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ANALYSIS AND MODERNIZATION OF THE DUAL MANIPULATOR OF SERVICE ROBOTS

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Abstract

In this study, some shortcomings in the design of the manipulator were identified. In order to improve the design of the AMUR-307 service robot, a search for existing more advanced alternative solutions was conducted. The uArm robot was chosen as a prototype for structural solutions. A new scheme of a two-link parallel-plane manipulator was proposed, which orients the end effector of the manipulator in a horizontal position.
A 3D design of the upgraded manipulator for the AMUR-307 service robot was created. By analyzing the obtained 3D model using the KOMPAS-3D computer-aided design system, the workspace of the manipulator was determined and a kinematic diagram of the manipulator's link movements was constructed, which allowed identification of additional useful functions. The analysis of the manipulator's drive showed, that its existing design does not meet the declared technical characteristics of the AMUR-307 service robot. A comparative calculation of the manipulator's drive was carried out using a cyclo gear box and the existing design. The use of a cyclo gear box as part of the drive for rotating the manipulator's links allowed for an increase in torque and a reduction in the size of the drive. The manipulator is also supposed to be used on crawler and walking robots.

Keywords: Service mobile robots; parallel-plane kinematics of manipulators; cyclo gear box; parallelogram mechanisms and it's 3D workspace; kinematic diagram.

1. Introduction

Keldysh Institute of Applied Mathematics with partners is engaged in the development of service robots to assist medical personnel in moving objects between rooms within a single building. The developed mobile service crawler robot, AMUR-307, can capture and hold objects weighing 5-7 kg. The manipulator's design consists of two rigidly connected manipulators that have parallel-plane kinematics (see Figure 1).

Fig. 1. 3D model of the AMUR-307 service robot

2. Description of kinematics

The manipulator has 2 links, which are swivels with angular movements [3]. We use an angular coordinate system. This design is compact due to the ability to fold almost completely without protruding beyond the dimensions of the robot base.

The lower link performs planar angular displacement using a drive installed in the robot's base. This drive consists of a worm gear motor connected to a two-stage spur gear. The upper link performs angular displacement using a cable transmission connected to a similar drive installed in the robot's base. Another drive is required for the angular displacement of the manipulator's gripping device.

Since the cable transmission in the considered manipulator is open and the distance from one pulley to another is about half a meter, it poses a danger to the user.

Based on the identified shortcomings, a search for existing more advanced analogues was carried out. As a result of the search, a two-link robot manipulator uArm, produced by the Chinese company Ufactory, was identified (see Figure 2).

Fig. 2. uArm Swift Pro robot manipulator as a prototype.

The feature of this manipulator's design is that the drives of the first and second links are located in the robot's base. The driving motion is transmitted through a linkage, that connects the drive to the link. This mechanism is similar to a parallelogram. This allows the use of a less powerful drive compared to the option, when the drive is installed in the link's hinge. The working tool of the manipulator is connected to the hinge of the first and second links by a linkage fixed to the base. This allows the working tool always maintain a horizontal position and eliminates the need for an additional drive with angular displacement.

3. Modernization of the manipulator

Based on this manipulator, an upgraded design was developed (see Figure 3). This manipulator consists of two linked manipulators. All drives of these manipulator links are installed in the robot's base to reduce its weight and increase its load capacity. The lower link is connected directly to the drive. The upper link is connected to the drive through a linkage. The described mechanism represents a set of parallelogram mechanisms (see Figure 4). The working tool of the manipulator is connected by two linkages, one end of which is connected to the triangle through hinges. The other end of the linkages is connected to the base and the working tool through hinges. In this case, the working tool always maintains a position close to horizontal.

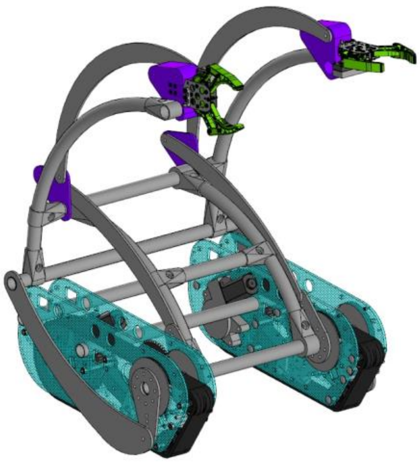

Fig. 3. 3D model of the upgraded design of the AMUR-307 service robot

To install objects with the manipulator's working tool for subsequent transportation, a table was added to the design. It contains another parallelogram mechanism, indicated in red in Figure 4. Thanks to this mechanism, the table remains in a horizontal position regardless of the manipulator's position. The inclined sides of the parallelogram form the lower link of the manipulator and the rear lever.

