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Wheeled and Walking Platform Motion Algorithm

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Abstract

Some tasks require accurate movement of loads when the vehicle acceleration transmitted to the load is limited and the load needs to be moved over a rough terrain. This problem may be solved either by improving the quality of the wheel suspension (by using a softer suspension), or by using a purely walking mechanism[1]. This paper suggests a new approach that combines wheeled and walking mechanisms. Walking algorithms are used for rough terrains, while traditional wheels are used for flat surfaces. Such approach for the wheeled and walking platform may be used for various purposes – from elimination of the consequences of accidents and disasters (transportation of the wounded persons) to exploration of natural resources[10].

Keywords: Algorithms, Robotics, Robot, Wheeled and Walking Platform

1. Introduction

The need for sustainable motion of various mobile platforms over rough terrains points out obvious insufficiency of the traditional ('classic') types of propulsion sources, including wheeled, tracked, combined wheeled and tracked vehicles and other types of devices.

The wheeled and walking system shown in Figure 1 is proposed for the improved performance.

Each wheel is installed on a manipulator with 2 degrees of freedom[5], which allows controlling the drive system in a wide variety of ways.

Some tasks require careful transportation of loads on uneven surfaces.[2-6,13,20] 'Careful transportation' means a motion in which the load is experiencing minimal acceleration in all directions and axes.

2. The Conceptual Basis of the Method

In order to achieve accurate motion of the platform on an uneven surface, the motion itself is performed by the rotating manipulator joints, on which the wheels are installed. The wheels are required in order to provide support to the underlying surface. The platform moves forward at the same speed.

Figure 2 shows motion of the platform drive gears.

This figure demonstrates that wheel 1 is moving to the initial, i.e. the most advanced forward position. Such motion is known as a translational motion. The other wheel, which is approaching the end of the range, is, probably, wheel no. 3. It is followed by wheels no. 5, no. 2, no. 6 and no. 4. Then the sequence is repeated.

Once wheel no. 1 moves forward and is able to provide the required support force on the underlying surface, wheel no. 3 will start the translational motion. The entire platform is moved only as a result of motion of the wheel manipulators. Of course, such type of motion is justified only for driving on an uneven surface, because the required smooth ride quality is achieved by simple rolling of all six wheels.

Figure 3 shows a motion sequence diagram for all wheels. Such sequence diagram shows translational motion using semi ellipses, and regular motion of manipulators is shown by straight lines.

3. Solution of the Problem

Let us formulate quantitative relations for such motion.[14]

Assume the following length parameters of the wheel manipulator links: Shoulder (first) link – a, elbow (second) link – b. Suppose also that the platform clearance is h.

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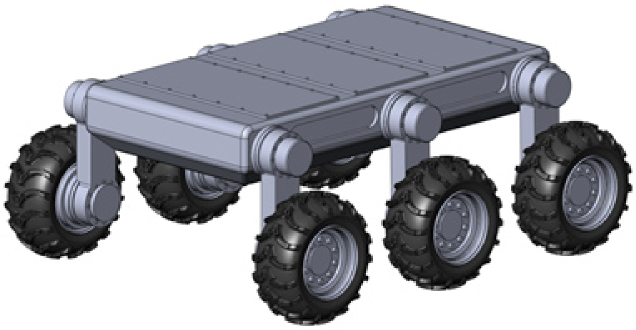

Figure 1. External appearance of the wheeled and walking platform.

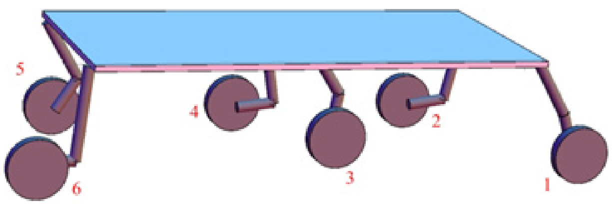

Figure 2. Design of platform drive gears.

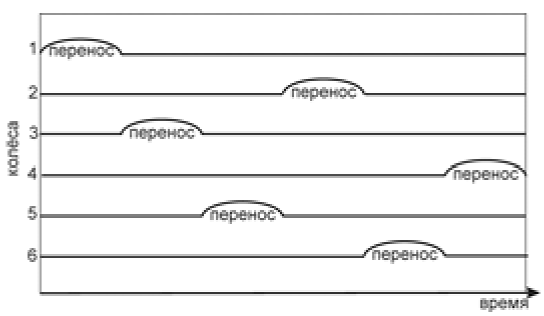

Figure 3. Motion sequence diagram for all wheels.

The following restriction emerges: 'walking' is possible if a + b > h.

The condition for the start and end of the translational motion is shown in Figure 4.

Horizontal line in this figure refers to an imaginary surface, in respect of which h clearance should be maintained. The translational motion may take place in any way: Rolling of the released wheel over the underlying surface; 'ambling', when the shoulder moves first, followed by the elbow, just like a person walks, or the wheel is carried over the top.[11]

Let us consider the translational motion when the wheel is lifted from its initial position by the shoulder joint up to h-m level and then carried by both joints straight to the full length condition and, finally, is lowered until contact with the support.

