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Autonomous Hexapod Walker Robot “Szabad(ka)”

Intelligent mechatronics and robotics

“Szabad(ka)” is an Autonomous hexapod walker robot (Fig. 1.), developed for testing and developing algorithms connected to motion, robot vision, decision making and robot networking. This hexapod robot was given the name “Szabad(ka)” because it incorporates the name of the city where it was designed as well as hinting at its main feature, namely that it can be openly (‘szabad’) developing platform for user specific needs.

The robot is a complex system both considering its mechanical structure as well as its electronic developments and processor structure.

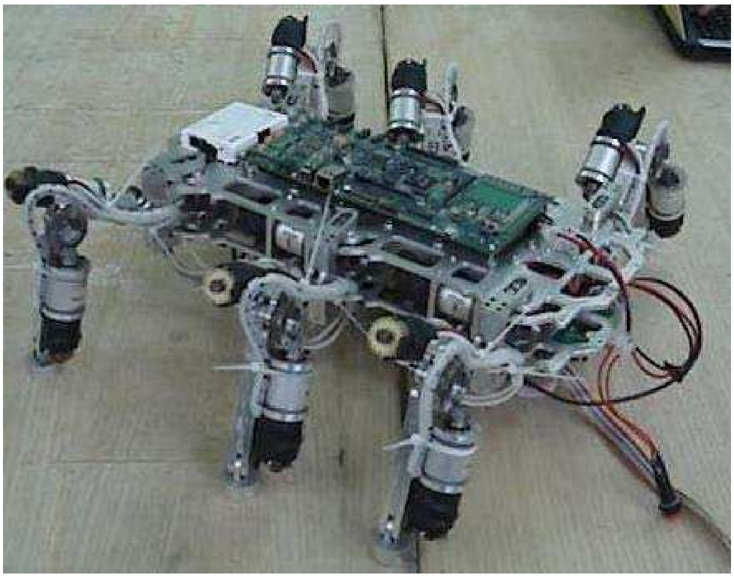

Fig. 1. Prototype of “Szabad(ka)”

The robot has MATLAB development platform. It contains one TMS320C6455 DSP (1GHz frequency) and 10 MSP430F6412 processors, an access point and fully-built it contains 2 cameras, 2 ultra sound radars, several accelerometers, gyroscopes and other sensors for navigation and motion control.

In the robot’s 10 microcontrollers, there are various algorithms for sensor processing and basic motion control. Higher level software can be written on personal computers, (in C++ or in MATLAB) and following that it can be implemented into the robots DSP processor which has really high processing abilities. Its software platform (with the already written algorithms) is designed in a modular way, which makes possible for the developers and researchers to develop codes in their own fields of interest without having to be familiar with other software parts of the robot.

The DSP and the 10 MSP processors are connected into network through SPI and I2C protocols. Beside the DSP processor, the robot has 5 PCB-s (2 MSP controllers on each). From these 5 boards, 3 are for controlling the legs, and the other two are for processing signals from 2 gyroscopes, 2 accelerometers, 2 radars, several IR collusion detectors. Also every leg has an accelerometer and a force sensor in its foot. The communication with the computer is realized wirelessly with an integrated high speed access point. A Video Interface is implemented for connecting 2 digital, high resolution cameras. This is used for stereo visioning.

The robot's body is made from more than 150 aluminium and steel parts. All of them were designed in SolidWorks™. The parts were manufactured with CNC milling machines.

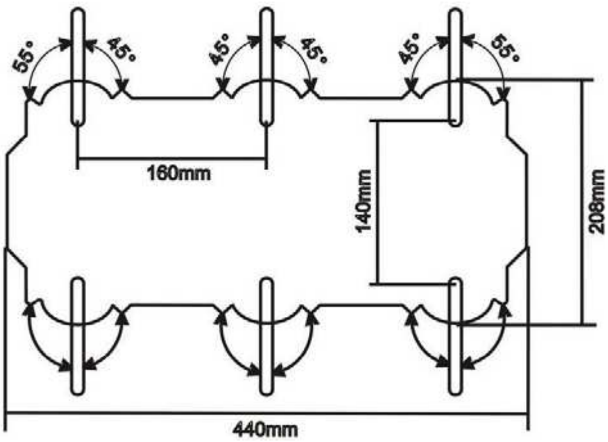

Fig. 2. The main dimensions of the body.

