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DEVELOPMENT OF AN INTELLIGENT MEDICAL ROBOT FOR ULTRASOUND DIAGNOSTIC STUDIES

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Abstract. The main reason for using robotic ultrasound is to improve the accuracy and robustness of ultrasound examinations. By removing the human factor from the examination process, robotic systems can perform ultrasounds at a level of accuracy that is difficult to achieve manually. This leads to more accurate diagnoses and treatment plans for patients. This article reviews the research and development trends of ultrasound medical robots.

Keywords. robot systems, ultrasound diagnostic device, intelligent medical robot, control algorithm, control software

ULTRATOVUSH DIAGNOSTIKA ISHLARI UCHUN AQLLI TIBBIY ROBOTNI ISHLAB CHIQISH.

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Annotatsiya. Robotik ultratovushning asosiy foydalanishning sababi bu ultratovushli tekshiruvining aniqlik va mustahkamligini oshirishdir. Tekshiruv jarayonida inson omilini olib tashlash orqali robot tizimlari ultratovushlarni qo‘lda erishish qiyin bo‘lgan aniqlik darajasida bajarishi mumkin. Bu bemorlar uchun aniqroq tashxis qo‘yish va davolash rejalariga olib keladi. Ushbu maqolada ultratovushli tibbiyot roboti bo‘yicha olib borilgan tadqiqotlar hamda rivojlanish tendensiyalari keltirilgan.

Kalit so‘zlar. robot tizimlari, ultratovush diagnostik qurilma, intellektual tibbiyot roboti, boshqaruvining algoritmi, boshqarish dasturiy ta’minoti

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Intelligent medical robots are mechanical systems designed to make ultrasound examinations more efficient and accurate using artificial intelligence (AI) and machine learning (ML) technologies. They are designed to scan the patient’s body with ultrasound,

analyze the results, and automatically make a diagnosis. Such robots are able not only to acquire ultrasound images, but also to process the data obtained from them using advanced algorithms and increase accuracy. Ultrasound examinations are processes that require high accuracy and precision, and are usually controlled by human hands. However, these processes can sometimes cause errors, inaccuracies, and time consumption. Intelligent robots help solve these problems. Robots allow ultrasound images to be obtained with high accuracy and repeated under the same conditions. This increases the reliability of diagnostics. Robots analyze images in real time and automatically analyze them using artificial intelligence to identify pathologies. Robots allow for faster diagnostics, which helps provide patients with prompt care. Automation of processes simplifies the work of doctors and allows them to focus their attention on other important areas.

For ultrasound research, robots are equipped with high-precision ultrasound sensors. These sensors help to scan the internal structure of the human body with high accuracy. Ultrasound technologies allow for in-depth diagnostics without damaging the human body. New technologies, such as 3D ultrasound or elastography (study of the elasticity of organs) systems, can be integrated into the robot's sensors.

One of the main features of robots is their ability to analyze data and perform automatic diagnostics. Using deep learning algorithms, robots analyze ultrasound images at a high level and produce accurate results. For example, robots use SI and ML technologies to detect heart diseases, tumors, or changes in other organs. Ultrasound robots are often equipped with mechanical systems to move and place sensors in the correct position. The robot arms and control system must be highly precise, since the sensors must be precisely positioned for imaging and diagnosis. Precise mechanical systems and kinematic approaches are used to control each movement. Robots can be controlled by doctors or operated automatically. A good user interface allows the doctor to intuitively control the system. With remote control technologies, medical robots can be remotely controlled and used to check patients' temperature, blood pressure, and other indicators. Figure 2 shows the structure of the robot. This robot has 6 degrees of freedom. That is, 6 stepper motors are installed, turning in 6 directions. Load capacity 3-5 kg

