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Report on the dissertation entitled "Distributed manipulation by controlling force fields through arrays of actuators" submitted by Jiri Zemànek to obtain the degree of Doctor of Philosophy at CTU FEE, Praha.

Mr Jiri Zemànek has presented their PhD works in a manuscript entitled « Distributed manipulation by controlling force fields through arrays of actuators ». The document written in English contains 172 pages, has a short preface, a short introduction, height main chapters distributed in two parts, a conclusion and a list of numerous references. The author has published their works in three articles in international scientific Journals included one article as first author in Electrophoresis Journal. He also has presented their results in 10 conference papers. It should also be mentioned that Mr Zemànek receives three awards on their works in which the EEA Demonstrator Paper Prize in IFAC World Congress and the award for IEEE CSS Video Clip Contest, both in 2017.

The general framework of the dissertation is the robotic manipulation at the microscale also called "robotic micromanipulation". The current most interesting and explored ways to perform micromanipulation consists in controlling the micro-objects trajectories with non-contact forces such as magnetic forces (magnetophoresis) or electrostatic forces (dielectrophoresis). Mr Zemànek proposes an original way, which has been applied in both domains (magnetophoresis and dielectrophoresis). The proposed approach consists in using distributed actuators (coils or electrodes) placed in a plane to control the trajectory of micro-objects up to the plane with closed loop control based on vision. Combining closed loop control and distributed actuation in micromanipulation is an original scientific approach at the international level.

The first part of the thesis deals with closed loop control of micromanipulation powered by dielectrophoresis and is the most relevant part of the thesis including numerous scientific contributions. The approach proposed by Mr Zemànek consists

in performing closed loop control using the phase of electric potential of the electrodes when the current works at the international level are focused on the amplitude of the electric potential. This original approach enables to simplify the electronic hardware implementation. Mr Zemànek presents a whole analysis from system design to dynamic control and including a strong experimental part. We may highlight two major scientific contributions. Firstly, the proposed digital microscopy principle enables the estimation of the height of the particle up to the electrodes which is currently a major challenge in non contact micromanipulation. Secondly, the proposed "noise aided manipulation" is a very relevant and original idea enabling to cross the trajectories of two microparticles in dielectrophoresis for the first time in the world. These two scientific contributions will be probably exploited by the international microrobotic community in the future. It should be also notice that the thesis manuscript reports lot of experiments done on a device designed and built by Mr Zemànek. The experiments on microparticles are crucial in the scientific analysis but are time consuming because of the small scales considered. The part I presents a very interesting scientific work contributing to the non-contact manipulation at the international level.

The second part deals with the control of a millimeter scaled balls actuated by magnetic forces. The balls are placed on a surface containing an array of 8x8 coils inducing a controlled magnetic field up to the surface. Two types of surfaces have been considered: flat surface and non-flat surface in which the weight has to be considered. Mr Zemànek has proposed a complete analysis of the system including modeling, control synthesis and experimental validations. Two major contributions can be also highlighted. Mr Zemànek proposes to model the magnetic field using Green functions which enable to reduce significantly both the calculation time and the memory requirements. He also proposes a whole analysis of the control synthesis based on local linearization enabling to control the trajectories of three balls on the flat surface and to stabilize the damping of ball on the non-flat surface. Moreover, we may also emphasize the efforts to build the experimental device including mechatronic hardwares and softwares. This part is also concluded by the presentation of a new design to control trajectories of micrometric ferromagnetic particles which illustrates the promising perspectives of this work.

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In conclusion, the original ideas proposed by Mr Zemànek is absolutely relevant and original at the international level. It enables major progresses in several fields in non-contact manipulation of micro-objects. On account of the high quality contributions detailed in Mr Zemànek thesis, I recommend to accept his thesis for the degree of Doctor of Philosophy at CTU FEE.

Besançon, July 9th

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