NEW DESIGN OF OFF-ROAD MOBILE PLATFORM FOR SERVICE ROBOT

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Abstract: Service mobile robots have not become market products so far, as their development emerges from the ideas of manufacturers, research centers and the institutes. The existing solutions and mechanics, sensor motorics and controlling are various. The work presents a new concept of a mobile robot platform having multiple purposes to be applied in open space on uneven terrain. The Platform has four drive wheels each having independent drive. In order to turn the drive wheels, an original spatial leverage mechanism has been designed in order to transmit motion from the motor worm gearing to the system of the drive wheels suspension. This robot has been created mainly for service and development-research purposes, but it is also intended for the educational purposes.

KEYWORDS: mobile robot, mobile platform, 4-wheel-drive/steer robot, off-road robot.

1. Introduction

Mobile robotics represents a growth of an engineering field which has achieved an incredible progress in the last decade. Today, almost every significant Faculty of Engineering has an institute researching mobile robots. In the world research institutes, different types of service robot capable of performing versatile tasks such as, transportation, searching for and saving people, investigating critical or unreachable terrains, setting the scientific instruments, exploring planets, providing assistance to old or disabled persons, assisting in the house works, for military and defense purposes, etc.

The new trends in the robotics field researches, other than traditional industrial applications, are getting more focused to robots for providing multi-functional services in unstructured environment and interaction between people and robots.

Mobile robots stand for an ideal field for researching, education and creation of values as being multi-disciplinary field which requires knowledge of different fields, such as: engineering and mechanics (design of vehicles, motion mechanism, stability), electronics (supply system, energy converters, drive wheels), computer science (programming techniques in real time, process control, knowledge presentation, image processing, speech processing and planning algorithms), electronics (controlling and communication electronics), automatics (system integration, planning and controlling mobile robots, sensors and communication), mathematics, psychology, perception and science on neurons (understanding how biological organisms solve similar problems).

Fig. 1 Conceptual map of the methodology (source: [2])

For development of robots as typical systems of mechatronics, a mechatronics method is used which is also used for development of industrial machines and for research projects in the field of mechatronics. Figure 1 [2] shows a concept of the method used. Having the tasks of mobile robot conceptual, on the very beginning of the project, the following subsystems are defined: a) team for design and simulation, b) production team, c) team for controlling and testing [2]. In case when the projects are realized by small teams, almost all team members are involved in realization of all subsystems, each subsystem is controlled by a different person.

2. Terrain robotics

Terrain or off-road robotics is a very active research domain where a significant progress has been achieved in the last years. Improvement of classic sensors and development of completely new systems, such as, 3D cameras or 3D laser scanners provide all detailed information on the robot’s surroundings. However, a large number of data generated by the sensors of high technology can be used only if sophisticated algorithms are available.

Unlike the robots that operate in closed, predefined environment, the vehicles intended to perform tasks in open environment must deal with rough, less structured environment which means much more complex world. This is particularly important when the robots leave an urban area and start moving off the roads. Lack of terrain structure, which can be easily recognized and used for navigation, makes huge challenges for performing tasks, such as: perception, navigation and environment preservation.

3. Description of mobile platform for service robots

Project task demands to design and make a mobile service robot. Design of a mobile platform on which a manipulator could be placed is required to be made. A robot is intended to move within an open area and not only along a flat road but along an uneven road as well, performing certain task. A task assigned to a robot could be: taking samples (water, gas, soil) from contaminated zone, recording critical terrain, detecting and marking mine-explosive appliance, etc.

3.1. Mobile platform design

Service robot consists of a mobile platform and a manipulator. Mobile platform is a special vehicle with four-wheel drive; motion of the vehicle is controlled having all four wheels turned. Furthermore, mobile platform is designed to have a high clearance (distance from the base), independent suspension of each wheel and wheel turns at ±45°, which ensures good performances for off-road driving. It is important to emphasis that sizes, distance between
wheels axis, and a frame construction allow high angle of clearance which is very important for overcoming the obstacles.

3.2. Drive and controlling the mobile platform

Four servomotors with a gearbox and an encoder controlled by a central controller are designed to drive a mobile platform. Executive modules and user interface will be made particularly for this vehicle. The vehicle is turned, i.e., all four wheels are controlled by a servomotor with a gearbox which turns the wheels using the system of leverage connected by the sphere joints.

3.3. Mobile platform controlling

The mobile platform and a manipulator will be controlled by a PC (laptop) through a WIFI connection with a central processing unit – a module, which will be made particularly for this service robot. CPU will be placed in the frame of the platform. PZT IP WIFI camera will be installed on the service robot so that the operator could observe on the screen space in front of the robot and to control its motion. Similar model used when driving the platform will control a manipulator (robot hand) which will be installed on the platform.

3.4. Supply

Service robot will be supplied by batteries through a module supplier 24 VDC, which will be also placed in the platform frame.

4. Construction of the mobile platform

Mobile robot platform (shown in the Figure 2) is similar to terrain vehicles. It needs to have a system for supporting a mobile platform like the vehicles. **Supporting system** includes mechanism and elements intended to transmit to the frame (chassis) all reactive forces and moments appearing between the wheels and the base, during different motions. It is necessary to absorb bump load as much as possible, and to enable required stability of the platform, particularly when moving in curves. The supporting system is generally a very complex system consisting of four separate systems or mechanisms, as follows: mechanism for controlling the wheel, elastic supports, elements for absorbing oscillation and stabilizer.