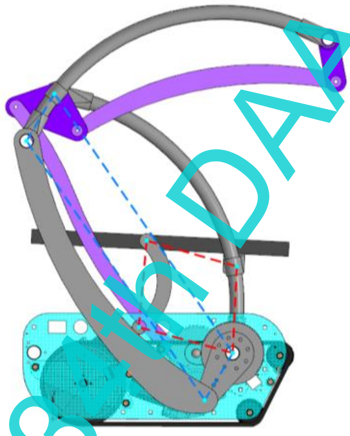

Fig. 4. Parallelogram mechanisms in the upgraded design of the AMUR-307 service robot

The movement of the upgraded three-dimensional model of the manipulator was analyzed using the KOMPAS 3D modeling software, and the extreme points of the manipulator's workspace were determined. By connecting them, the workspace area was constructed. The resulting kinematic diagram of the manipulator's links movements was constructed is shown in Figure 5.

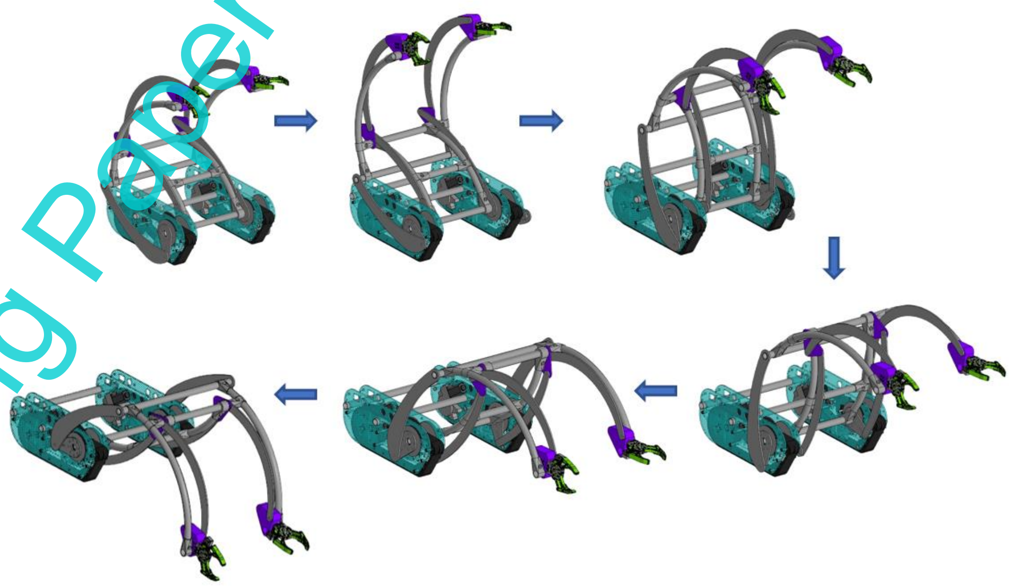

Fig. 5. Kinematic diagram of the manipulator's links movements of the AMUR-307 service robot

The drive of the lower link has the ability to rotate 360 degrees. This rotation mode allows the robot to perform stepping movements, which can be an additional function for overcoming obstacles during the movement of the crawler chassis. Figure 6 shows the workspace of the obtained manipulator.

