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PROGRAMMING OF OBJECT CAPTURE SYNERGIES FOR MOBILE SERVICE ROBOTS

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Abstract

When creating service mobile robots with manipulators used in cramped rooms (home/office/hospitals), there is a problem of capturing and transporting both small-sized objects, that make up a significant part of the robot's weight. When constructing the control of the lifting process of such objects, the task of dynamic capture arises while maintaining the stability of the robot. The article considers the solution of the problem of countering the overturning of the AMUR-307 robot with a two-armed manipulator circuit. The basis for the construction of such control is proposed to take the solution of the dynamics problem using the kinetostatics method. The article describes the conditions for tipping the robot. The application of the synergy of movements is considered. The synergy of movements consists of simultaneous acceleration of the transport platform and the gripping movement of the manipulator. Recommendations are given to increase the load capacity depending on the removal of the object outside the support surface of the robot.

Keywords: Robotics; Mobile Service robot; Movement synergy algorithms for heavy object manipulation; Kinetostatic dynamics analysis.

1. Introduction

Designers of modern mobile robots approach the problem of stability using several techniques. The most obvious way is to use a structure with the widest possible support area and limit the working area in such a way, that almost any movement of the robot could not lead to overturning. The disadvantage of this approach is the large dimensions of the robot, which negatively affects the mobility of the MR. An example of such a robot is the KUKA youBot robot (Fig 1a and [9]).

Another approach is to use a special design of the robot manipulator, which, in case of overturning, allows you to restore the vertical position of the robot. Otherwise, the problem is solved by using outriggers, when the robot is working. The advantage of such structures is an increase in the support area. A significant disadvantage of this approach is the inability to move the robot during the manipulator operations. An example of a robot with this approach is the Husqvarna DXR 310 disassembly robot (Fig 1b).

It is possible to use a multi-track design of variable geometry (Fig 1c) allows not only to increase the stability of the robot without losing the ability to move, but also to overcome various obstacles. However, these designs are relatively complex in technical execution.

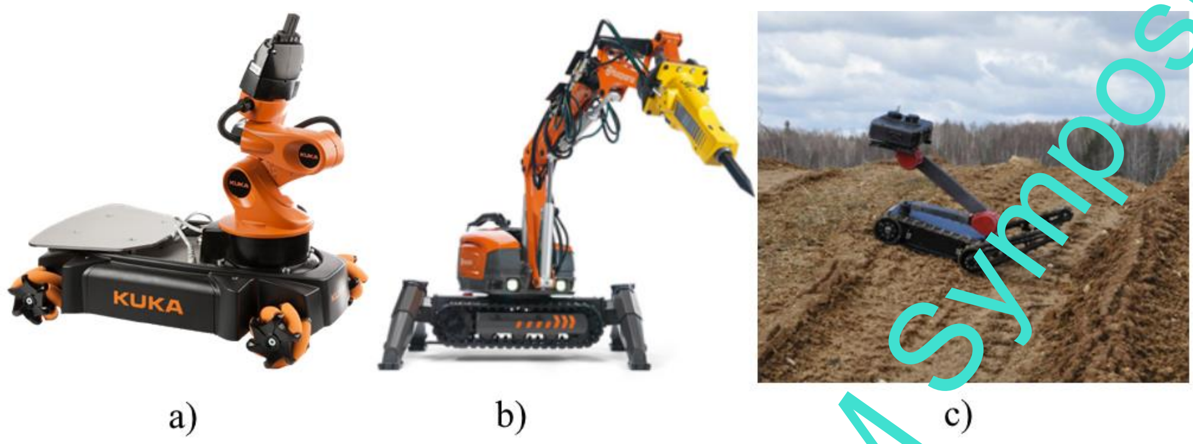

Fig 1. Examples of the mobile robot design.

The topic of kinetostatic analysis of industrial robots is widely covered in the literature, for example, see the monograph [1] and the article [2]. However, in these works, the kinetostatic analysis of industrial robots of various configurations is consecrated. At the same time, the kinetostatic analysis of mobile robots is not considered. For mobile robots, dynamics analysis is often performed using third-party systems for solving the dynamics problem [3] or using the Lagrange method [4], [5].

The advantages of the kinetostatic robot model [6] are the absence of integration operations. This makes it possible to use this model as part of the on-board software of the robot both in the classical form [7] and in the form of separate modules [8].