![Mobile platform appearance](image)

**Mechanism for controlling the wheels** (elements for controlling) has been designed to ensure their relative motion as much as suitable against the frame (chassis). Elements for controlling also must provide transmission of horizontal reactive forces and reactive moments from the wheel to the frame. **Elastic supports** (elastic elements) basically have task to transmit vertical reactive forces to the frame. Actually, their task is to absorb vertical forces during their transmission, that is, to reduce bump load as much as possible. Basic task of the elements for silencing is to silence oscillation of the elastic supports, i.e., the suspension system and the vehicle as a whole, and to reduce bump load.

![Basic dimensions of mobile platform](image)

The road vehicles, in addition to the above defined mechanisms and elements of the supporting system, sometimes have special elements, **stabilizers**, aiming to provide high stability of the vehicle, i.e., the mobile platform when moving in the curve. Design of the mobile platform made in Autodesk Inventor Professional 2012 is shown in Figure 3. The wheels diameter is 255 mm, and the wheels width is 20 mm. Basic dimensions of the platform are given in the Figure 3.
Mobile platform frame generally consists of a system of mechanical elements whose basic task is to ensure rigidity of the platform (the vehicle) and to allow attachment of other assemblies of the vehicle chassis (control servo motor, wheels supporting system, manipulator, battery (accumulator), control system, camera, sensor, car body, etc.). The frame should be light (small mass), to prevent shape deformation under force pressure generated when driving in extremely difficult, but anticipated conditions, following the purpose of the mobile platform. For the stated reasons, the frame has been designed by principles of a light steel construction. The frame of the mobile platform is shown in Figure 4.

A mode of the wheels suspension is shown in Figure 5. Independent wheels suspension is provided by a double frame (upper and lower) in the vertical plane. Both frames are installed over the center of each wheel aiming to enable the wheel turning at the angle of ±45° around the axis inclined for the angle $\beta$ against the vertical axis. The frames have been installed so high for the following reasons:
- To provide high clearance i.e., distance between the frame and the base which allows mobile platform to move along uneven terrain (off-road)
- Possibility to overcome obstacles along uneven terrain
- Wheels turning freely (the wheel drive is set-up in the wheel axis).

In addition to a basic function - turning the platform, driving wheels need to be able to keep a neutral position when the platform moves, i.e., turned wheels (intentionally or accidentally) tend to return to neutral position. Such ability is called - stability of the driving wheels.

5. Mechanism for turning the mobile platform

The biggest challenge for the driving mechanism of the road vehicles is to realize complete rolling with good traction of wheels in the curve. This requirement is met only if the turning center of each wheel is placed in one point- rotation center, that is, if the axes of all wheels are crossed in one point (Figure 6).

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Additionally, the wheels get stable by having a sleeve shaft installed at certain angles against the vertical axis. These angles are, as shown in Figure 7.a), in cross section, the angle $\beta$ – the angle of supporting the wheel, and in horizontal section the angle $\gamma$.

The angle $\beta$ has a double function, as follows:
- To make the shaft axis penetrate the base not too far from the center of the wheel print (as if the shaft was installed vertically), but as near as possible. Using this mode, a certain distance $a$, so-called, radius of the wheel turning is provided.
- To keep the wheel in neutral position. When the wheel is turned from neutral position around the shaft which is vertically tilted, the wheel of the vehicle placed in inner side of the curve is lifted, while the wheel being on the outer side of the curve is slightly descended (as if the wheel sank into the base), for the reason that the contact point of the wheel and the road is moved in the plane $b-b$ which is normal against the sleeve shaft axis.

The angle $\alpha$ (figure 7.a) is called the side angle of incline or the wheel inclination. The basic purpose of the side angle of incline of the wheel, in addition to impact to have the turning
radius a reduced, is also to annul influence of side clearances in the wheels bearings which must be there for the constructive reasons.

Turning, i.e., controlling the mobile platform will be performed through a servo motor with an encoder that will be placed on a frame of the mobile platform and the system of leverage with spherical joints (figure 8). Such constructive solution of the leverage system enables the wheels turning at ±45° against the vertical axis of the vehicle. Such big angle at which the wheels turn will allow extremely high mobility of the platform.

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6. Conclusion

The work contains a study of basic assumptions and requirements for the mobile robot platform. An original solution of mechanics of the mobile platform has been presented with original spatial leverage mechanism for controlling the wheels turning. Advantages of the proposed mode of the wheels suspension have also been highlighted. The turning angle of ± 45° will ensure extremely high mobility of the platform. The work provides short description of the drives and mode of the platform moving control.

The next step in designing the mobile platform for the service robot will be to select a motor, define a controlling mode, input information, sensors, etc.

The following factors are important for the mobile terrain robots: mechanical robustness, easy maintenance, low purchase costs and good usability. From the mechanical point of view, a proposed concept of mechanics of the robot platform meets these requirements in complete.

6. Literature: