Modeling and Control of Robotic Systems

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Modeling and control of robotic systems

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***Abstract*—The research presented in this article focuses on mobile and stationary robotic systems, especially in terms of the classical methods of modelling and control, taking issues that were already developed by author as initial state into account. The simulation models of robotic systems are primarily mentioned among the other achieved results, since they are the foundations for the Library of simulation models and control structures. This paper is enclosed by plans for library extension with neural models and intelligent control structures, according to selected future dissertation theses.**

***Keywords*—control, robotics, modelling, robotic arm, Matlab/Simulink**

I. Introduction

Robotic systems [1] are the subject of intense research for last decades and due to the increasing capability of computing devices, intelligent actuators, sensors and advanced networks, it is possible to realize even algorithms that were theoretically developed in past and that could not be previously implemented through the computing time or communication speed. A new opportunities for application of algorithms that use features of this modern components are also opening.

The focus of presented research is oriented on mobile robots and robotic arms [2], their mathematical modelling and various tasks of their control. One of the main goals of future dissertation is the comparison of selected classical and intelligent control methods for identification of specific scenarios, where the classical methods are not effective or applicable and a better results can be achieved with use of artificial intelligence methods.

II. Previous analysis and achieved results in research field

Research field of robotic systems has been the subject of author's previous analysis, especially in terms of hardware for robotic arm with four degrees of freedom, discussed in previous SCYR article [3]. It's main topic was the analysis of OWI 535 robotic arm digital controller board potential for interconnection with computer program written in C# programming language via USB interface. This communication channel was successfully tested, but with the introduction of new, additional joint position sensors it is necessary to replace the original micro-controller board with universal controller platform, for example the Ardunio or Raspberry may be suitable.

Due to the fact that the subject of research is mainly identification, mathematical modelling and implementation of control algorithms for robotic systems, mentioned model of the robotic arm or any other similar models should serve primarily for the verification of the results that will be the outcomes of simulation experiments. However, the interconnection of model with MATLAB / Simulink requires adequate attention, because it is not a simple task.

A similar task was already addressed in case of laboratory model of hydraulic system control, specifically there was an interconnection between program, that was realizing the control loop calculations in Matlab environment with PLC, which was used to get the water level sensors data and to control the water pump in real time. This communication channel based on DDE is presented in more detail in [4].

III. Modeling and control of robotic systems - the classical approach

During the last year of study, there was a slight modification of future research focus and dissertation thesis is now more reflective in terms of projects VEGA and Technicom that are currently realized by research Centre of Modern Control Techniques and Industrial Informatics (http://kyb.fei.tuke.sk/), of which is the author member.

The research field of robotic manipulators [2] is wide and therefore the analysis in past year was devoted to:

- methods for description of robotic manipulators with n-degrees of freedom, especially through simple matrix transformations and description using the Denavit-Hartenberg convention
- solving the direct kinematic task for specific robotic arms,
- analysis of potentially applicable methods for solving the inverse kinematics task.

A more attention has been given to the issues of mobile robotics because this research field contains many common features and tasks, that can be applied even in the case of modelling and control of robotic manipulators.

Mobile robot types, that have been analysed in dissertation prospectus [5] involve movement only in plane and the non-holonomic differentially driven two wheel mobile robot have been considered as main subject of analysis, since this kind of model is available for later verification of results obtained by simulations. Namely, it is a robotic soccer robot of Mirosot class, however development of similar robots is planned in research Center of Modern Control Techniques and Industrial Informatics.

The first major area of interest for the non-holonomic mobile robots is their modelling. Mathematical model of this kind of robot can be often divided into kinematic and dynamic parts and this feature can be used later in the control design.

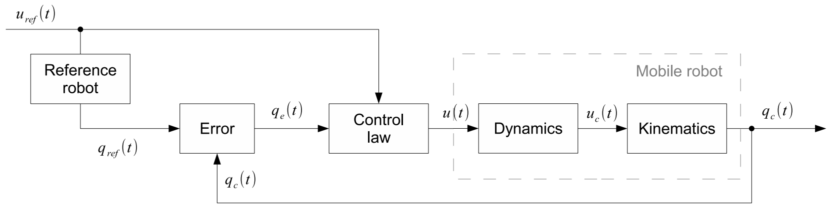

Fig. 1: Control structure for mobile robot trajectory tracking with reference model

Kinematic part respectively the kinematics model is in its basis the model of ideal robot moving in plane and it can be defined for multiple pairs of excitation variables like the linear v and angular ω velocities of robot, wheel linear velocities v_R, v_L or wheel angular velocities ω_R, ω_L, wherein the transformation matrices between selected variables can be defined. The outputs of this model are the robot momentum position plane coordinates $\dot{x}(t)$, $\dot{y}(t)$ that are changing in time and robot orientation angle $\dot{\varphi}(t)$ against the definition of global coordinate system in which is the robot moving [1].

The dynamic part of model can incorporate physical influences of robots mass and inertia to its movement, impacts of friction force between wheels and surface or effects of skid while moving on curved trajectory [6]. In these cases, the dynamic model can be defined for traction forces F_R, F_L produced by wheel motors or their torques T_R, T_L.

In certain cases, when the wheel motors are over-dimensioned, it is possible neglect the impact of dynamics and consider only the kinematic model of the robot. These models were programmed in Simulink environment as a basis for robotic systems library in order to be used later in the implementation of control algorithms.

The second extensive area of analysis has been devoted to the control of mobile robots, which covered the implementation of various control algorithms and structures. From the hierarchical point of view, a lower level control, which suppresses the impact of robot dynamics using an internal feedback control loop ensuring compliance with the required wheel angular velocities can be considered [7]. However, the main objective of mobile robots control is mostly it's position in the plane. The control algorithms can be divided depending on whether they consider the orientation of the robot respectively, according to the method of control loop deviations definition.

The focus in control of future dissertation thesis is oriented on mobile robot reference trajectory following (Fig. 1), also implemented and verified by simulation experiments because of its potential for further extensions with the intelligent control methods [8].

IV. Application of Artificial Intelligence Methods in Modeling and Control of Robotic Systems

The objectives for future the research should be the implementations of multi-layer perceptron neural networks as neural models of mobile robots and their verification in simulations. The forward neural model can be obtained using the identification structure based on prediction error with a reference model considered as mathematical model with internal control loop that suppresses the impact of robot dynamics [7]. Inverse neural model can be obtained using Specialized training and the input data will be acquired by simulations on models from robotics library. The next step should be the application of these neural models in intelligent control structures like the Control with an internal model. Except neural networks, other artificial intelligence methods like fuzzy logic may show potential of application in this field of research.

Similar tasks can be applied to robotic arms, namely the subject of further analysis should be the use of neural models especially in two perspectives: firstly, the training data are obtained from the simulation in a closed control loop using mathematical model and secondly, neural model is trained with the data defined as achievable points within robotic arm's effector working area in sufficient density.

V. Conclusion

Subject to further research efforts will be the development of robotic systems library in Simulink and implementation of mentioned intelligent control models and algorithms. Robotic systems can be represented as mathematical models or virtualized in 3D space based on OpenGL, that was already programmed in C# programming language.

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