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DEVELOPMENT OF THE SUPPLY SYSTEM, CONTROL ALGORITHM AND ARCHITECTURE OF VERBAL ROBOT

This work is supported by grant from the Ministry of Education and Science of the Republic of Kazakhstan within the framework of the Work №AP08053034 «Development of new methods for modeling and recognition of Kazakh sign language», Institute Information and Computational Technologies CS MES RK. This article reviews the supply system, control algorithm and architecture of verbal robot. The robot is based on publicly available 3D printer. In this research was developed architecture of general programme system of verbal robot, also improved supply system and control algorithm of overall system. Using Jetson Tx1 equipment and a touch screen for interaction with InMoov, an interface was made to control the entire system. The Kinect detector plays a major role in the process of studying this topic. Compared with the existing humanoid robots, the verbal robot is highly automated platform, low cost and fully functional.

Key words: *Verbal robot; Power system; Control algorithm; Architectura; Jetson tx1.*

Introduction. Humanoid robots have a human-like design and are able to imitate human movements [1]. Among humanoid robots with double manipulators and dexterous hands, maintenance is of great importance. They can provide with companion, operation, manipulation, material handling and many other services to people. Research into humanoid robots is always the most active field in intelligent robotics and many large scientific research institutions. Many humanoid robots have been built over the past few years, such as ASIMO [2,3b4], HPR [5], WABIANRV [6], NAO [7,8,9] and the latest robot [10] [11]. The current humanoid robots are either too expansive or too clumsy. There is a trade-off between robot flexibility and expenses. This is a huge obstacle blocking the path of a humanoid robot to our daily life. Some humanoid robots have partial human functions, most humanoid robots do not have human-like appearances. Some humanoid robots are made of metal, steel or aluminum, which are too heavy as in the example of the CALUMA robot [12]. To interact with humans flexibly, robots need a lightweight structure to accommodate their configuration and be energy efficient [13]. The heavy component of a humanoid robot needs powerful consumption, and a decrease in battery duration. And besides, tough materials also bring potential to people, since there are no shock absorbing devices. We can also produce humanoid robots with plastic material, but this is economical and reasonable only in mass production. 3D printing is a rapidly developing technology in recent years [14]. Thanks to 3D printing technology, it is possible to bring an idea from a virtual to a real prototype very quickly. Some humanoid robots like Flobi [15] and iCub [16] are taking advantage of 3D printing. Based on the flexibility of 3D printing, a humanoid robot can be assigned with a vibrant human-like appearance. Also commonly used printing materials such as

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PLA or ABS are inexpensive and can significantly reduce overall manufacturing cost and time. Moreover, 3D printing is economical and environmentally friendly. Some 3D printing materials like PLA are biodegradable and the strength of the materials is sufficient for a humanoid robot. Robot components made from 3D printing are lighter and more resilient, i.e. the robot can be easy and very easy to move.

Research methodology and results. Figure 1a, b shows a diagram of the developed 3D printed inexpensive verbal robot. The height of the robot is approximately 170 cm, which is similar to the normal height of an adult. This robot consists of two parts: the 3D printed front of the verbal robot, the 3D printed back of the verbal robot and the mobile base. The mobile base is made of iron and is driven by three 750 W motors. For a life-size verbal robot with strong mobility, this is very cost effective.

As shown in Table 1, the verbal robot has 50 degrees of latitude, 27 motors, 25 servos with different loads and 3 center motors, specially designed for the electrical control of the 24V system, a 16Ah lithium battery pack is installed in the mobile base, and provides all the electrical operation of the robot.

Table 1 – Degrees of freedom of verbal robot

Part	Degree of freedom	Motors
Right and left hand	30	10
Wrist	2	2
Elbow	2	2
Shoulder	6	6
Head	3	3
Waist	1	2
Mobile base	6	3

The advantages of the wheeled robot: they are faster, more stable, easy manageable, more efficient and can provide with more payload in implementation, more degree of freedom allows to move efficiently diagonally, right, left and forward, backward.

The verbal robot consists of 1-head, 2- shoulder, 3- face recognition device, 4- elbow, 5- torso, 6- hand, 7- arms, 8- platform for controlling the entire system, 9- omnidirectional mobile platform, 10- touch screen.

The mobile platform contains three universal wheels, each wheel spaced 120 degrees apart to make the robot static and with three distinctive motor wheels to make the robot move.

3D printing front part of the verbal robot. The front side of the robot's body is completely 3D printed usage (PLA) plastic, which is a kind of biodegradable plastic and has no pungent odor. The 3D printer which we used has a working area of 200 * 200 * 300mm, which meets the requirements of the "InMoov" robot. The left and right modular hand has five fingers and a wrist joint. The fingers have 15 degrees of freedom (DOF) and are driven by five servo-MG996R through the wire.

Each finger runs through two wires, one wire drives the number to return to straight, and the other wire drives the number to bend. Because there are 15 DOFs of left and right

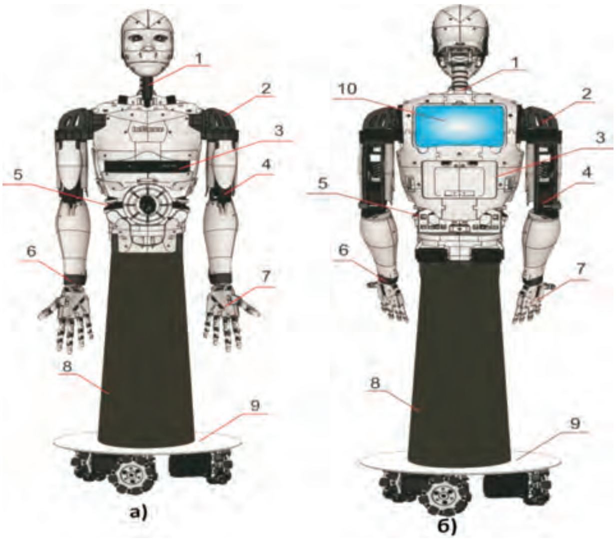

Figure 1 **–** a) 3D printed front side of the verbal robot;
b) 3D printed back side of the verbal robot

nimble hand modules, they are under a powered mechanical system. When the left or right hand grabs the object, the finger will convert the object automatically. For the wrist joint, another MG996R servo is needed to control back and forth rotation.

The mouth and head rotate to the right and left with a total of 7 degrees of freedom. The left shoulder elbow module has 4 DOFs and this leads to the HS-805BB hi-tech servo. The arm and elbow module is symmetrical with the left arm and with the elbow module. The main module and the waist module are considered one module in our “Inmoov” robot because they are linked to the same control panel. The main module has 3 DOFs, while the waist module can be controlled by the Inmoov robot to tilt about 20 degrees.

Onboard equipment. As shown in Figure 4, the onboard equipment is installed in an automated system. In addition to the nested Mega Arduino, six verbal robot “Inmoov” modules are used to study human robot interaction problems.

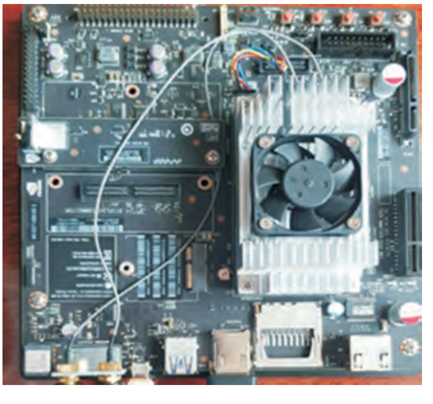

Figure 2 – Onboard equipment

Figure 2 shows to increase the processing capacity, Jetson tx-1 CPU with 32G memory, 128G solid state drive is installed at the end of the robot. A PC running Linux and Robot Operating System (ROS) can communicate with the Mega Arduino via a serial interface.

Figure 3 – Microsoft Kinect Sensor

Figure 3 shows a Microsoft Kinect sensor is incorporated into the robot's belly to sense the environment and interact with humans. Kinect connect to Jetson tx-1. Existing ROS libraries such as the openni startup are used to get information about the sensor. A 7-inch touchscreen is installed in the rear to provide additional feedback and interoperability.

Electrical connection of the verbal robot. Onboard equipment is powered by a 24V, 16Ah lithium battery pack. Battery management and breaker units are installed on a mobile basis. The equipment has different power ratings and requirements. Servos and Arduino are powered by 6V, but must be isolated from each other. The Kinect requires a 12 volt power supply. The Jetson tx-1 requires a 19 volt power supply. In addition, to ensure the safety and stability of the Jetson tx-1 and the touch screen, the 24-volt DC to the inverter is set to 220 V. A block diagram of the power management system is shown in Figure 4.

