Journal of Engineering and Applied Sciences 12 (13): 3421-3426, 2017
ISSN: 1816-949X

Anthropomorphous Type Robot Control System Research Tests Results

[1]A.A. Bogdanov, [1]A.A. Shponko, [2]N.V. Novoseltsev, [2]M.V. Krasnobaev, [2]O.V. Tolstel
[1]Peter J. Solomon Company "SPA "Android Technics" Moscow, Grayvoronovskaya, Russia
[2]Immanuel Kant Baltic Federal University, Kaliningrad, A. Nevskogo, Russia

Abstract: Current piloted astronautics is developing with restrictions caused by human factors (specialization of crew members, duration and conditions of extravehicular activity, etc.). A competitive advantage in achieving a leading position in the piloted astronautics can be obtained through use of series of innovative solutions such as various robotic technologies. Several systems of an anthropomorphic robot that can work in low earth orbit in open space have been developed and produced. This study describes the preparation, program development and conduction of the research tests over the created control system. Collected test data analysis gives the needed information to ensure correct operation under different loads and supports further development.

Key words: Robotic system, Robot of Anthropomorphous Type (RAT), International Space Station (ISS), manipulator, control system, extravehicular activity of astronauts

INTRODUCTION

A competitive advantage in achieving a leading position in the piloted astronautics can be obtained through use of series of innovative solutions. One of them is the use of robotic systems. Such systems could provide functionality similar to the one of an astronaut in both accuracy and complexity.

Creation of such systems can be seen in the research done by foreign space agencies. Such developments are conducted also by domestic researchers (Saprykin *et al*., 2016; Esfahani *et al*., 2013). Several systems have been developed and created for these purposes: RAT manipulation system, RAT control system (Tahmassebpour, 2017) and RAT Thermal Control System (TCS) (Krochak *et al*., 2016).

According to the mentioned, it is necessary to implement some plans in way of use of nature of clean energies with approach of sustainable development and create some powerful foundations for this purpose through an overview of Iran's traditional architecture, which has paid specific attention to climate and the designations and constructions have been based on climatic approaches (Krochak *et al*., 2016).

The set of tasks solved by rat: The RAT control system is designed to control the manipulation system. There are several possible ways to control the mechatronic system of RAT: autonomous control by loaded externally program. It is possible to form a sequence of commands on a Personal Computer (PC) by an operator and their sequential execution by the manipulator. The commands are transmitted via a communication line; control by means of a Device of Copying Type (DCT) or a follow-up control system: control motion generated by the movement of an operator. In this case, a manipulator similar to the manipulator of the RAT mechatronic system acts as a DCT. The operator controls the manipulator with the help of its last link thereby forming the rotation angles that are transmitted to the RAT. The disadvantage of this method is that the intermediate links of the RAT can meet obstacles that arise in their path which makes it difficult for the manipulator to work and can lead to their preliminary failure; control of the movement of all links of the manipulator-the principle of "similarity". This method is done with the help of full-size DCT by reading the changes in the position of the body parts of the operator. This is archived by a lever circuit connected to the operator's arm. The suit's levers have a feedback function. The formation of forces on servo drives ensures that the operator is informed of obstacles that occur on the path of the manipulator links. Such a control method can be used as a learning system for the RAT by forming the simplest stereotyped movements that will be recorded in the database and then form the RAT motion program. The most optimal way to control the mechatronic system of PAT for performing various operations in the complex conditions of the open space and on the surface of the planets will be the DCT with the possibility of autonomous control. The software method complements the main management method, expands the possible area of use of RAT without operator involvement.

Corresponding Author: A.A. Bogdanov, Peter J. Solomon Company "SPA "Android Technics" Moscow, Grayvoronovskaya, Russia

Preparation for control sytem tests: The main goal of the research tests of the RAT model control system is to check the developed and manufactured system for compliance with the following requirements:

- The maximal mismatch of movements of the manipulator should not exceed 0.08 rad (4.58°) when controlled by an operator using DCT
- The control system should provide a sustainable remote connection at a distance of at least 4 m, namely
- The delay time of the control signal and the feedback data must not exceed 100 msec
- The number of control packets lost during data transmission (at distances not exceeding 35 m) should not exceed 12%

MATERIALS AND METHODS

Research tests program and methods development for the rat control system: In accordance with the requirements for the RAT model control system, the following test program was developed: testing the control system for the desynchronization of manipulator movements. This test allows confirming the accuracy of transformation of the movement actions produced by the RAT model control system.