2. Object capture strategy

The following object capture strategy is proposed (Fig 4):

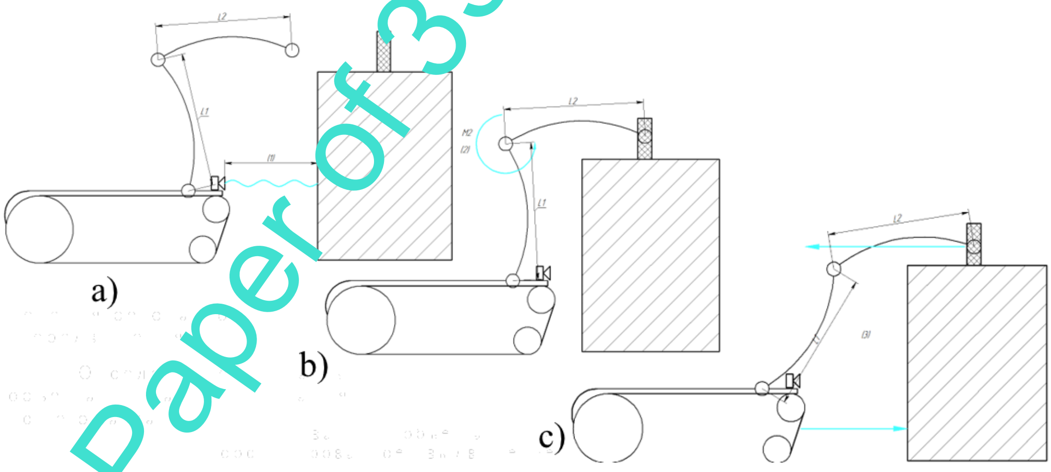

Fig 2. Object capture strategy

Navigation system data is used to determine the safe area of movement during capture (Fig 2a). The mass of the manipulated object is determined, when it is captured, using a special test movement (Fig 2b). The object of manipulation is transferred inside the service area to the transport table, while the robot is moving forward in a coordinated manner to maintain balance (Fig 2c).

3. Robot rollover condition

Using the kinetostatic model of the robot's capture of an object, considered earlier, it is possible to determine the stability of the robot during this operation.

The equations of moments, relative to the front and rear support points. Equation, relative to the front support point:

$$\vec{M}_{Nb} = -\left(\vec{M}_{MF} + \vec{r}_{FNf} \times \vec{F}_{10} + \vec{r}_{mNf} \times (m_0\vec{g}) - \vec{r}_{m0Nf} \times m_0\vec{a}_{m0}\right) \quad (1)$$

$\vec{M}_{Nb}$ the sum of the moments of the reaction forces of the supports relative to the front fulcrum;
$\vec{M}_{MF}$ – the sum of the moments of the manipulator forces acting relative to the front fulcrum;
$\vec{r}_{mNf} \times (m_0\vec{g})$ – the moment caused by the action of gravity on the transport platform;
$\vec{r}_{m0Nf} \times m_0\vec{a}_{m0}$ – the moment caused by the action of the inertia force on the transport platform;

If we assume, that the right coordinate system is used in the calculation, then it is obvious, that the stability condition of the robot is:

$$\vec{M}_{Nb} < 0 \quad (2)$$

If the reaction moments directed towards the support plane are necessary to maintain equilibrium, which is impossible, then the robot will lose stability and tip over.

Similarly, it is necessary to write down the equation of moments relative to the rear support point:

$$\vec{M}_{Nf} = -\left(\vec{M}_{MB} + \vec{r}_{FNb} \times \vec{F}_{10} + \vec{r}_{mNb} \times (m_0\vec{g}) - \vec{r}_{m0Nb} \times m_0\vec{a}_{m0}\right) \quad (3)$$

The condition for the stable position of the robot will be the equation

$$\vec{M}_{Nf} > 0 \quad (4)$$

It is worth noting, that the cases $\vec{M}_{Nb} = 0$ and $\vec{M}_{Nf} = 0$ are boundary positions and theoretically stable. However, for a mobile robot, such a position is unsafe, so we can assume, that the robot is not stable.

5. Simulation results

The simulation of the object capture by a robot with objects in various masses was carried out. The image (Fig 3) shows the location of the robot's masses (gray points) and the direction of acceleration (green lines) at the initial (Fig 3a) and final positions of the manipulator (Fig 3b).

