Humanoid robot AR-600

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***Abstract*— This article describes the hardware design and some of the software of autonomous humanoid robot AR-600. It is a full-sized humanoid robot that can be used in human-centered environment. It supports ROS and can be controlled via mimicking device. Collaborative work of several research institutions will bring more applications of the robot.**

I. INTRODUCTION

One of the main applications for robots in nearest future would be to replace (or assist) humans in dangerous situations and hazardous environments. Another important niche for robots is to help humans in their everyday life: assist in study and research, in housekeeping, in the kitchen, elderly care, etc.

AR-600 (fig. 1), developed by Russian company Android Techniques [1], is aimed to be a multitasking antropomorphic robotic platform that can interact with humans and operate in human infrastructure.

It was designed to have a size of a 14-16 years old teenager. And that was done by purpose. Robot that is a bit smaller than a typical human can be treated with all respect like a younger brother who's trying to help in everyday routine. Looking at the robot from above will lead to a better attitude while communicating with it.

Abilities of robots to accomplish certain tasks autonomously relies mostly on a high level software that implements all the best from the field of artificial intelligence. The other way that allows to use robots now is to make them mimic our moves like avatars. Our AR-600 robot can be controlled by a developed mimicking device (fig. 3). It sends joint angles to robot and gets back force feedback and video stream. With this "suit" on an operator can naturally control the upperbody of the robot and use it to manipulate tools in uninhabitable or hazardous environments (e.g. welding or screwing).

AR-600 is already used in 6 Russian universities as a robotics research platform. Some of the research topics are object grasping and bipedal walking.

This paper describes specifications of the robot, software developed so far and some future work.

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Fig. 1. Antropomorphic robot AR-600.

Fig. 2. Mimicking device for the robot.

Fig. 3. Mimicking device for the robot.

II. SPECIFICATIONS OF AR-600

A. Dimensions and kinematics scheme

Height of robot is 155 cm, width is 38 cm, weight with batteries is 54 kilograms. Not counting palm assembly robot has 26 degrees of freedom (see table I). Palm asseblies have 5 fingers with 1 degree of freedom each. The overview of kinematic structure is shown in Fig.4.

Fig. 4. Kinematic scheme

TABLE I
JOINTS DEGREES OF FREEDOM

	degree of freedom	range of motion	
head	roll	-15	15
	tilt	-20	30
	pan	-90	90
shoulder	pitch	0	105
	yaw	-15	90
elbow	roll	-45	+45
	flexion/extension	0	130
wrist	roll	-45	45
waist	yaw	-45	45
hip	abduction/adduction	-11	20
	flexion/extension	45	-70
	rotation	-20	20
knee	rotation	-140	0
ankle	flexion/extension	-33	70
	abduction/adduction	-20	11

B. Hardware selection

In order to place center of mass as close to hip joints as possible while carrying accumulator batteries in chest cage, aluminium alloy was selected for most inner structure elements to make leg assemblies heavier and, thus, make load balance easier.

Maxon motors actuate major joints thought belt transmission with tooth belts and pulleys. Elbow and knee joints are shown on fig. 5.

There are 3-DOF hip joints, which obtain movements from belt transmissions. Three motors driving a hip assembly are situated in leg segment and lower body, their positioning reminds position of musclules in corresponding human body parts. Elbow joints compose of two motors each - rotation motor assembly, directly arrached to harmonic drive reducer and flexion belt-transmission placed directly in joint axis.

Fig. 5. Elbow and knee assemblies

Head assembly has a 3-DOF joint powered by brushed motors in order to observe environment.

Main controller board built on top of 3 STM 32F107 microcontrollers, minor driver controllers are built on STM 32F103 microcontrollers. Placement of controller boards is shown on fig. 6. Both types use Cortex-M3 ARM cpu and provide softwatre interfaces for hardware interaction.

Joint drives are accompanied by two encoders. Main encoder provides absolute position data with quite a broad error rate, supplementary encoder provides relative motion data for more accurate position estimation.

IMU is Analog Devices ADIS 16400, placed just in center of mass. This point considered as base point of robot. There are also CCD camera, speakers, microphone and foot pressure sensors.

There is a frame on the chest, that allows to mount additional sensors like kinect or laser rangefinders, however there no holes in plastic cover for that. There also two small displays in head mount, that mimic eyes and eyebrows.

C. Power

Robot can run on internal LiFePo cells assembly as well as on external power source. Main voltage is 48V, individual parts operate with 6V, 8V and 12V. Autonomous work time depends on many factors, but typically robot can run for a 30-40 minutes.

D. Wrist and palm assembly

Robot has palms with five fingers one opposite to another four. All finger motors are placed in wrist-elbow section, movement of motor translated to finger via system of strings(fig. 7). This system limits wrist rotation, but makes whole assembly significantly lighter. Our current arm is capable to grab objects like tennis ball, Rubik‘s cube or

Fig. 6. Controller boards

coffee cup, however there are another types of hands under development - palm assembly is under constant development.

Fig. 7. Palm assembly

E. Control PC and communication bus

Internal communications are built on ethernet. Controller boards are connected via Zigbee interfaces to switch, which governs internal network as shown in fig. 8.

There is also an embedded PC placed in back of robot and connected to same internal LAN. PC is Avalue ECM-QM78 with Intel Core i7-4700EQ CPU and 8GB RAM, capable to carry out performance-demanding sensor-processing tasks. However, there is an option to connect any other PC via ethernet interface.

III. SOFTWARE

Main software interface for controller boards is UDP with specially formed datagrams. There are two types of datagrams - one is for commands transmission, another returns sensors data. Both UDP streams are independent.

Fig. 8. Internal network scheme.

Datagram types encapsulate specific byte arrays, which encode movement commands and sensors data, so anyone can easily interact with robot via standard socket interface libraries.

Support for Robot Operating System [2] is a key to make the robot available to the community and to benefit from open-source software. Not reinventing the wheel and applying ready-to-use navigation and planning solutions significantly increase speed of research and development for robotics laboratories that work with AR-600.

Crossplatform drivers and ros_control interface were implemented alongside with Rviz and Gazebo models(See fig. 9). Motion planning is based on MoveIt! package [3] that uses state-of-the-art planning libraries. One can test planning and obstacle avoidance for robot's limbs. Full body motion planner is under development. Ar600_vision package is capable of detecting, recognizing and tracking human faces. Its implementation is based on cascade classifiers and OpenCV library [4]. Ar600_speech package lets the robot engage in dialogue with people, answer simple predefined questions and execute motion or vision commands. Pocketsphinx engine [5] developed by CMU is used as a core of speech recognition for AR-600. ROS packages for the robot are not available for public yet, but they are expected to be released soon.

Fig. 9. Moveit demo and Gazebo simulation.

IV. CONCLUSIONS

This paper presented a humanoid robot AR-600, its hardware design and specifications. Drivers and software that

work under ROS framework are also described.

The next generation of the robot, named AR-600E (fig. 10) is expected to be available soon and this will be more powerful, more lightweight, more autonomous system.

Future work includes releasing ROS support packages for public use, development of full-body motion planning with MoveIt (including bipedal walking). Switching from position controller to torque controller is also a priority that will enable more gentle and human-like moves.

We hope AR-600 and his successor AR-600E will be among top humanoid platforms used in robotics research and capable of working alongside with humans.

Fig. 10. AR-600E robot.

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