Testing the control system of the RAT for the stability of the remote control of the manipulator. This test allows finding the reliability of the developed control system which is an important factor for using the developed system for functioning in the conditions of open space. In accordance with the requirements developed in this test, it is necessary to verify the reliability of the data transmission channel between the device for generating and issuing control signals and devices that receive and convert control signals. The following methods of research tests were developed.

Movement desynchronization test: Since, the RAT control system should ensure the movement of joints of the manipulation system with the specified accuracy, therefore, during this test it is necessary to determine the accuracy of the manipulator movements according to the commands received from the control system (Zhidenko and Kutlubayev, 2014). To do this, it is sufficient to rotate the joints of the manipulation system of the RAT to a specified angle and compare the actual position of each joint (according to the special software of the control system) to the target position.

To determine the error margin in various operating conditions, control sequences for movement with different speeds as well as with a sudden change in the direction of motion were developed. When performing movements according to these control sequences, it is possible to objectively estimate the value of errors of the manipulation system of the RAT in modes of different intensity. Both long pauses for achieving the manipulator of a stable position and fast changes in the direction of motion to determine the edge values are included in the developed sequences.

Since, the links of the manipulation system are arranged sequentially with simultaneous use of the manipulation system in the movement of all joints, there is an additional load that the control system must correctly process and ensure accurate positioning of all joints. In this regard, the control sequences set the simultaneous rotation of all the joints of the manipulation system of the RAT.

During the test, the target and actual angles of rotation of each joint are fixed with a resolution of 0.005 sec. The magnitude of the error is calculated separately. The number of control operations performed is six. If the absolute difference of the angles does not exceed 4.58° (0.08 rad) for any of the joints during the whole test, the RAT control system is considered to have passed the test.

Manipulator remote control stability test: During this test, it is necessary to make a standard control sequence, during which it is possible to record the data packet loss and the delay between control and the feedback data. To eliminate the randomness factor and ensure the reliability of the data obtained, the manipulation system of the PAT layout is controlled from a distance of <10 m, the tests are conducted in different load modes.

To obtain the specified data, control sequences for movement with different speeds were developed as well as with a sudden change in the direction of motion. Such control modes allow estimating the noise immunity of the control system both in the rest mode and in the mode of intensive data transmission. The response time and the number of packets sent, received and lost is saved using the built-in tools of the special control system software and the standard tools of the windows operating system. Then the analysis of the received data is carried out: Calculation of the average time of the signal lag and the number of lost data packets from the total number of sent and received data during the operation.

A total of six control operations are performed. If the average time lag of the signal does not exceed 100 msec and the number of lost data packets does not exceed 12%, then the RAT control system is considered to have passed the test.

RESULTS AND DISCUSSION

Conducting research tests on the rat control system: Research tests of the control system were carried out at the Immanuel Kant Baltic Federal University, at the laboratory "Intellectual Robotics". The research was done in accordance with the program and methods of research tests for the RAT model control system. Based on the test results, several protocols were created. Figure 1-6 graphically represent the process of testing under subparagraphs 1 and 2 of the test program. The research tests results are represented in Table 1 and 2.

Summary: Research tests of the RAT model control system gave the following results: as can be seen from Table 1, the maximum value of the error value was 4.15°. That is considered as an acceptable error. The average delay time of the control signal and the feedback data did not exceed 4 msec and the maximum percentage of lost packets was 0.36%. It is also an allowable result. Therefore, the conducted research tests can be considered as successful.