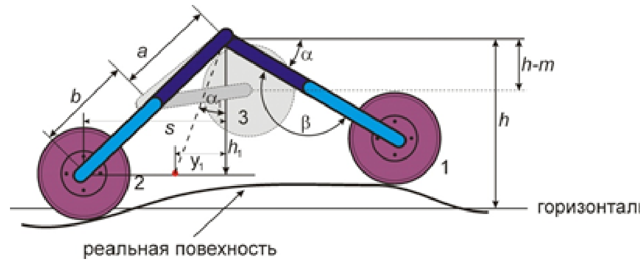

Figure 4. The translational motion triangle.

Therefore, the angle at which the wheel is raised to the desired height will be as follows:

$$\alpha_1 = Arcsin\frac{h-m}{a+b}; \tag{1}$$

Changes in the angles of the shoulder and the elbow in order to move the wheel along a straight line should be made according to such laws:

$$\alpha = v_\alpha t, \tag{2}$$

$$\beta = \alpha + Arcsin\left(\frac{h-m-a\,Sin(\alpha)}{b}\right), \tag{3}$$

Where: v_α is speed of change in the shoulder angle;

t - time.

In order to change the angles of the supporting wheels, the linear (i.e. translational) speed of the platform v_α[17] should be introduced. The actual height of the shoulder joint rotation axis above the support is denoted by h1. Then we have:

$$h_1 = (a+b)\sin\alpha$$

$$s = (a+b)\cos\alpha$$

$$y_1(t) = (s - v_n t)$$

$$\alpha_1(t) = arctg\frac{y_1(t)}{h_1}$$

$$l(t) = \sqrt{y_1^2(t) + h_1^2}$$

$$\beta(t) = 360° - Arccos\frac{a^2+b^2-l^2(t)}{2ab}$$

$$\alpha_2(t) = Arccos\frac{a^2+l^2(t)-b^2}{2al(t)}$$

$$\alpha(t) = 90° + \alpha_1(t) + \alpha_2(t)$$

Time-dependent values in chain (4) are clearly identified as time functions. h_1 and S are the initial parameters, i.e. they are estimated once – at the end of the translational motion when the wheel is leaned upon the underlying surface[7].

4. Discussion

Using chain (4), the desired quality of the mobile platform motion may be achieved, as the platform does not 'ride' on the surface, but is moved by the much more accurate manipulator wheels.

One aspect here needs to be taken into account. Let us look at Figure 5.

This figure shows a top view of the Mobile Robotic Platform (MRP). Support wheels are shown in green, and the translational wheel is shown in red colors. Light brown dashed lines show the geometric center of the platform, and the blue quadrangle shows the zone of stability, in which the platform center of mass (so the platform does not tilt) may be located at the moment. If we define the intersection of all 4 possible zones of stability, we will get a purple diamond, shown in the center[16,19]. The center of mass (gravity) of the platform-load complex should be located within the diamond.

At the time of the wheel separation from the support (first translational motion), and at the time of pressing it to the support (after translational motion) due to the fact that the load starts to be distributed in another way, slight oscillations may be observed.[13,15]

This effect can be minimized if we start moving the next wheel in concert with the moving one. Moreover, the other wheels may play up a little bit. Manipulator wheel drive gears are equipped with a force sensor, so that this method is quite feasible.

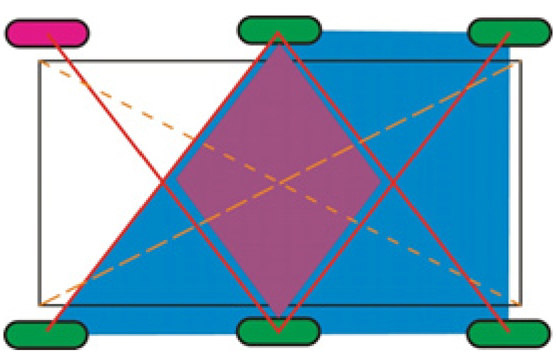

Figure 5. Load distribution on the platform.

5. Conclusion

Modeling of this method showed its complete feasibility. Moreover, the described platform with a load may automatically switch from the wheeled mode to the walking mode. This will not require any additional sensors – torque sensors in drive gears would be enough.

When driving on a flat surface, efforts in the joints of the drive gears are constant and depend only on the location of the center of mass of the platform-load system. When the platform starts running over an uneven surface with one wheel (in any case, only one wheel will be the first to collide with the uneven surface), these efforts in the joints will change. Maximum torque change will be observed for the first wheel running over the uneven surface. The algorithm of the walking start will change in such a way that the first wheel becomes the first walking wheel.

Unfortunately, it is impossible to solve (from the algorithmic point of view) the problem of defining the transition from a rough terrain to an even surface using the torque sensors in the joints[19]. Other approaches and sensors of the external environment (such as machine vision) need to be applied for this purpose.

The main limitation of such approach is obvious: Very uneven terrain, i.e. such one when the wheel suspension manipulators have insufficient dimensions (and the platform frame clearance) in order to compensate for roughness.

Such algorithms may be applied to any transport tasks with uneven surfaces, particularly for premises.

6. Acknowledgements

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