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Concept for the Construction of a Universal Mobile Robot †

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Abstract: This paper presents a mobile robot concept. To understand what has led to the choice of this particular design, one must first understand mobile robots in general: what are the trends, where are they used, etc. Then, some of the necessary elements for robot propulsion and navigation were considered, looking at their principle of operation, as well as their application. A description of the robot structure follows. Thanks to the software, the approximate value of the various parameters can be calculated, and an initial three-dimensional model can be built. First, the idea of the robot will be introduced in the abstract and then be outlined in detail, showing how the various components work. It will conclude by looking at the most important elements of a mobile robot, as well as what makes a robot successful.

Keywords: mobile robot; mecanum wheel; 3D camera; sensors; automation

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1. Introduction

The technological development and progress of industries would be almost impossible without the automation of the production and other services associated with it. Mobile robotics is one of the most rapidly progressing branches of the industry nowadays. Automation through the use of mobile robotics has many advantages compared to traditional automation, such as more flexibility and efficiency. This technology also allows for increasing the capacity of enterprises, minimising the number of people involved in the manufacturing process, as well as mitigating the risk of serious injuries to the workers.

The ability to move autonomously ensures that mobile robotics have better odds to be implemented in various industries where they could serve a multitude of different tasks. The variety in their overall design is another big advantage, which makes them very versatile and flexible enough to perform tasks in different environments, including those which might be harmful to human beings. For example, in this sense the mobile robots can have diverse use in the military and defence services.

The fact that they are mobile does not mean that they cannot be as effective and precise as the static ones. In fact, in some industries, there are strict restrictions and regulations in place which can guarantee the quality and efficiency of the tasks undertaken by them. Much of their precision is by virtue of recent technological progress regarding sensors, navigation systems and actuators [1].

2. Essence and Types

Depending on the environment they operate in and the means of their movement, mobile robots can be terrestrial, flying, and moving on the surface of water or underwater. These different types of mobile robotics are widely utilised in fields like science exploration, military and defence. While flying, moving above- and underwater mobile robots are being heavily capitalised on by the aforementioned industries, terrestrial mobile robots are commonly used in other businesses.

Terrestrial mobile robots can be sub-divided into several categories: chain-tracked, wheel-based or having limbs resembling natural living beings. The chain-tracked ones are usually used for difficult-to-access terrains; hence, they are much heavier and cumbersome compared to wheeled-based mobile robots. The chain-tracked mechanism can damage the ground they are operating on. For this reason, they are mainly deployed in open spaces, serving their purpose in the military industry and agriculture. Manufacturing industries mainly utilise wheel-based mobile robots, which can offer more flexibility and reliability.

Mobile robots can be controlled remotely or be completely autonomous. The ones used in manufacturing industries and factories can orient themselves by the ground markings (for instance, a line which the robot can track). Conductors, QR codes and others can be also used as navigation markers for the robots. It is not uncommon for big factories to use multiple different robots; that is why sensors or a centralised system may be necessary for their safety functioning. The sensor systems allow the robot to avoid possible obstacles on its way (for example, factory workers or other objects), which allows for a safe work environment.

In factories, mobile robotics can be used for the transportation of goods, as well as performing a variety of other tasks such as welding, fastening bolts, etc. Most robots are adjustable in terms of the height platform, which allows them to go underneath the object before lifting it up. There are robots which can handle small objects through their mechanisms, much like industrial robots [2].

3. Required Elements

One of the required elements is the mecanum wheel (Figure 1). This is a wheel with rollers which are attached to the whole parameter of the wheel's rim. These rollers have their own axis of rotation which is usually 45° in relation to the wheel's plane and 45° in relation to the wheel's axis line. Each mecanum wheel can be moved and controlled independently. The wheel itself cannot rotate around its vertical axis, and movement in different directions can be achieved through the rotation of the rolls [3,4].

Figure 1. Mecanum wheel.

The typical mecanum wheel configuration is illustrated in Figure 2. There are four wheels, which allow for forward, backward, sideways and diagonal movements. The forward movement is achieved by the rotation of all four wheels in one direction and with the same speed of movement. When two of the wheels are rotating with the same speed and in the same direction, but the other two move in the opposite direction, the whole transportation unit turns around its vertical axis. Because of its rollers, the transportation unit can also move diagonally [4].