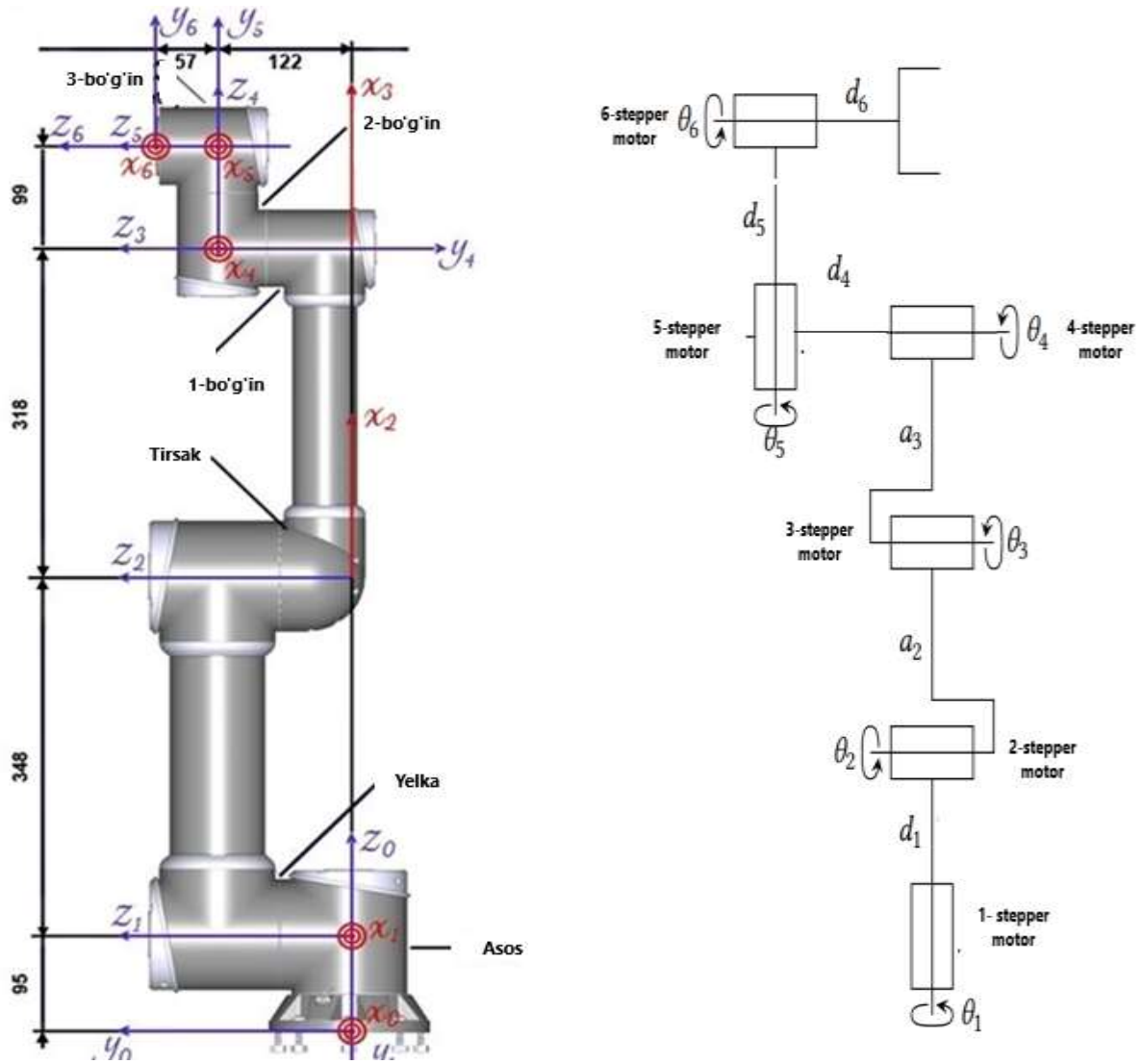

Figure 1. Robot and its parameters

The kinematic model describes the robot's motion without considering forces. For a 6-DOF robot, this includes forward and inverse kinematics. The end effector positions in all three dimensions in the robot coordinate system are obtained as follows.

$$T_i = \begin{bmatrix} \cos\theta_i & -\sin\theta_i \cos\alpha_i & \sin\theta_i \sin\alpha_i & a_i \cos\theta_i \\ \sin\theta_i & \cos\theta_i \cos\alpha_i & -\cos\theta_i \sin\alpha_i & a_i \sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

θ_i: turning angle.

d_i, : shoulder lengtha_i

To obtain the end effector position and direction, the transformation matrices are multiplied:

$$T_{end} = T_1 \cdot T_2 \cdot T_3 \cdot T_4 \cdot T_5 \cdot T_6$$

$$x_{rr} = d_4 s_1 + a_2 c_1 c_2 + d_6 c_5 s_1 + a_3 c_1 c_2 c_3 - a_3 c_1 s_2 s_3 + d_5 c_1 c_2 c_3 s_4$$
$$+ d_5 c_1 c_2 s_3 c_4 + d_5 c_1 s_2 c_3 c_4 - d_5 c_1 s_2 s_3 s_4 - d_6 c_1 c_2 c_3 c_4 s_5 + d_6 c_1 c_2 s_3 s_4 s_5$$
$$+ d_6 c_1 s_2 c_3 s_4 s_5 + d_6 c_1 s_2 s_3 c_4 s_5$$
$$y_{rr} = a_2 s_1 c_2 - d_6 c_1 c_5 - d_4 c_1 + a_3 s_1 c_2 c_3 - a_3 s_1 s_2 s_3 + d_5 s_1 c_2 c_3 s_4$$
$$+ d_5 s_1 c_2 s_3 c_4 + d_5 s_1 s_2 c_3 c_4 - d_5 s_1 s_2 s_3 s_4 - d_6 s_1 c_2 c_3 c_4 s_5 + d_6 s_1 c_2 s_3 s_4 s_5$$
$$+ d_6 s_1 s_2 c_3 s_4 s_5 + d_6 s_1 s_2 s_3 c_4 s_5$$
$$z_{rr} = d_1 + a_2 s_2 + a_3 c_2 s_3 + a_3 s_2 c_3 - d_5 c_2 c_3 c_4 - d_5 c_2 s_3 s_4 + d_5 c_2 s_3 s_4$$
$$+ d_5 s_2 c_3 s_4 + d_5 s_2 s_3 c_4 - d_6 c_2 c_3 s_4 s_5 - d_6 c_2 s_3 c_4 s_5 - d_6 s_2 c_3 c_4 s_5$$
$$+ d_6 s_2 s_3 s_4 s_5$$

Intelligent robots for ultrasound research are based on several technological layers. The robots are equipped with high-precision ultrasound sensors. These sensors help to accurately scan the internal structure of organs. The data obtained from ultrasound images is analyzed using artificial intelligence and machine learning algorithms.

