Doctoral Thesis Review

Title:*Distributed optimization for multi-object manipulation by shaping spatial force fields*

Author:*Martin Gurtner*
Supervisor:*Zdeněk Hurák*

The reviewed doctoral thesis presents a comprehensive study on real-time feedback distributed micro-manipulation by DEP (dielectrophoresis). The thesis covers three major topics: position sensing of manipulated objects, control-oriented DEP model and force model inversion through distributed optimization. All **topics can be considered as open challenges in the field of micro-manipulation** and form the main contribution of the thesis. The thesis consists of a brief introduction; the main part includes three published papers in peer-reviewed journals (the first paper was published in 2016, the last one in 2022; Ing. Gurtner was the first author of all the papers); and finally, one paper prepared for publication represents the final chapter of the thesis.

Formally, the **thesis is well written, prepared carefully, concisely and clearly**. Despite the format (compilation of the published papers), the work is compact and comprehensively covers the topic. The introduction gives a basic definition of the field of study and briefly discusses addressed problems and achieved results. The introduction is relatively monotonous but gives an excellent introduction to a broader professional audience. The **references are relevant** and well-listed, and the **figures are clear** and well-chosen. I appreciate the publication of the source codes used for numerical experiments (Chapter 4). Movies from the described experiments in supplementary materials (for example, in the form of Schol-AR extension) will be very beneficial. In one sentence, the thesis formally meets all the requirements for an academic qualification thesis.

From a technical point of view, it is advisable to approach each topic differently. Position sensing of manipulated objects in 3D space (Chapter 2) is an ingenious solution to a non-trivial technical problem, and the proposed method is original compared to commonly used localization methods. I consider the proposed sensing method interesting mainly from an engineering point of view. The **approximation of the DEP mathematical model** allowing the application of the analytical framework of Green's functions

(Chapter 3) is **original research** and represents the major core of the thesis, further extended by the inversion through distributed optimization (Chapter 4). Combining both topics demonstrates a complex approach and represents a valuable result. The academic level of the thesis is underlined by the presented approach of decomposition and distribution of the optimization problem (Chapter 4), which is generalized and applied to three different methods of distributed manipulation (DEP, magnetophoresis and acoustophoresis). Finally, all **proposed methods are extensively verified** on the developed compact platform for DEP micro-manipulation (Chapter 5).

Overall, the thesis presents innovative approaches and algorithms for real-time micro-object feedback control through shaping force fields, primarily focusing on DEP. The numerical and experimental results provide evidence of the effectiveness of the proposed methods and algorithms. The thesis's contributions have the potential to advance the micro-manipulation field, especially in biomedical engineering. In one sentence, the **thesis describes a current topic**, **combines a theoretical approach with experiments**, and **presents original results** that can significantly contribute to the micro-manipulation field.

The thesis meets the requirements of scientific work and the formal criteria of a doctoral thesis. I consider the presented results to be rigorous and original. **I recommend the thesis for presentation with the aim of receiving a PhD degree.**

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František Mach