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Review on the Doctoral Thesis of Ing. Milan Anderle titled

„Modelling and control of walking robots"

Content of the Dissertation

The dissertation investigates the problem of modelling and controlling biped robot locomotion utilizing the methodology of feedback linearization. The contents focus on the fundamental properties of biped modelling and the theoretical implications of exact feedback linearization for that system. Specific parts of the thesis are:

1. Introduction to the field of research, definitions, basic notions and history of robotic walking.
2. Modelling of simple biped systems with impact model.
3. Exact feedback linearization for the biped models derived in Chapter 2.
4. Design and discussion of different walking trajectories.
5. Tracking control of reference trajectories designed in Chapter 4.
6. Suitable observer design, hybrid stability of walking, and conclusions.

Overall, the dissertation is clearly dedicated more to the theoretical foundations of biped walking than on the practical and technological implications of the related control problems.

Appraisal and Discussion of the Dissertation

The topic of the thesis of Mr. Anderle is of high interest for the scientific community. The thorough theoretical treatment for controlling the biped locomotion by exact feedback linearization calls for several solutions of different problems all of which are necessary to be solved on a high scientific level.

The main goals and contributions of the work have been clearly stated in the thesis (Chapter 1); correspondingly, the scientific publications are listed and the individual author's contribution is detailed. All objectives have been fulfilled, and the resulting performance is illustrated by simulation results.

The work has been conducted in a methodically correct and adequate way; citations of references are extensive and up to date. The theoretical treatment of the problem including an impact model poses a challenge by itself, since it is difficult to come up with solutions of high quality for modelling, control, trajectory planning, reference tracking, and stability analysis. Although only briefly treated, I very much liked the approach of Poincare sections to check for stability of the walking motion. Overall, the publications in peer reviewed quality journals prove that the scientific quality of the work meets international standards.

Mr. Anderle has clearly proven that he is capable of applying existing methods to new and challenging nonlinear control problems, and that he can adapt and extend state-of-the-art algorithms where necessary (e.g. LMI based analysis and design, Section 5.2).

The problem posed in the thesis is of high interest in the scientific community, and due to the nonlinear problem nature and the underactuated system control design is inherently complex. Mr. Anderle tackles the associated problems in an efficient and structured way, moreover, he comes up with a theoretically sound methodology for analyzing each of the associated sub-problems. It is therefore out of doubt that the thesis and the related scientific publications constitute a significant contribution to the further development of science.

All elements of creative scientific work are contained within the thesis. Additionally, Mr. Anderle has proved that he is able to master different complex methods and tools to investigate a given control problem, and to cover thus all aspects of a sound theoretical foundation for the development of a functional control solution.

Some specific questions related to the contents would be of additional interest:

- The core problem of control design using exact feedback linearization and reference trajectory tracking has been solved for the nominal system with perfect parameter knowledge. What would be possible ways to deal with parameter uncertainty/variation (see e.g. H.K. Khalil, Nonlinear Systems, Prentice Hall, 3rd Edition, pp 530 - 543)?
- Another important extension towards practical implementation is the ability to robustly navigate rough terrain (i.e. walking surface is not perfectly flat). What about the implications to control design and reference trajectory planning, respectively?
- Walking trajectory design is an interesting field. What about an approach where the trajectory is the result of an optimal control problem (e.g. minimizing control energy), with some (mild) constraints to secure a reasonable posture?

The author of the thesis proved to have an ability to perform research and to achieve scientific results.
I do recommend the thesis for presentation with the aim of receiving the Degree of Ph.D.

Best regards,

Ao.Univ.Prof. DI Dr. Martin Kozek

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