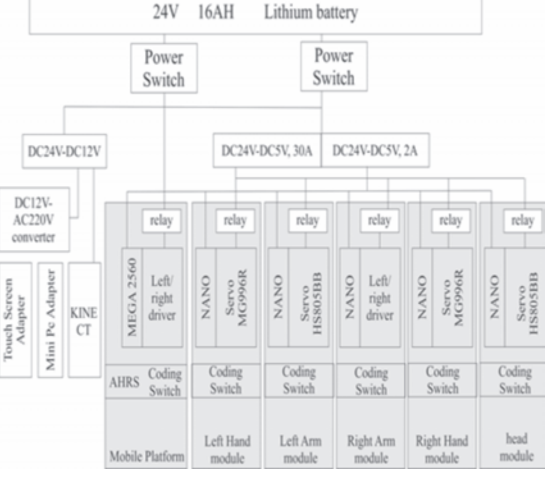

Figure 4 – Block Diagram of Power Management System

Verbal robot software structure. This software is designed to be modular in order to match the hardware. The modular drive is easy to operate and maintain. Six modules have six control panels, and all of these six modules are linked and used in RS485 to communicate with the main Arduino Mega 2560.

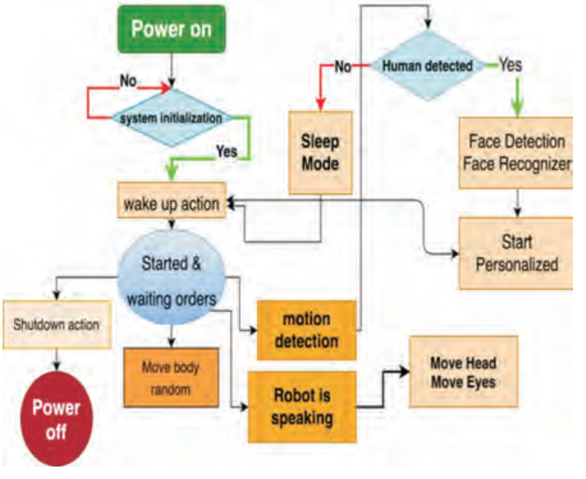

Figure 5 – Verbal robot control algorithm

As we can see from Figure 5, when the robot is turned on, the system begins to initialize. After the whole system is connected to the robot modules with 50 degrees of freedom, it starts to move in a chaotic manner, and in parallel, the platform for controlling the entire system will have voice guidance, and in parallel it will read the motion sensor data. If there is movement, then the face recognition device recognizes the moving face of the person. Further, the personalization of the person begins and will conduct a dialogue with the person and a database is created for each person with whom the robot communicated. After the dialogue is over, the data is sent to the propulsion system. If the sensor does not recognize movement, then the robot goes into sleep mode. After sleep mode at a certain time, the entire system is turned off.

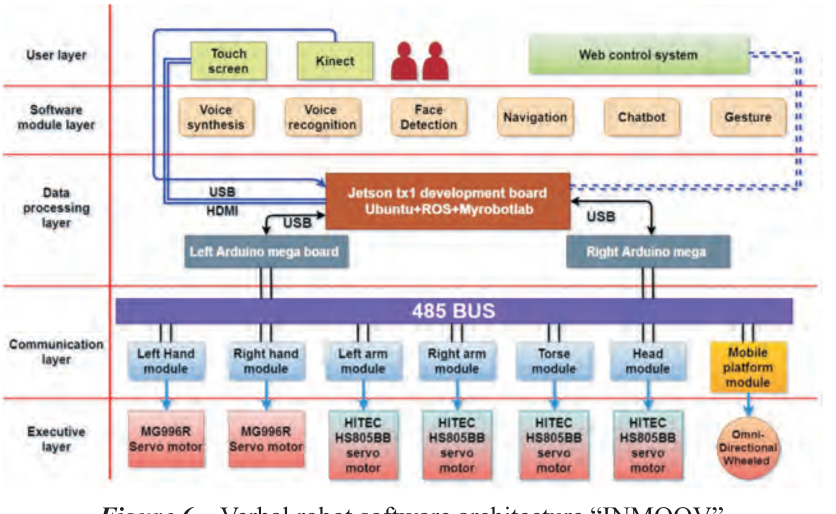

Figure 6 – Verbal robot software architecture “INMOOV”

Figure 6 shows the proposed structure of the verbal robot software architecture. The software is divided into five layers, the user layer, the software module layer, the data processing layer, the communication layer, and the Executive layer. The user layer includes a function that directly interacts with the robot operator, touch screen, Kinect sensor, and web monitoring system.

