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Optimal control of 2-wheeled mobile robot at energy performance index

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ABSTRACT

The paper presents the application of the optimal control method at the energy performance index towards motion control of the 2-wheeled mobile robot. With the use of the proposed method of control the 2-wheeled mobile robot can realise effectively the desired trajectory. The problem of motion control of mobile robots is usually neglected and thus performance of the realisation of the high level control tasks is limited.

1. Introduction

Nowadays mobile robots are essential group of utility robots. Even though utility robots are far less formally considered than industrial robots, they become very important and numerous group of robots. As the utility robots they become useful in domestic, office or even war environments. Mobile robots are also applied in industry. However they usually do not achieve the level of precision and reliability of typical industrial manipulators. Nevertheless they are used with success as efficient means of automatic transportation.

The most effective way of transportation or generally speaking – movement, in most cases is to use wheels. Thus wheeled mobile robots are more popular than others, non-wheeled mobile ones. Let us consider relatively small robots which are moving with relatively small velocities over the flat and even surface. Such robots may be very simple, not expensive, but they are still very useful. For example, they may be used for cleaning floors, entertainment, communication, transportation and inspection. For realisation of more complicated tasks there may be used more complex mobile robots, where instead of wheels the tracks are used and additional hybrid movement mechanisms could be engaged [1]. However even such complicated structures most of the time move in similar way as wheeled mobile robots, and thus similar movement supervising methods could be applied.

Mobile robots could be used as utility robots to perform more or less important tasks. Some examples of their usage could be cleaning [2], mowing [3], inspection [4] and cooperation with the other agents [5] (i.e. by using them as means of transportation in hospitals [6]). In most cases of mobile robots' applications any inaccurate movements should be limited [7]. It may not be so important in case of robots performing cleaning work, because small velocity and position uncertainties will be likely eliminated in next iteration of cleaning task [8]. Although if the robot has to move something accurately into

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the desired position, or for example – perform some painting jobs [9], the kind of work that should not be repeated, then accurate movement of the mobile robot base is highly advisable. Robot used for inspection tasks may be equipped with the limited-degree-of-freedom manipulator which is connected to the moving base by non-holonomic constraints [10]. Any position inaccuracy in the base movement may cause that manipulator would be unable to perform its job because it is askew and the mobile base could not move sideways. Moreover in case of multi-agent applications, where several robots cooperate together [11], it is important that position and orientation errors should be limited. For example, mobile robots could relocate various objects to the desired positions, or track each other in a limited space.

Generally ability to work of the mobile robots depends highly on application of complex, high-level control algorithms. Such control algorithms evolve intensively and now mobile robots are for example able to find effectively safe trajectory and perform exploration of unknown environments [12,13], localise themselves [14] or even perform more complex actions [15]. However, an important problem of the low-level control is often neglected. Thus wheeled mobile robots are not moving as accurately as they should.

The problem of low-level control could be highly simplified with the use of special wheels [16]. Thanks to the special wheels the problem of kinematics of the wheeled mobile robots is very simplified and thus their performance may be better in case of the use of trivial, low-level control algorithms. However usage of special wheels is not an ideal solution, because of their higher cost, noisy work, vertical vibrations and limited lifespan. In case of using normal wheels we should consider an analysis of a strongly nonlinear system which is restricted by non-holonomic constraints [17]. In such a case, trivial low-level control algorithms may be responsible for limited accuracy. Sophisticated movement mechanisms [18] of the wheeled mobile robots may be used to limit odometry errors, but such mechanisms make construction of the mobile robot more complicated and thus – expensive. On the contrary, low-level control algorithms based for example on artificial neural networks [19], fuzzy logic [20] or adaptive control methods [21] may be accurate, but they are generally complicated and thus may be effective only for specific solution, i.e. construction of the mobile robot including its geometrical, weight properties or computing power of control unit. In case of the real mobile robot, it is very important to generate smooth control signals, without rapid changes of driving torques, in order to limit possibility of slippages. In practice, methods of low-level control that are not based on dynamics of the controlled object cannot assure such requirement.

This paper presents a method of optimal control at energy performance index of wheeled mobile robots on example of a mobile robot with only two driven wheels (such movement construction is sometimes called “differential drive”). The presented method is very effective solution for the low-level control of the wheeled mobile robots. The performance index has a physical interpretation, because it is based on mechanical energy of the controlled system. This control method was previously and successfully implemented in many practical applications towards vibration surveillance and motion control [22–28]. Because of the physical interpretation the presented control method could be easily adopted to the other construction of wheeled mobile robots. Theoretical approach towards control simulation of the 3-wheeled mobile robot at the energy performance index, was introduced [29]. Computer simulation as the convenient way of implementing and testing the control method with the use of the microcontroller is proposed as well [30]. However the optimal control at energy performance index was further developed in order to apply it into the full mechatronic design procedure (including the Hardware in the Loop Simulation) for building the controlled 3-wheeled mobile robot [31].

2. Material and methods

For purpose of experimental investigations, the low-cost 2-wheeled mobile platform was constructed and built (Fig. 1). The mobile platform is a simplified version of appropriate mobile robot, in which we concentrate our attention only on robot’s motion system and robot’s motion control. This type of mobile platform is a simple structure (Fig. 2) and thus – it is commonly used. It is driven by two direct current electric motors (Micro Motors E192.12.25) with the integrated planetary

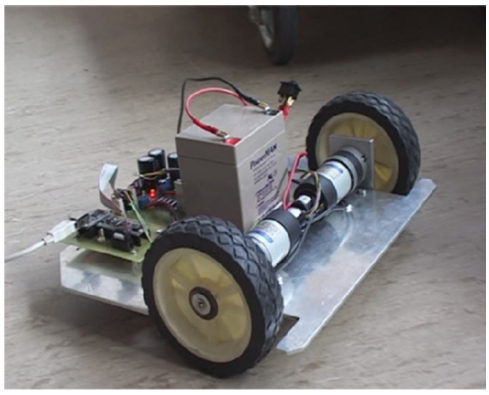

Fig. 1. 2-Wheeled mobile platform.