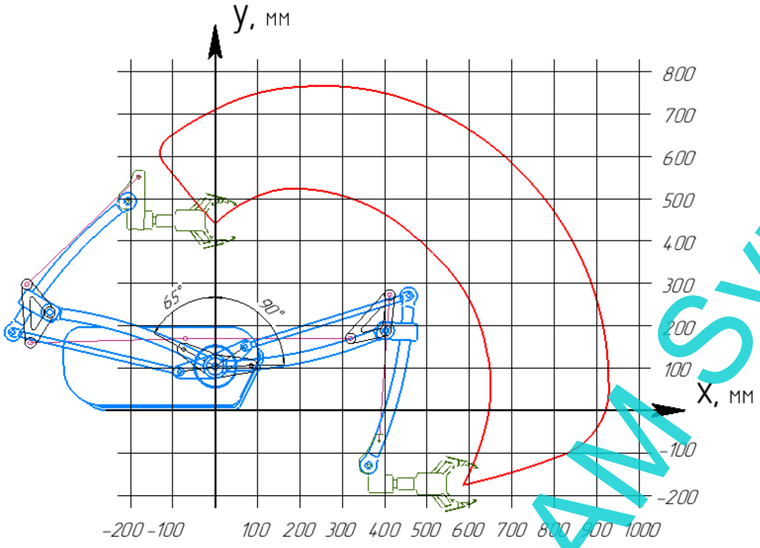

Fig. 6. Workspace of the AMUR-307 service robot manipulator

The obtained workspace of the manipulator is sufficient for performing the necessary technological operations by the AMUR-307 service robot.

4. Research of the manipulator drives

The existing design of the AMUR-307 service robot manipulator included worm gear motor connected to two-stage spur gear as the drives of the manipulator links (see Figure 7).

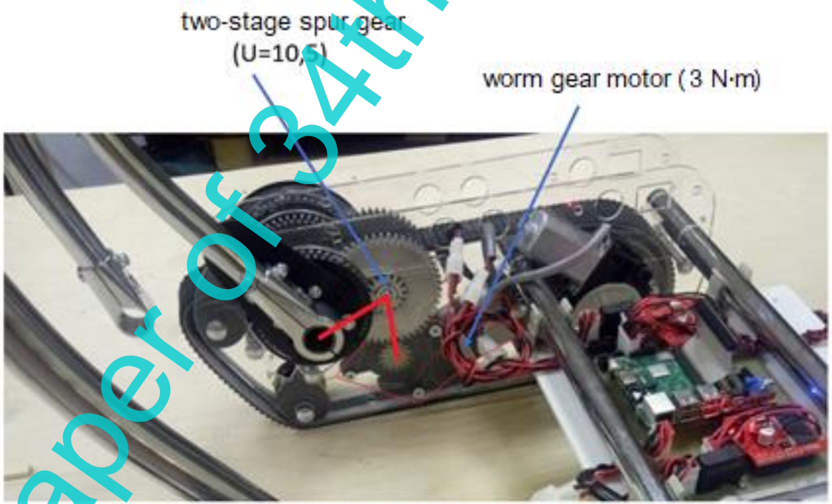

Fig. 7. Design of the drive for the lower link of the AMUR-307 robot

The nominal torque of the worm gear motor is 3 N·m. The two-stage spur gear has a gear ratio U = 10.5.

With these drive parameters, without taking into account the safety factor, the total torque of the entire drive is equal to:

$$M = U \cdot M(w.g.) = 30.5\ N \cdot m$$

The required torque for one of the connected manipulators with a load on the entire manipulator of 7 kg is 84.5 N·m. With the main parameters of the manipulator, where the safety factor is 1.3, the load mass is 3.5 kg, the manipulator mass is 3 kg, and the length of the first and second links of the manipulator is 0.4 m and the length of the manipulator's working tool is 0.2 m.

This drive is not powerful enough for the declared characteristics of the AMUR-307 service robot. Taking into account the conclusions obtained from earlier publications [1] and [2], it was decided to replace the two-stage spur gear with a modified cyclo gear box with a gear ratio of U = 29. This drive has a torque of 87 N·m, more compact dimensions, and a lower mass.

Fig. 8. Crawler and underwater walking robots

5. Conclusion

The upgraded kinematics and design of the manipulators made it possible to significantly improve such indicators as the load capacity of the manipulators - up to 30-40% of the total weight of the robot. It became possible to capture large-sized objects with two grips at the same time for further loading onto a built-in table-cargo platform. The same manipulator is also suitable for installation on a larger crawler robot (120 kg), as well as on an underwater walking apparatus [3-6], Fig. 8. The control and planning of the trajectories of such robots is carried out on the basis of earlier developments [8-12, 14-15]. The study was partially funded by the grant from the Russian Science Foundation № 22-21-20115 and with KIAM support.

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