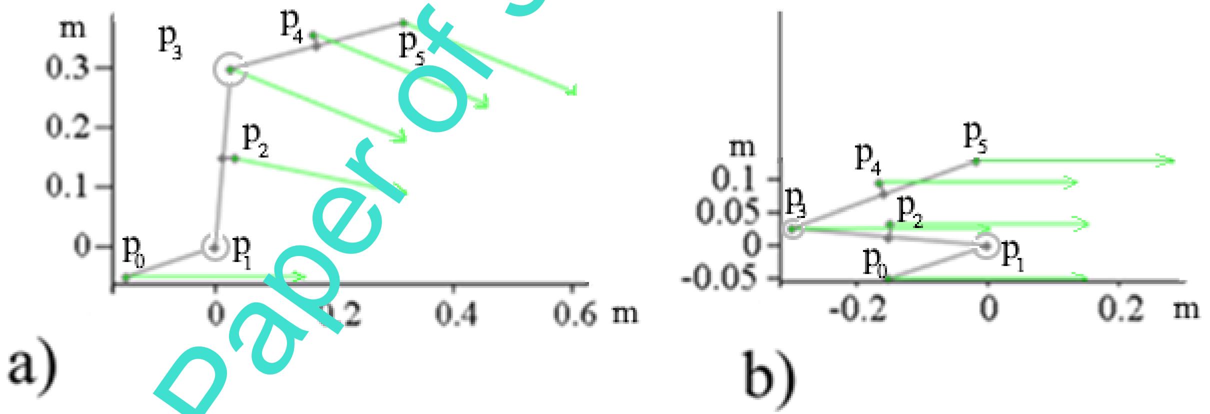

Fig. 3. The starting and ending positions of the manipulator (side view).

p_0 – position of the center of mass of the transport platform
p_1 – position of the first manipulator joint
p_2 – position of the center of mass of the first manipulator link
p_3 – position of the second manipulator joint
p_4 – position of the center of mass of the second manipulator link
p_5 – position of the center of mass of the manipulator

As a result, data on the maximum permissible weight of the object, that the robot is able to lift was obtained.

The object in forward position	Without acceleration	With platform acceleration 0.15 м/с^2	With platform acceleration 0.3 м/с^2
0.286 m	5.80 kg	6.35 kg	6.95 kg
0.312 m	5.15 kg	5.60 kg	6.10 kg
0.322 m	5.00 kg	5.35 kg	5.75 kg
0.403 m	4.00 kg	4.30 kg	4.60 kg
0.420 m	3.35 kg	3.55 kg	3.80 kg
0.530 m	2.45 kg	2.65 kg	2.80 kg

Table 1. Maximum mass of the captured objects

Based on the graphs of the reaction moment of the supports (4) relative to the front point (Fig 4), it can be concluded, that the acceleration of the robot platform must be maintained only at the initial stage of movement.

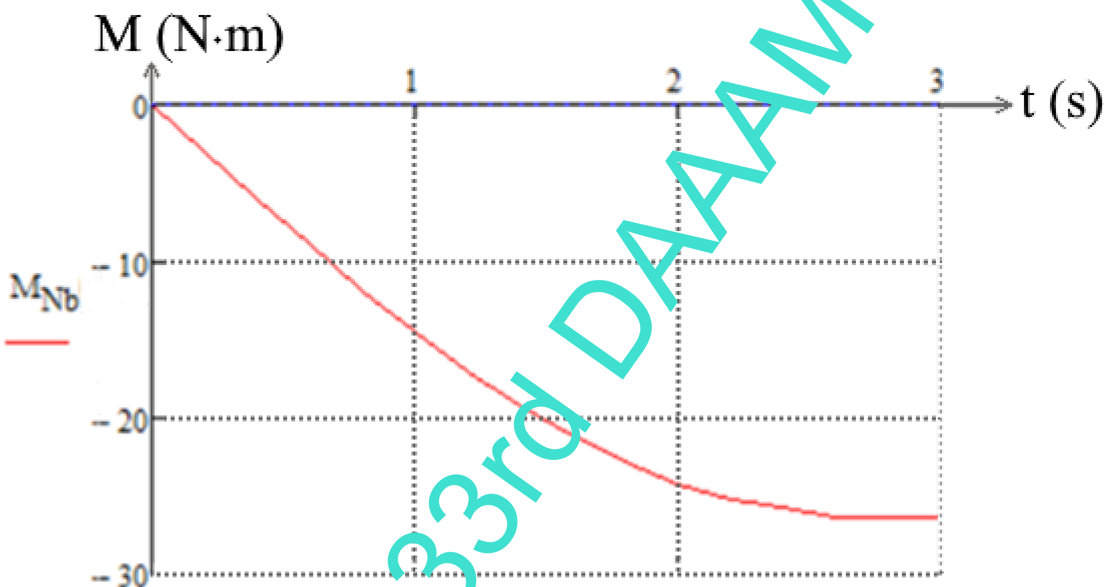

Fig. 4. The reaction moment of the supports, relative to the front point.

The simulation shows (Table 1), that the additional acceleration of the robot during object capturing allows you to get an increase in load capacity up to 14-20%. The amount of additional mass depends on the configuration of the manipulator during capturing. For example, the higher the output link is, the greater the gain will give additional acceleration of the platform.

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