic. 30).



Pic. 30: Code map of the RC-100 / CM-5 [4]

.

```
FUNCTION Forward
{
    data = 1
    Remocon TXD = data
}
FUNCTION Backward
{
    data = 2
    Remocon TXD = data
}
FUNCTION Turn_Left
{
    data = 4
    Remocon TXD = data
}
FUNCTION Turn_Right
{
    data = 8
    Remocon TXD = data
}
```

```
data_received = data
IF ( data_received == U )
{
    CALL Forward
}
IF ( data_received == D )
{
    CALL Backward
}
IF ( data_received == L )
{
    CALL Turn_Left
}
IF ( data_received == R )
{
    CALL Turn_Right
}
```

```
FUNCTION Forward
{
    Motion Page = 60
}
FUNCTION Backward
{
    Motion Page = 69
}
FUNCTION Turn_Left
{
    Motion Page = 96
}
FUNCTION Turn_Right
{
    Motion Page = 87
}
```

Pic. 31: On the left of the vertical red line you can see the transmitter commands, on the right you can see the reactions of the receiver for the received instructions.

3.2.2 The receiver program

The other three buttons, the "D", "L" and "R" work on the same principle, like the "Start" button (Pic. 31). If the CM-510 receives the buttons' codes it will call forth the functions that are associated with the received codes.

Although the stop function is a little bit more complex. If the "Start" button is pressed during a running motion, the program gets the value "555", which means that is the value we want, so the program stops the motion with the "Motion page = 0" command and then leaves the loop.

```
IF ( data == U || data == D || data == L || data == R )
{
    data_received = data
    ENDLESS LOOP
    {
        IF ( Remocon Arrived == TRUE )
        {
            data = Remocon RXD
            IF ( data == 555 )
            {
                Motion Page = 0
                BREAK LOOP
            }
```

Pic. 32: RoboPlus Task program piece of the "Stop" function.

3.3 The control program

The control program is used to help the user follow and monitor robot movements. The wireless camera is mounted on the "head" of the robot, so the user can see, what the robot "sees". The program itself was made in Microsoft Visual C#. For this work we have used an open source library, the Direct Show Library. It is a free library, where free means freedom of use and freedom to distribute copies of free software. The user can change the software and use pieces of it in new free programs.

The application creates a preview window for available video capture devices it locates on the user's system. The main function of this application is the logging of the snapshots taken. If the user starts the logging, the application starts to make snapshots in a chosen time interval. It creates a second window too, where the user can see the last picture taken. The taken shots are saved on the hard disk.

This application is the predecessor of a more serious program, where the application will not only view the picture of the camera and log the seen pictures, but it will do a serious picture processing with image recognition and obstacle judgment. Then the data of the processed picture will be sent to the robot, which will act by these data.

3.2.1 Graphical User Interface

The Graphical User Interface (GUI) is a type of user interface that allows users to interact with electronic devices with images rather than text commands. [16]

On the picture below you can see the actual image of the GUI of the application. It is a very simple, but user friendly environment with 2 preview windows - the smaller one is the actual image of the camera, and a larger one shows the last snapshot taken - and several funtion buttons and a menu.

Pic. 33: The Graphical User Interface of the application.

3.2.2 Functions

There are several functions usable on the interface. In this chapter we will talk about these functions in detail. You can see the buttons and the menu on Pic. 33.

- **Start**
  By clicking on the Start button, the picture logging is started. The application starts to take snapshots by the selected time interval. The logged pictures are saved in the directory chosen before by the "Browse" function.

- **Stop**
  The started logging and snapshot taking is stopped by clicking on the Stop button. Now the user can check the saved pictures in the defined directory.

- **Select device**
  The select device function uses the "DsDevice" class, which is the Direct Show Device function. With this class' functions the user can find all video input devices on the user's PC and choose the indexed device for use.

- **Browse**
  With this function the user can choose the directory where the snapshots will be saved. This function is executed by the "FolderBrowserDialog" command.

- **Time interval**
  In the "Edit" menu the user can find the "Set time interval" function. Like its name says, the user can choose from four time intervals: 0.5, 1, 2, 3 seconds. This time sets how many seconds have to elapse between two snapshot takings.

4. CONCLUSIONS

The goal of this work was to establish a vision system on Bioloid robot. The Bioloid is an all-around robot kit by the Korean company ROBOTIS, that can be assembled in many ways. We have chosen to vivify a bipedal humanoid robot from the Bioloid Comprehensive Kit for this work. The robot was built by the Bioloid Quick Start Guide, its motions and behaviors were programmed in the RoboPlus software.

