

# Team Description ARNE

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**Abstract.** This paper outlines ARNE humanoid robot developed by NE Company, St. Petersburg, Russia. ARNE is 123 cm tall, weighs about 61 kg, and has 28 degrees of freedom. Especially for robot arms and legs low-speed brushless DC 16 and 60 W motors were developed by NE Company. All robot drives, motion generation and stability are controlled by Motorola DSP56F805 microcontrollers. High-level decision-making, video and audio processing is performed by remote PC.

## Introduction

This paper outlines ARNE Humanoid Robot project started in 2001 at NE (“New Era”) Company, St. Petersburg, Russia. The name ARNE stands for “Anthropomorphic Robot of New Era”. Two years of research using simulation models and prototype named ARNE-01 have resulted in ARNE-02 creation.

Main research interests are: (1) building the robot with electromechanical drives suitable for the soccer playing; (2) providing stable walking of the robot; (3) implementing integral perception of the robot using vision, acoustic, gyroscope, force sensor systems; (4) providing complex behavior of the robot, such as navigation in the dynamic environment with obstacles, skills and personal operations in the soccer game, purposeful behavior in the team. Currently appreciable outcomes are obtained in the first and second directions.

## Specification

The ARNE-02 robot is 123 cm tall and weighs about 61 kg. It has 28 degrees of freedom: 6 in each leg, 5 in each arm, 2 in each hand and 2 in head.

## Electro-mechanical

Main robot body elements are made of polyamide. Trunk carcass to arrange electronic components and joining hardware are aluminum.

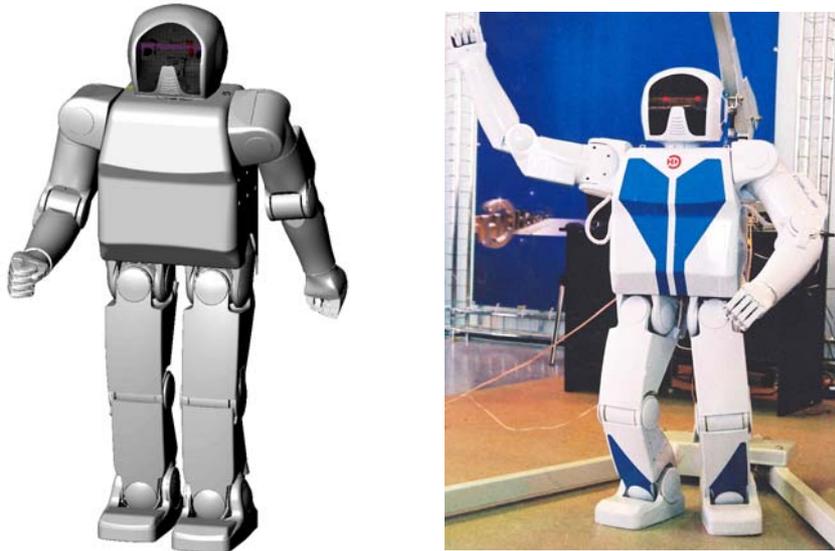


Fig. 1. SolidWorks model and photo of ARNE-02

Especially for robot arms and legs low-speed brushless DC 16 and 60 W motors were developed by NE Company. They are used with Harmonic Drive's wave gearheads. Head and hand motors are DC micromotors by Faulhaber DC Motors. Microencoders 2048 impulses per turn and potentiometric sensors are used as rotation degree sensors.

To control robot stability each robot foot is supplied by 4 FlexiForce tactile sensors.