Mechanical The robot weighs about 10 kg and it is 300 mm high if it stands. All the parts of the legs and the body are made mostly from aluminum. This material is strong and light enough for our needs.

The leg attachments all lie in the same plane, with all the α axes parallel. Besides holding the legs, the function of the chassis is to hold the electronics and the accumulator, too. The legs are all identical and have three revolute joints each. The first two are orthogonal to each other and the third is parallel with the second. All the joints use identical 10W DC motors running through 1:100 planetary reduction gearboxes.

After the gearbox, there is a metal bevel gear pair (with 12-36 teeth), providing 1:3 additional reduction, for smoother moving, and more torque (Fig. 3.). For angle measurements on the servos home made optical quadrature encoders were used. Calibration of their offset can be done with software by moving the joints until they hit the bumpers, which generates known reference angles for each joint. In every jointed foot there is a force measuring stamp and a 3D accelerometer providing additional data.

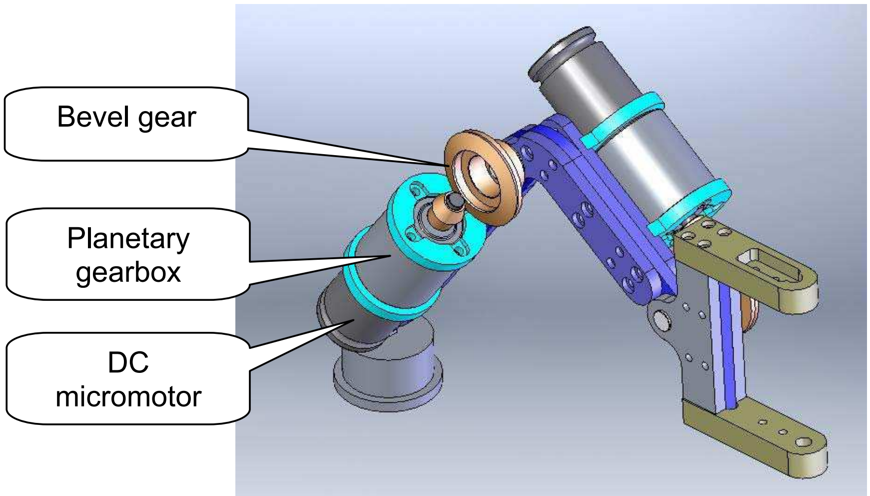

Fig. 3. The construction of the leg.

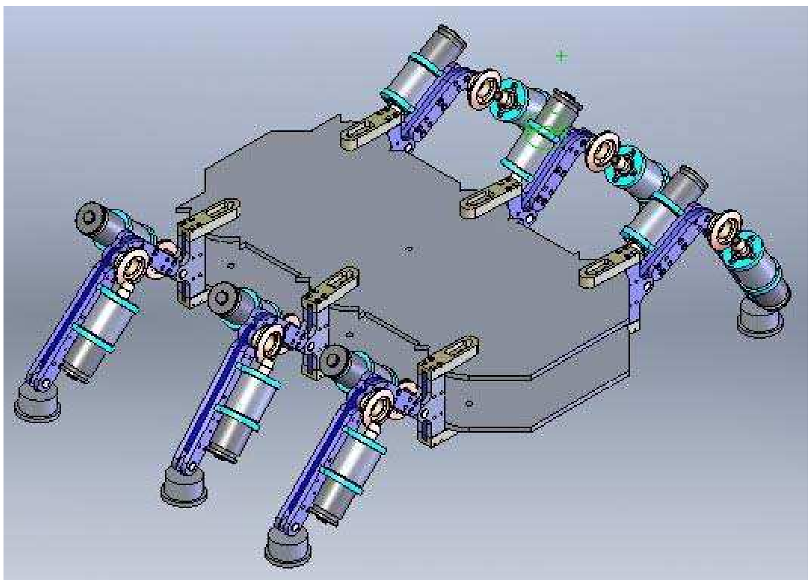

Fig. 4. The mechanical 3D modell.

