Master thesis

Dynamics and control of underactuated planar manipulators

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1. Introduction

A goal of this thesis is to perform an analysis of the dynamics and partial synthesis of control systems for two planar, underactuated manipulators. The underactuation is defined as a state in which the number of control inputs of the system is smaller than the number of its degrees of freedom. Because of this, design of control systems for such robots may be a difficult task. Main challenge is a derivation of control inputs (forces and torques) for actuated degrees of freedom in such a way that the influence of other, passive kinematic pairs is compensated.

2. Theoretical introduction

The thesis contains a description of a number of mathematical methods and tools that are necessary for control synthesis. Among the most important of them one can find a general model of underactuated systems, input-output normal form of equations of motion in state space and two methods of deriving the appropriate control inputs – one with the use of so-called linearly combined output and second one, based on servoconstraints formulation. Other described topics include a numerical way to generate the equations of motion, a method of formulation the boundary value problem to solve internal dynamics of the manipulator and classification of underactuated systems.

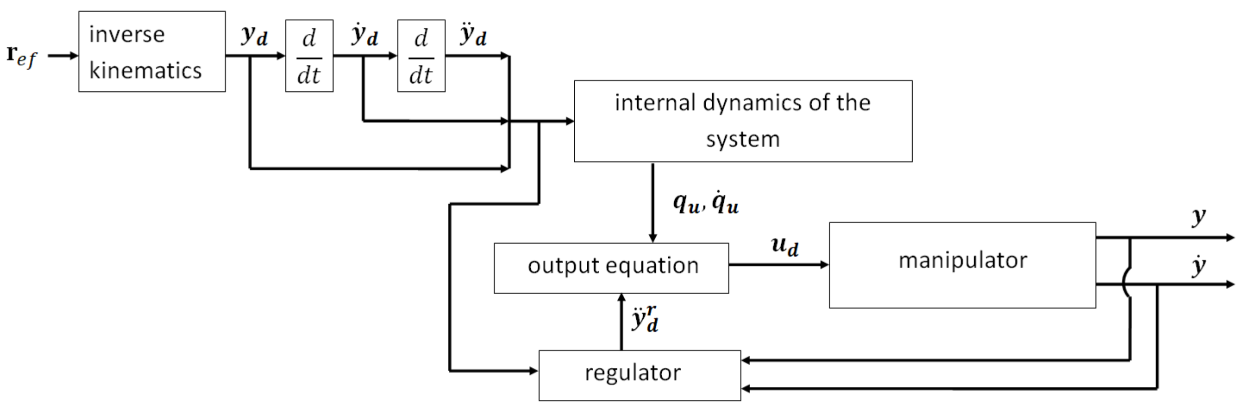

Figure: Schema of control system for underactuated manipulator obtained with method of linearly combined output.

3. Simulation results

Described methods were used to perform case studies of two underactuated planar manipulators with three and four degrees of freedom.

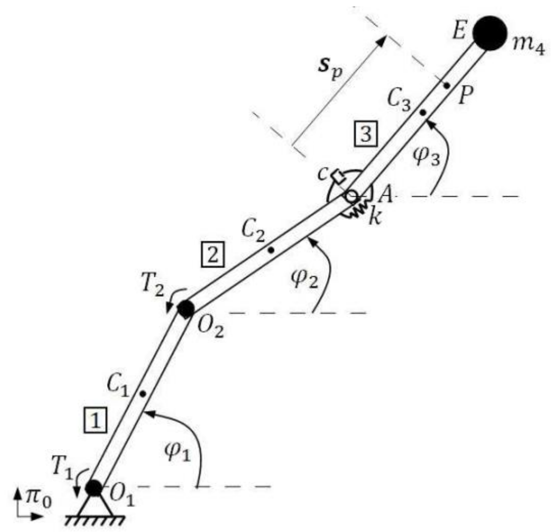

Figure: Manipulator with three degrees of freedom

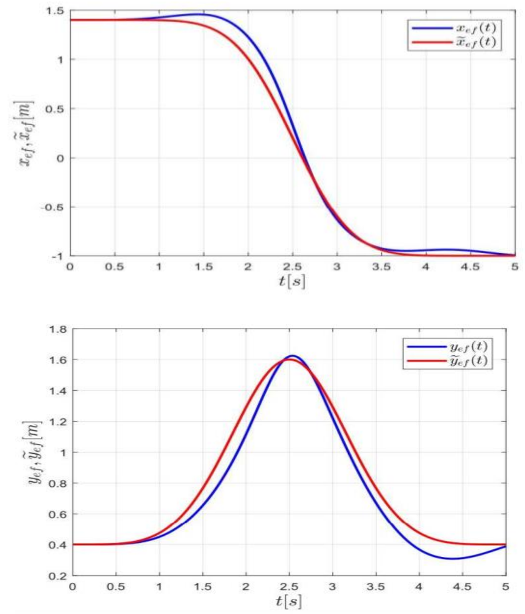

Figure: Comparison of desired and simulated output trajectories for 3DOF manipulator.

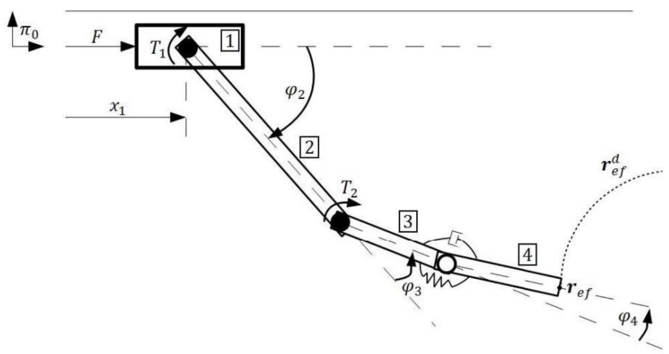

Figure: Manipulator with four degrees of freedom.

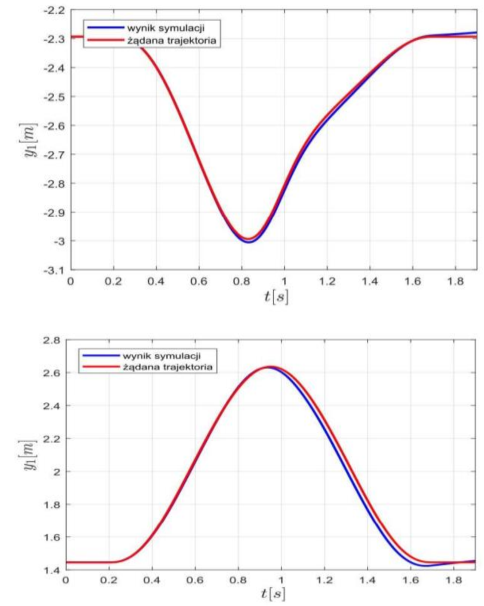

Figure: Comparison of desired and simulated output trajectories for 4DOF manipulator.

Software

Both simulations were performed with use of MATLAB ®. Alternative feasible tool for such task is Python programming language, with appropriate libraries like Scipy, Matplotlib, etc.

4. Conclusions

- Both methods turned out to be effective – they allow to recreate the desired output with good accuracy.
- There is no single, generic method applicable for whole class of underactuated systems.