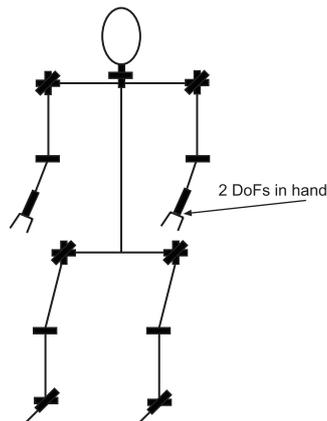


Fig. 2. ARNE-02 kinematic diagram

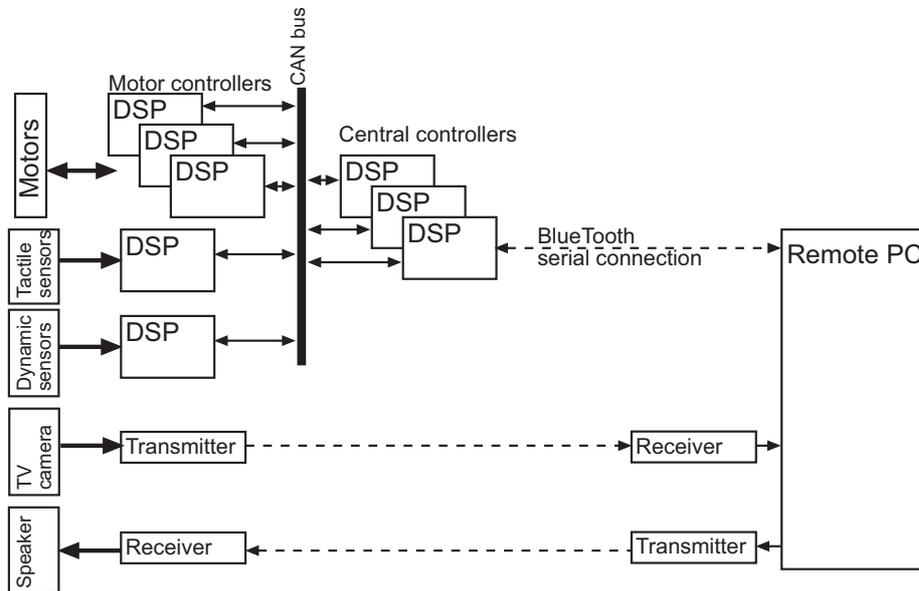


Fig. 3. Block diagram of ARNE-02 control system

## Electronics

All robot drives are controlled by Motorola DSP56F805 microcontrollers with IR2132 drivers (each microcontroller controls 2 or 3 drives). Motion generation and stability control are also implemented on Motorola microcontrollers. All of 16 microcontrollers are connected in CAN (Controller-Area Network).

Head of the robot has single color TV camera, TV signal transmitter and speaker. Robot has digital speech processor that provides several diagnostic speech messages. In the case of malfunction, robot reports by corresponding speech message.

At present high-level decision making, video and audio processing is performed by remote PC. Main Control Module microcontroller is connected with remote PC by RS-232 BlueTooth connection. Analog video signal from camera is transmitted to the PC over radio-channel. In order to provide speech communication with human, speech synthesis program running on the PC is used. The speech synthesized by the PC is transmitted to robot's speaker over another radio-channel.

## Software

Robot behavior control software consists of 5 levels:

- the lowest level of control provides DoF's drives control software running on drive controllers;

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- 2<sup>nd</sup> level performs robot movement control with a coordinated control of robot body parts by solving Inverse Kinematic tasks;
- 3<sup>rd</sup> level generates robot gait trajectories and controls robot stability;
- 4<sup>th</sup> level allows robot to gather information about the world and interact with world objects;
- 5<sup>th</sup> level provides external robot control and other high-level tasks: execution of beforehand given action sequences, voice command control, direct control by operator, speech synthesis.

The software has following peculiar properties:

Robot stability is provided using special criterion of keeping dynamic mass center projection to the floor inside bearing area formed by robot feet. Usage of the dynamic mass center allows taking into account static mass center and accelerations of body parts' movement. To calculate the dynamic mass center a special procedure is used. Inverse kinematic problem solving procedure allows robot to execute complex flexible movements using all of the robot's DoFs simultaneously. This is useful for good soccer playing.

Robot vision system is executed on the remote PC. The analog video signal received from the robot's camera is being captured and processing by vision software. The software is based on Intel Open Source Computer Vision (OpenCV) library. The vision system can recognize and detect location of color objects like color markers used for robot navigation in field, or colored ball.

Voice control system is also executed on the PC. It analyzes sound coming from external microphone and can recognize up to 20-30 simple commands like "go forward", "turn around" etc.

For speech synthesis standard Lernout&Haspie and Digalo Windows ASPI speech engines are used. Speech synthesis allows robot to say long messages prepared beforehand or generated by operator.

## Conclusion

During development of two variants of robots (ARNE-01 and ARNE-02) and auxiliary systems difficulties of this work became clear. A lot of the information and the practical experience have been gathered. Further problems planned to be solved are:

- integrating the high-level control, vision, speech recognition and synthesis systems from the remote PC into the robot;
- improving movement techniques;
- creating stereo vision system to gather information about the world;
- improving speech recognition system to be able to recognize continuous human speech in noisy conditions;
- improving vision-based robot control.

We believe that it can help to greatly improve robot performance in soccer playing and other applications.