Electronics The electronics consists of the DSP Starter Kit (DSK), the MSP boards, and the Stereo Video Interface (Fig. 5.).

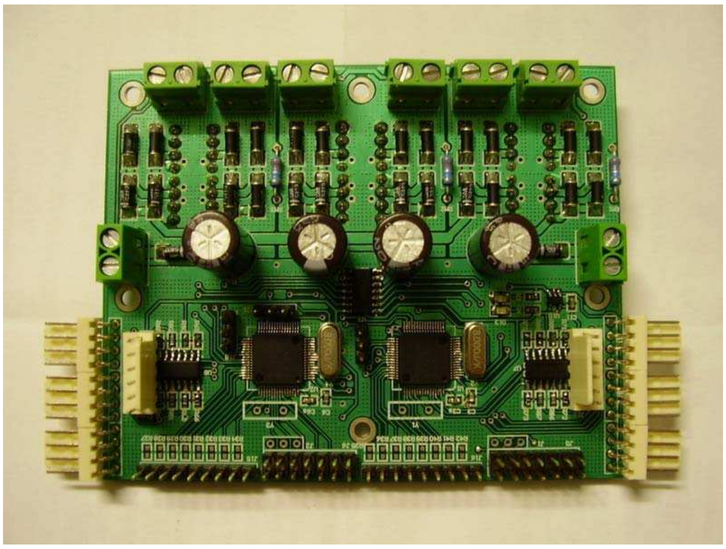

Fig. 5. The picture of the DSP.

The DSK has a high-end DSP TMS320C6455 processor, running on 1 GHz, having 128 MB of RAM memory, 4 MB of ROM memory, an Ethernet connector and an audio in/out port. Because this DSP is Texas Instruments' most advanced processor, it is a good choice for the current needs. The DSP and one MSP board is connected through SPI protocol and communication with the computer is established wirelessly through an access point and the Ethernet connector. From the 5 MSP boards, there are: 1 Sensors board, 1 Communications – Motion Algorithm board, and 3 Inverse Kinematics boards.

The Communications – Motion Algorithm board, contains 2 MSP processors. One of them is the one, which is connected to the DSP processor. Its main tasks are to transceivers the commands between the DSP and the other MSP-s, and to generate the walking coordinates in dependence of time. The other MSP's job is to process the rear gyroscopes, the rear accelerometers, and some infra red collision signals.

The task of the 3 Inverse Kinematics boards is to receive the coordinates from the Communications – Motion Algorithm board and to generate the desired angles of 3 joints for a leg. Logically, every IK board has 2 MSP-s, one for each leg. This board's other task is to process the data received from the force sensors and the accelerometers placed in the feet.

The **Sensors** board's first MSP controls the 2 ultra sound radars (it moves RC servo motors, and processes data), and the second MSP's job is to process the front gyroscopes, the front accelerometers, and some infra red collision signals.

The **Stereo Video Interface** connects 2 digital, high resolution cameras with the DSP-s EMIF (External Memory Interface). This board contains a FIFO memory. This is needed because the camera is sending its video data continuously and slowly, but the DSP can read data only rapidly, and in smaller parts. Because of the current special needs, the Digital Camera boards are also home made, using OV7640 video IC-s.

Fig. 6. The control display of the robot softvare.

Software The robot's software is physically divided into 3 parts. These are: the software running on the PC, the DSP software, and the MSP software.

For the PC, currently there is some controlling software written in JAVA Script (Running from the DSP`s Webserver), and a MATLAB platform. Both of them are capable for moving the robot in various directions, with various speeds, and with other options (Fig. 6.). The JAVA software is also prepared for receiving video data and other information from the robot. Further, it can set some behaviour.

About the DSP software: currently its only task is to transmit data between the PC and the Communication MSP but it will be used for image processing and decision making as soon the Stereo Video Interface will be finished. Some contour recognition and other algorithms are already written for it, and ready to use. The DSP software is written in C++ with Code Composer Studio.

The tasks of the software on the 5 MSP boards (on the 10 MSP controllers) were already described under the electronics section, thus 6 MSP-s are for Inverse Kinematics, 2 MSP-s are processing one gyroscope, one accelerometer, and some IR sensors (per each controller), 1 MSP is for controlling, and processing 2 US radars, and

1 MSP is for communications, and for motion algorithms.

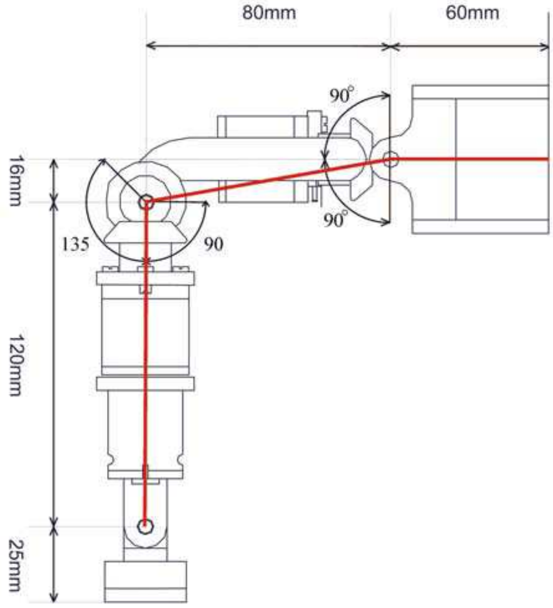

Fig. 7. The dimensions of leg.

Inverse kinematics – ANFIS The role of inverse kinematics - just like in any other system – is that it creates the necessary angles of joints (in our case the alpha, theta1 and theta2) if the end point (base of the foot) coordinates are given – x, y and z. Inverse kinematics calculations are normally complex and are needing high processor resources. We implemented specialy optimized algorithms, to run the IK calculations, in simple microcontrollers. Also, we are working on replacing the classic IK codes, with ANFIS (ANFIS method is a hybrid neuro-fuzzy technique that brings learning capabilities of neural networks to fuzzy inference systems), what will give us the ability for more adaptive codes. We already wrote the algorithms on PC (MATLAB), and now we are working on implementing the algorithms on the DSP, and the MSP-s.

Animation In order for our calculation results to be visualized more easily, without a implementing or using the robot, we created an animation 'subsystem'.

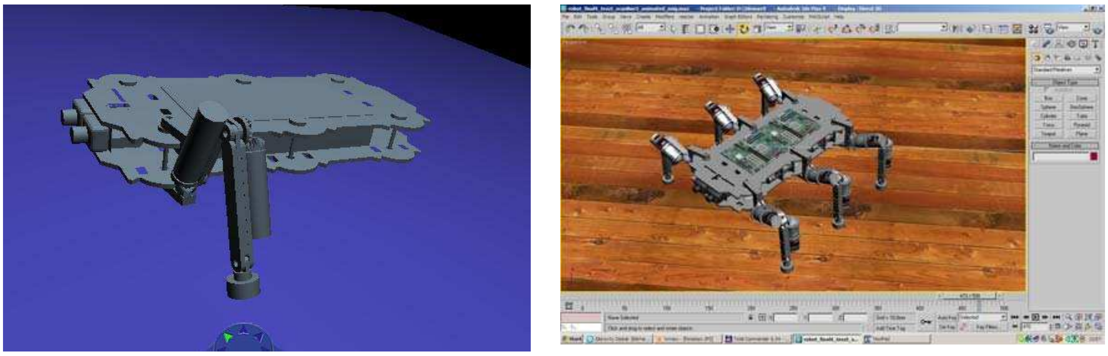

Fig. 8. 3D Studio Max ™ robot modell.

A 3D Studio Max robot model (Fig. 8.), which is able to create an animation based on data from imported using Matlab generated databases containing movement data. This procedure produced good results, but its drawback is that it needs an outside program (outside of Matlab), therefore the animation is not real-time.

So as to fix this problem we started to develop an 'animation system' within Simulink environment. With this we are currently able to visualize an animation within a Matlab environment, and are currently working on making it real-time. Figure 3 shows a detail of the robot's MATLAB Simulink animation.

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