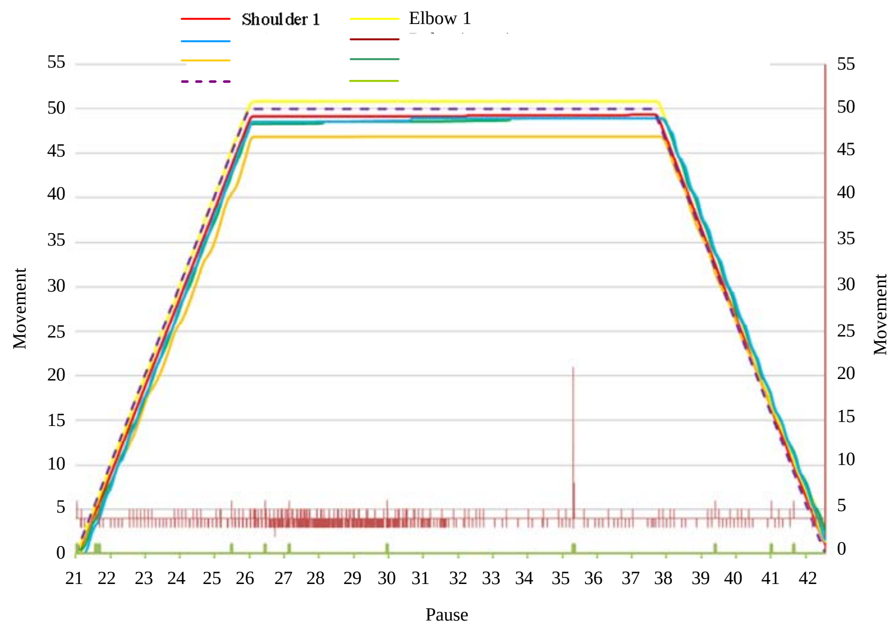

Fig. 1: Research test No. 1: 5 sec movement, 11 sec pause, 5 sec movement

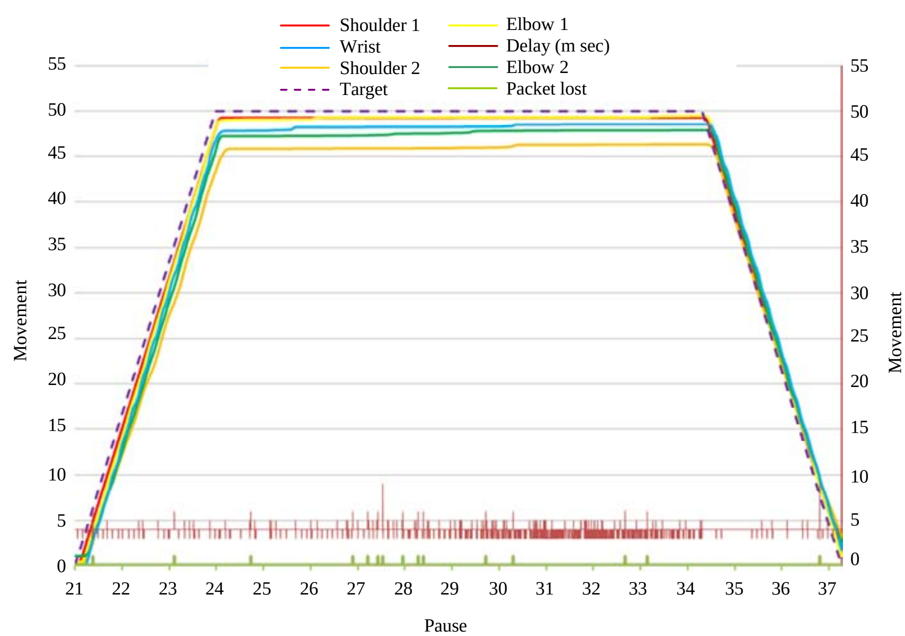

Fig. 2: Research test No. 2: 3 sec movement, 10 sec pause, 3 sec movement

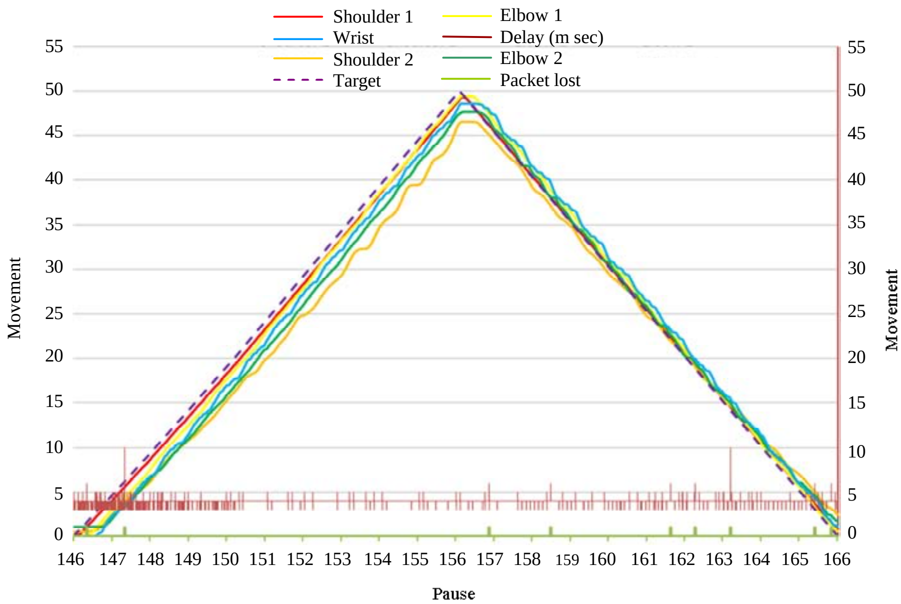

Fig. 3: Research test No. 3: 10 sec movement, No. pause, 10 sec movement

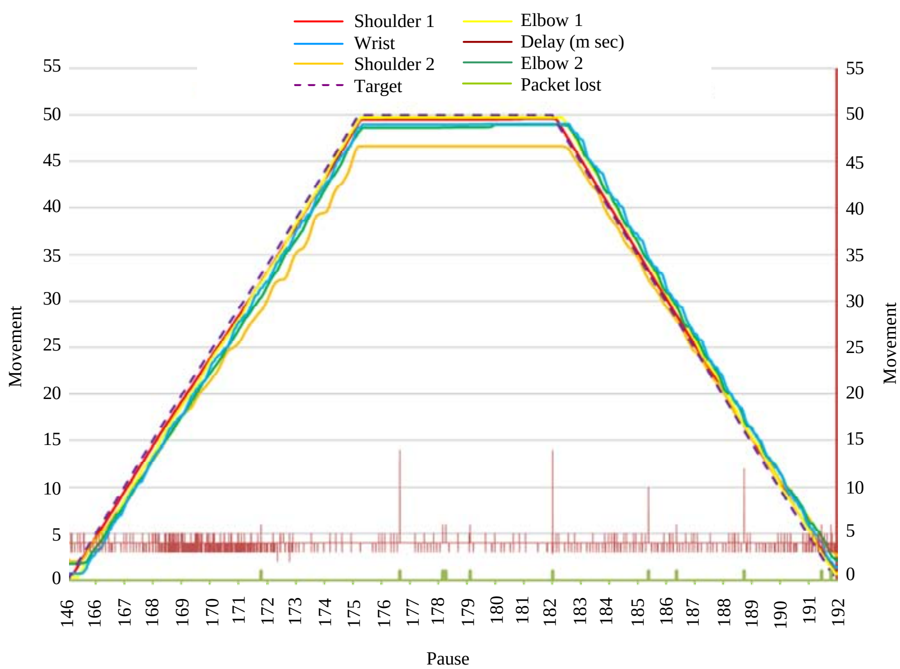

Fig. 4: Research test No. 4: 10 sec movement, 7 sec pause, 10 sec movement

Table 1: Movement desynchronization test results

Target joint position (°)	Shoulder 1 (°)	Shoulder 2 (°)	Elbow 1 (°)	Elbow 2 (°)	Wrist (°)
0.00	0.01	0.26	0.27	0.35	0.07
50.00	0.84	3.13	0.82	1.71	1.43
0.00	0.24	1.97	0.87	2.05	1.28
0.00	0.11	0.06	0.34	0.96	0.46
50.00	0.74	4.15	0.92	2.72	2.14
0.00	0.15	1.45	0.34	1.43	0.90
0.00	0.14	0.50	0.08	0.98	0.03
50.00	0.96	3.59	0.77	2.53	1.57
0.00	0.69	2.40	0.54	1.66	0.97

Table 1: Continue

Target joint position (°)	Shoulder 1 (°)	Shoulder 2 (°)	Elbow 1 (°)	Elbow 2 (°)	Wrist (°)
0.00	0.67	2.39	0.53	1.66	0.94
50.00	0.48	3.34	0.31	1.37	1.02
0.00	0.46	1.93	0.36	2.06	0.97
0.00	0.11	0.37	0.29	0.62	0.53
50.00	0.90	3.70	0.37	1.85	1.40
0.00	0.60	2.28	0.50	1.67	0.83
0.00	0.60	2.28	0.50	1.67	0.83
50.00	0.46	3.61	0.25	0.98	0.70
0.00	0.45	1.94	0.35	2.05	0.78