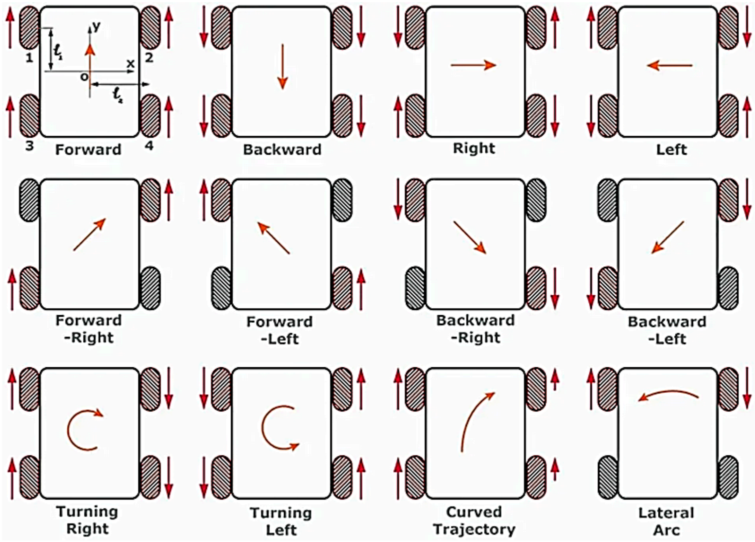

Figure 2. Configuration with four mecanum wheels.

For their navigation, most robots use 3D cameras which can detect the difference in the depth of water. In most cases, these cameras construct their 3D model from a multitude of images taken from different angles, and can thus compare the relative distances of the objects. The method used by such cameras is triangulation: two cameras record the given object, and their images are adjusted and overplayed on top of each other (Figure 3). The distance between the two cameras is known, which explains how, through the method of triangulation, the actual distance to an object can be measured precisely. In practice, we can have multiple objects and the cameras would have to calculate the distances to each one, resulting in a compilation of images, which, combined, create a 3D model of the environment, allowing the robot to navigate the space freely. There is almost not a single field where mobile robots cannot be implemented. They are mobile and can be autonomous, which makes them flexible and capable of replacing humans in mundane and monotonous tasks which usually do not require any particular qualifications in order to be completed. Not only can they carry out almost every task which manual workers can, but they can also be more efficient than them. Despite the fact they are mobile, they can also be very precise. This makes them capable of undertaking important and sometimes dangerous tasks. Whatever the type of factory or type of task they have been programmed to carry out, they ought to be the perfect assistant. They can contribute to the safety of the work environment and ease the workload of the workers so they can focus on more elaborate tasks which require tight regulations and human interaction.

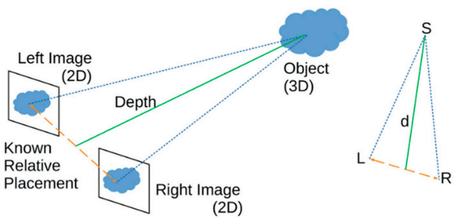

Figure 3. Calculation of the distance to the object.

For navigation purposes, it is necessary for robots to have additional sensors detecting the distance because cameras are usually located relatively high, which allows them to have wider field of view but does not allow them to detect lower kerbs, for example. In such cases, sensors detecting the distance to the object are positioned lower (Figure 4). The advantage of these sensors is that they are much more cost-efficient compared to 3D cameras.

Figure 4. Ultrasonic sensor.

Such sensors typically work on the principle of echolocation. They send signals, which can, in most cases, be ultrasonic waves (depending on the type of technology used, it can also be IR, LED, etc.) and receive back the echo signals, and can thus calculate the travel time for its return and the intensity of the signal (Figure 5) [5,6].

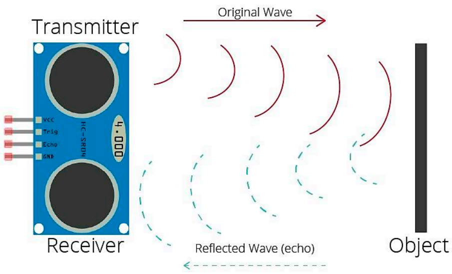

Figure 5. Work principle of ultrasonic sensors.

The information from the sensors is combined with the information from the cameras to allow the main computer to create a holistic model of the surrounding environment. This synergy enables the robot to navigate itself autonomously throughout the vicinity. Apart from that, the robot can also detect and avoid obstacles which can obstruct its way in any given moment. Other necessary elements are the modules for linear movement, batteries, and a computer. For the moving and manipulation of objects, the robot might necessitate a lightweight robotic arm. Such types of robotic arms can usually have a range of up to 500 mm and can handle up to 5 kg max load.

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4. Concept and Working Methodology

Robots can be divided into several sections. The first section has the ability to move the transportation unit. The macanum wheels, which can be controlled remotely or move autonomously, are located in this section. They are four in total and provide the machine with the ability to move independently in all directions. The energy supply comes from the battery, which is located in the centre and on a lower level so that a balance can be achieved. The battery is accessed via the access panel at the back of the machine. The main computer is situated above the battery. In this section are also located the sensors and cameras for the navigation system. The robot is connected to the internet network, enabling its control via a computer. The main requirement for safe and clean operation is that the machine has a lower centre of weight because the height of the robot can be relatively high.