The software module layer consists of software modules for speech recognition, speech synthesis, face recognition, navigation modules and a chat bot that simulates a real conversation with the user, as well as a software module for gestures. There is a logical connection and intelligent control between them. In "INMOOV," the humanoid robot Jetson-tx1, running Ubuntu and ROS act as the main controller and coordinator. Based on the rich ROS libraries, it becomes easier to get the human skeleton and other sensor information from the Kinect, camera, and microphones. The data processing layer consists of Jetson-tx1, which can receive commands from Kinect. The communication layer consists of Arduino Mega 2560 and six nested dispatcher modules. The executive layer consists of servo motors and 120 degree three motors. The RS485 has a simple structure and can have many slave modules. In the RS485 network Arduino Mega, as the main computer and control panel of each module, serves as a computer. The main computer is responsible for the control command, for acquiring data and for executing the control signal. When the control panels communicate with the host computer, it follows the Modbus protocol, which uses the mechanism to eliminate communication errors. In this network, each control panel serves as a node, which has a different ID. ID can be configured using the onboard Dip Switch.

Results. This article proposed a fully functional low cost 3D printed verbal robot using InMoov. The robot is based on the publicly available 3D printed verbal robot "InMoov". A dispatcher in mechanical parts and an electrical power system has been developed, which makes all parts interchangeable. Jetson-tx1 explores a new type of robot software technology. The verbal robot has a human-like structure as well as a variety of interactive patterns. The person can communicate with the touch screen and the Kinect sensor. The Kinect sensor plays a major role in learning progress. The robot has two mobile manipulators with DOFs.

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ҚУАТ ЖҮЙЕСІН БАСҚАРУ, АЛГОРИТМІН ЖӘНЕ АУЫЗША РОБОТ АРХИТЕКТУРАСЫН ДАМЫТУ

Бұл жұмыс Қазақстан Республикасы Білім және ғылым министрлігі грантының №AP08053034 «қазақ ым тілін модельдеу мен танудың жаңа әдістерін әзірлеу», ҚР БҒМ ҚҰО ақпараттық және есептеу технологиялары институтының қолдауымен орындалды. Бұл мақалада қуат жүйесі, басқару алгоритмі және ауызша роботтың архитектурасы қарастырылады. Робот жалпыға қол жетімді 3D принтерде жасалған. Осы зерттеу барысында ауызша роботтың жалпы бағдарламалық жүйесінің архитектурасы жасалды, сонымен қатар қуат жүйесі мен жалпы жүйені басқару алгоритмі жетілдірілді. Jetson tx1 жабдығын және InMoov-пен өзара әрекеттесу үшін сенсорлық экранды қолдана отырып, бүкіл жүйені басқаруға арналған интерфейс жасалды. Kinect детекторы осы тақырыпты зерттеу процесінде маңызды рөл атқарады. Қолданыстағы гуманоидты роботтармен салыстырғанда, ауызша робот жоғары автоматтандырылған платформа, арзан және толық жұмыс істейді.

***Түйін сөздер**: ауызша робот, энергетикалық жүйе, басқару алгоритмі, сәулет, Jetson tx1.*

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РАЗРАБОТКА СИСТЕМЫ ПИТАНИЯ, АЛГОРИТМА УПРАВЛЕНИЯ И АРХИТЕКТУРЫ ВЕРБАЛЬНОГО РОБОТА

Данная работа выполнена при поддержке гранта Министерства образования и науки Республики Казахстан в рамках Работы №AP08053034 «Разработка новых методов моделирования и распознавания казахского языка жестов», Института информационных и вычислительных технологий КНЦ МОН РК. В данной статье рассматриваются система питания, алгоритм управления и архитектура вербального робота. Робот основан на общедоступном 3D-принтере. В ходе данного исследования была разработана архитектура общей программной системы вербального робота, а также усовершенствована система питания и алгоритм управления общей системой. Используя оборудование Jetson Tx1 и сенсорный экран для взаимодействия с InMoov, был создан интерфейс для управления всей системой. Детектор Kinect играет важную роль в процессе изучения этой темы. По сравнению с существующими гуманоидными роботами вербальный робот представляет собой высокоавтоматизированную платформу, недорогую и полностью функциональную.

***Ключевые слова**: вербальный робот, энергетическая система, алгоритм управления, архитектура, Jetson tx1.*