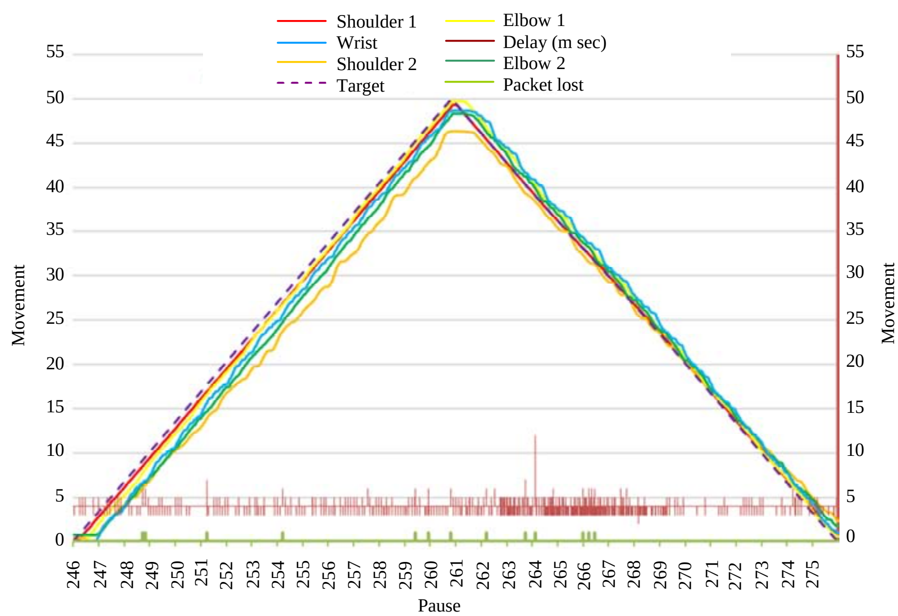

Fig. 5: Research test No. 5: 15 sec movement, No. pause, 15 sec movement

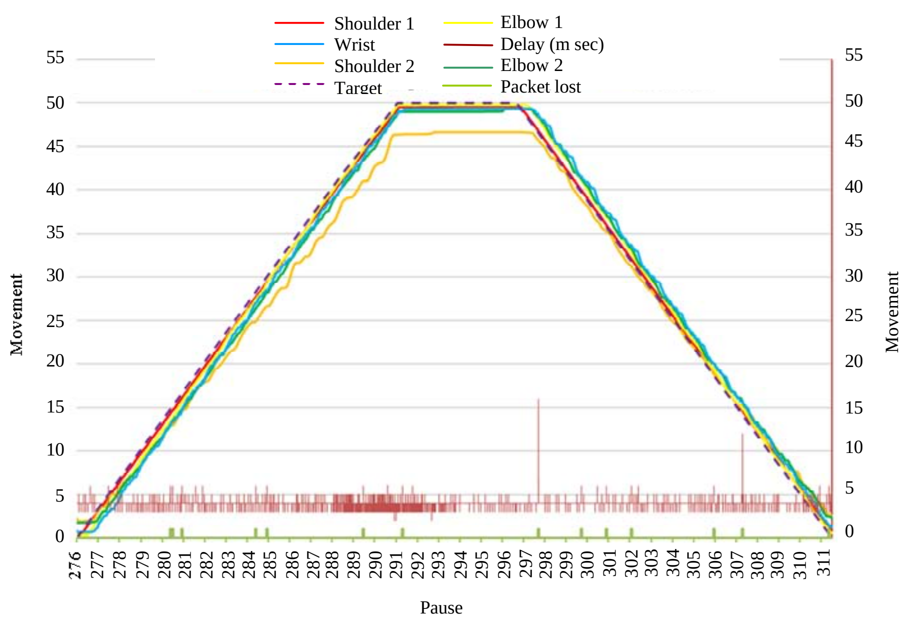

Fig. 6: Research test No. 6: 15 sec movement, 5 sec pause, 15 sec movement

Table 2: Remote control stability test results

Average signal lag (msec)	Data packets lost (PCs)	Total data packets	Data packets lost (%)
3.91	12	5498	0.22
3.87	15	4150	0.36
3.93	9	5106	0.18
3.92	11	6875	0.16
3.94	13	7642	0.17
3.93	14	9054	0.15

CONCLUSION

The control system research tests have been successfully prepared and executed, all of the results comply with aforementioned requirements. Collected data will be used in further development of the control system and other parts of the project.

ACKNOWLEDGEMENT

The rsearch was supported by Ministry of Education and Science of the Russian Federation under the agreement No. 14.578.21.0141 (unique project identification number RFMEFI57815X0141).

REFERENCES

Esfahani, M., M. Emami and H. Tajnesaei, 2013. The investigation of the relation between job involvement and organizational commitment. Manage. Sci. Lett., 3: 511-518.

Krochak, L.Z., P.N. Chubov, O.V. Tolstel and O.A. Saprykin, 2016. Thermal control system of the robot of anthropomorphous type for work in space near iss and on the moon surface. Intl. J. Pharm. Technol., 8: 26708-26717.

Saprykin, O., E. Baksheeva, V. Safronov and O. Tolstel, 2016. About the concept of using anthropomorphic robots during human exploration of the Moon. ARPN. J. Eng. Appl. Sci., 11: 9674-9679.

Tahmassebpour, M., 2017. A new method for time-series big data effective storage. IEEE Access, 2007: 10694-10699.

Zhidenko, I.G. and I.M. Kutlubayev, 2014. Method of definition of control signals of anthropomorphic manipulator. Mechatronics, Autom. Control, 2014: 41-47.