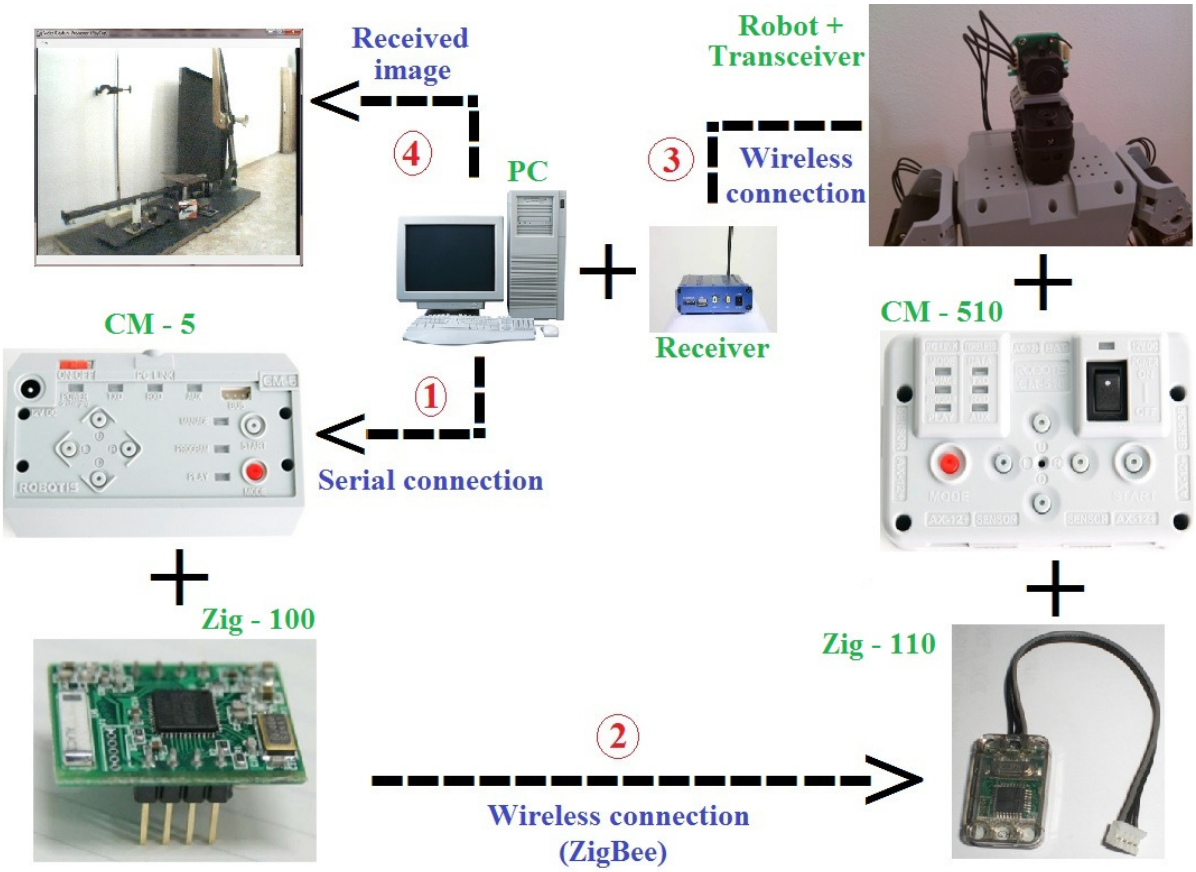
We have used two Bioloid controller units in this work. The first one is the CM-5, an older version controller by ROBOTIS coming with the Bioloid Comprehensive Kit. We used this unit to send instructions wirelessly to the second controller unit, so use it as a transmitter. The CM-5 combined with the Zig-100 module is able to send data wirelessly. Without the Zig-100 the CM-5 is only able to establish wired communication. The Zig-100 is a small module capable of transmitting data wirelessly to a paired Zig-110 module. The Zig-100 comes along with its paired counterpart the Zig-110. They have similar identification numbers and that is why they can communicate with each other. These modules use the ZigBee standard, which is a low-cost, low-power wireless networking standard. The Zig-110 is connected to our second controller unit, the CM-510, which is the newer version of the CM-5. The CM-510, which is coming with the Bioloid Premium Kit, combined with the Zig-110 is capable of receiving wireless instructions coming from the CM-5 transmitter. The CM-510 is mounted on our humanoid robot, and connected to the servos. In fact, the CM-510 is not compatible physically with the older, Comprehensive Kit humanoid robot. We had to change the controller unit area a bit in shape, so that the CM-510 could be mounted. This change made the robot a little bit instable during movement. The CM-5 sends commands to the CM-510 wirelessly and the robot realizes the received instructions.

The motions and commands were programmed in the official ROBOTIS software, the RoboPlus, which is in fact a set of robot software. The RoboPlus Task sets rules for the robot on situation recognition, situation judgment and behavior. The RoboPlus Manager manages robot parts, for instance the servos or the sensors. The RoboPlus Motion is the software where the user can program several robot motions. The RoboPlus Dynamixel Wizard and the RoboPlus Terminal are mainly for advanced users. By combining these software our robot will behave like we want to. The remote control and the robot motions were written with the help of these software.

The vision system is based on wireless communication between the camera and the router, which is connected to the controlling computer. The wireless camera kit is coming with the Bioloid Expert Kit, or it can be bought separately. It is a simple wireless camera kit composed of a wireless router and a small wireless camera. The router is connected to the controlling computer via USB connection. The camera needs power supply, so it has to be connected to a Bioloid controller unit via TTL serial connection. This controller unit is in our case the CM-510. The camera is mounted on the Bioloid's head, so it feels like the camera is the eyes of the robot. The camera sends the images to the controlling computer, where the computer with the help of the control program monitors the images.

The control program application is a simple Direct Show Library aided computer program, which has several functions. The main function of this software is the logging of the images received from the camera. By pressing the Start button on the software's user interface, the program starts to take snapshots in the selected time interval. These snapshots are saved on the controlling computer's hard disk, after the user has selected the desired directory. With these taken snapshots the user can easily follow the robot movements.

The main goal of this work was to build up a vision system, which will be a good base for further experiments. In the future, this basic system will be upgraded, so that our robot will navigate only by the mounted wireless camera and avoid obstacles autonomously. Finally, here you can see the whole communication system on an illustration. The robot is the center of a wireless communication system, where it receives and sends data simultaneously to several mediums.



Pic. 34: The wireless connection system

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