



Noise characterization in millimeter sized micromanipulation systems

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ABSTRACT

Efficient and dexterous manipulation of very small (micrometer and millimeter sized) objects require the use of high precision micromanipulation systems. The accuracy of the positioning is nevertheless limited by the noise due to vibrations of the end effectors making it difficult to achieve precise micrometer and nanometer displacements to grip small objects. The purpose of this paper is to analyze the sources of noise and to take it into account in dynamic models of micromanipulation systems. Environmental noise is studied considering the following sources of noise: ground motion and acoustic noises. Each source of noise is characterized in different environmental conditions and a separate description of their effects is investigated on micromanipulation systems using millimeter sized cantilevers as end effectors. Then, using the finite difference method (FDM), a dynamic model taking into account studied noises is used. Ground motion is described as a disturbance transmitted by the clamping to the tip of the cantilever and acoustic noises as external uniform and orthogonal waves. For model validation, an experimental setup including cantilevers of different lengths is designed and a high resolution laser interferometer is used for vibration measurements. Results show that the model allows a physical interpretation about the sources of noise and vibrations in millimeter sized micromanipulation systems leading to new perspectives for high positioning accuracy in robotics micromanipulation through active noise control.

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1. Introduction

High precision micromanipulation tasks are required in a wide range of microrobotics applications, for instance microassembly [1], force sensing [2] and surgical operations magenta[3]. In that sense, numerous micromanipulation systems (notably *microgrippers*) based on actuators with high positioning accuracy and good deformation/force ratio can be found in the literature [4–6]. The size of end effectors can vary from few micrometers [4] up to several tens of millimeters [7,8]. While micrometric structures are suitable for high resolution positioning, millimeter ones have the advantage of offering large displacements. In most cases, noise and vibrations are the main factors reducing the performances of micromanipulation systems for both actuation [9–11] and sensing [12,13] leading to a low repeatability and a loss of accuracy. Moreover, when end effectors are used as sensors, vibrations are reflected in the sensor output as a measurement noise reducing significantly the sensing resolution [7,14]. Undesired vibrations are partially caused by random motions of particles within materials known as thermal fluctuations leading to the *thermal noise*, and also by external perturbations coming from the surrounding envi-

ronment reflecting the so called *environmental noise*. Thermal noise is predominant in micrometric structures such as AFM (Atomic Force Microscopy) cantilevers which are characterized with high resonance frequencies (in the order of tens of kHz) [15,16]. Environmental noise can include effects of external temperature, humidity, pressure, etc. and also relates to human activity, operating machines, etc. at a given location.

When a high positioning accuracy is needed, one has to deal with this noise. Numerous solutions are possible: designing environmental isolation platforms [17,18], considering noise limitation during the design of micromanipulation systems by an appropriate choice of the resonance frequency of end effectors [19], or using appropriate controllers for noise rejection [20]. Multi-noise isolation platforms are generally very expansive and have a limited volume which can be a real problem if a micromanipulation station requires a large working space [21]. Moreover, vibration isolation tables commonly found in typical microrobotics laboratories allow efficient ground noise filtering but fail to filter acoustic noises. The perspective of our work is to provide a flexible solution, applicable in different environmental conditions for different micromanipulation tasks (microassembly [22], manipulation of biomaterials [12]) even if such operations require a large working space. Environmental noise is also usually not taken into account during microgrippers design. Then, the use of appropriate controllers for noise rejection is an interesting and low cost solution when considering a large kind of microgrippers. For this

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