Figure 2. Servo motor and its drive unit

These algorithms are used to process images and identify pathologies. The robot combines its movement mechanisms and ultrasound sensors, which allows for effective analysis. The use of intelligent medical robots in clinical practice has many advantages. They bring innovation to medical practice, increasing not only the quality of diagnostics, but also the efficiency of working with patients. Robots help minimize errors, as they always provide highly accurate and consistent results. Automatic analysis and rapid diagnostics save time for doctors and enable faster care for patients. Intelligent robots can be integrated into telemedicine systems, allowing patients living in remote areas to receive remote care.

Part No.	Time spent on a 3D printer	Theft of consumables	Length of consumable material
1	13 hours 14 minutes	168 grams	56.49 meters
2	28 minutes	4 grams	1.44 meters
3	23 hours 5 minutes	176 grams	59 meters
4	5 hours 50 minutes	46 grams	15.55 meters
5	28 minutes	4 grams	1.42 meters
6	28 minutes	4 grams	1.44 meters
7	23 hours 5 minutes	176 grams	59 meters
8	5 hours 47 minutes	46 grams	15.53 meters
9	28 minutes	4 grams	1.42 meters
10	2 hours 35 minutes	25 grams	8.48 meters

11	1 hour 57 minutes	17 grams	5.86 meters
12	1 hour 57 minutes	17 grams	5.86 meters
13	2 hours 35 minutes	25 grams	8.48 meters
14	23 hours 5 minutes	17 grams	59 meters
15	5 hours 53 minutes	46 grams	15.52 meters
16	28 minutes	4 grams	1.42 meters
17	28 minutes	4 grams	1.44 meters
18	20 hours 41 minutes	193 grams	64.58 meters
19	1 hour 34 minutes	13 grams	4.45 meters
20	1 hour 17 minutes	10 grams	3.51 meters
21	1 hour 17 minutes	10 grams	3.51 meters
22	1 hour 34 minutes	13 grams	4.45 meters
23	12 hours 28 minutes	96 grams	32.24 meters
24	3 hours 6 minutes	22 grams	7.46 meters
25	15 minutes	2 grams	0.66 meters
26	17 minutes	2 grams	0.81 meters
27	12 hours 28 minutes	96 grams	32.24 meters
28	3 hours 6 minutes	22 grams	7.46 meters
29	15 minutes	2 grams	0.65 meters
30	17 minutes	2 grams	0.81 meters
31	12 hours 28 minutes	96 grams	32.24 meters
32	3 hours 8 minutes	22 grams	7.46 meters
33	15 minutes	2 grams	0.66 meters
34	17 minutes	2 grams	0.81 meters

Table 1. Material consumption for robot construction.

This robot will need the following types of equipment:

Unit name	Number	Specification	Official
Nema 17 stepper motor 60mm	3 pieces	-Current: 2.1 A -Step rotation angle:1.8 ° -Size: 42x42x60 mm -*Rotor diameter*: 5mm Torque: 0.65 Nm	
Nema 23 stepper motor 76mm	1 piece	-Current: 2.8 A -Step rotation angle:1.8 ° -Size: 57x57x76 mm -*Rotor diameter*: 8mm Torque: 1.85 Nm	
Nema 23 stepper motor 82mm	2 pieces	-Current: 4 A -Step rotation angle:1.8 ° -Size: 57x57x82 mm -*Rotor diameter*: 8mm Torque: 2.4 Nm	

Stepper motor driver	1 piece	-Brand: TB6600 - Voltage: 9-42 V - Current: 0.5-3.5 A	
Power supply	1 piece	Type: 24V15A Output current: 0-15A Output voltage: 24 V Input voltage: 110V-220V	

Table 2 Equipment specifications.

Intelligent robot technologies for ultrasound examinations will continue to develop in the future. With the help of new algorithms and medical technologies, robots will become more accurate and more efficient. At the same time, the full integration of robots into medical systems will allow for effective communication between patients and doctors and the integration of medical databases. Robots can also expand their technical capabilities and be used in other areas of medical diagnostics. The development of intelligent medical robots for ultrasound examinations is an innovative approach in the medical field, helping to make diagnostic processes more efficient, accurate and faster.

Conclusion. The studies conducted have focused on optimizing the ultrasound path, controlling the robot from the spot or remotely. However, among the open source studies, there is no research on artificial intelligence-based rsource for performing ultrasound using a robotIt was not possible to find, so research in this direction may allow the creation of a new type of robotic ultrasound system.These technologies will not only expand the capabilities of medicine, but also create the opportunity to provide better medical care to patients. The development of medical robots will also enable the development of artificial intelligence and machine learning technologies, which will open up new possibilities for future medical technologies

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