The second section can be compared to an automated chest of drawers which can open and close on their own. This can be achieved by the linear movement module. For these modules to be mounted, there should be some space on both sides of the drawers. In the drawers, there should be designated spaces for objects to be placed. On top of the robot, a robotic arm is placed. It should be lightweight and it does not need to have a big range of motion because the whole robot itself is movable. On top of the robotic arm, an additional 3D camera can be placed to allow the arm to navigate itself to the given object.

Thanks to the Autodesk Inventor Professional 2025 software, the approximate weight of the entire structure can be calculated, as well as the stresses in the material obtained from simulations. This allows for the optimal dimensions of individual structural components to be chosen to reduce weight without compromising strength. Using this information, the parameters of the electric motors and the battery can also be selected. The required power of the electric motors depends on the weight of the entire robot.

Regarding the structure of the robot, we have a solid monostructural bottom composed of a single element (Figure 6). This ensures the necessary strength, which is important, since it is the main support for the framework that is mounted on it. The necessary electronics are installed on the bottom as well. The skeleton of the robot is made of rods that are attached to each other by clamps and bolts, ensuring that the robot is easy to be manually assembled. The containers are mounted on the rails, which, in turn, are mounted on the horizontal bars that are part of the skeleton. They are driven by linear actuators located below them on elements that are intended to carry them. The actuators and the supporting structure are calculated so that the containers can store a load of up to 30 kg on each container. The skeleton of the robot ends with an H-shaped structure of the rod elements. It is calculated for it to be able to carry a load of about 20 kg and the robotic arm placed on top of it. The wheels, along with the electric motors, are under the bottom panel. The motors are capable of outrunning the robot at a nominal speed of 0.3 m/s. The robot is mainly made of aluminum, which guarantees the necessary strength and weight. The robot weighs around 80 kg and is designed to carry a robotic arm weighing around 20 kg. Fully assembled, its carrying capacity is about 40 kg.

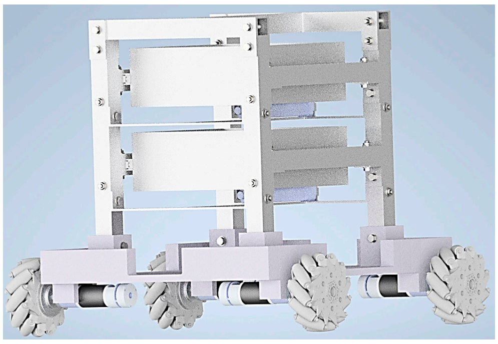

Figure 6. Structure of the robot.

The process should comprise 3–4 linear actions, resulting in an algorithm; the machine itself is moving towards the given object and then the robotic arm grabs the object and places it in one of the drawers. The next step is the movement of the mobile robot itself to the desired destination and the unloading of the objects. One of the aims of this design is to be multifunctional. For instance, the robot could be used to select objects. The different types of objects can be placed in different drawers, and by the help of artificial intelligence, the objects can be sorted and classified. In other instances, the robot is used to undertake different operations by placing a screwdriver into the robotic arm. In the drawer, different types of bolts can be placed and the robot can pick and choose which one to use. The aim is for the platform to be flexible enough to have the ability to be reconfigured by additional modules, even produced by a third party [7].

It is planned that the structure itself has an internal skeleton and external shell. The external shell should be lightweight and should consist of panels attached to the skeleton. This way, the internal parts could be easily accessed for replacement. This would make it easy to maintain and to be modified if needed. The structure should be the thinnest at the top and wider at the bottom so that stability can be guaranteed [8–10].

5. Conclusions

Mobile autonomous robots should be as compact and mobile as possible. In most cases, the size of the robot depends on the specific requirements for its loading capabilities. In general, a robot should be easily adaptable to the work environment, without the need of major reconfigurations in the layout of factories as well as its infrastructure. Big importance is given to the reliability of the robots, as they might be working constantly; in some cases, they would be functioning around the clock during periods of 24 h.

Most mobile robots consist of two rotating wheels and four to maintain their balance. This is a relatively easy and effective way of controlling; however, robots with more specialised applications use additional technologies for wheel rotation: mecanum wheels allow for much higher work precision. Apart from reliability and precision, a robot should be easily maintained. A good solution for the ease of maintenance could be that all the components are easily accessed and placed in separate compartments.

For navigation, most mobile robots rely on multiple cameras and sensors. The navigation system is highly important in allowing robots to be fully autonomous. The tendencies are that the software responsible for the control of the machines is centralised and could control the whole flotilla. Technologies based on artificial intelligence which can improve the robot's navigation systems are being developed. Robots' ability to adapt to dynamic work environments is of high importance. That way, they can allow for a safe workplace and not get in the way of factory workers. Factories can only benefit from the wider implementation of mobile autonomous robots.

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