Microrobot control from individual to collective

Kiana Abolfathi*, Ali Kafash Hoshiar*

School of Computer Science and Electronic Engineering, University of Essex, Colchester, UK

Abstract. Microrobots emerged as an ideal tool for minimally invasive medical interventions. In general, microrobots can be categorised into tethered, unthreatened and collective tethered (called microswarm). Initial works were centred on individual microrobot control. However, in many applications (e.g. targeted drug delivery) microrobots should be controlled collectively. This presentation will discuss the required changes to transform the individual to collective control for medical microrobots.

Introduction

Microrobots emerged as powerful yet underdevelopment technology ideal for minimally invasive medical applications. The microrobots size enabled the development of endovascular interventions. Ideally, microrobots are injected into the blood vessels and then guided inside the vascular network to reach the location of interest (e.g. deep brain tumour). Once in the location of interest, the microrobots can perform minimally invasive medical interventions ranging from microsurgery to drug delivery and hyperthermia. Many propulsion systems have been developed to actuate these microrobots, which include chemical, light, acoustic, and magnetic. Magnetic actuation emerged as the favourited approach due to the magnetic field biocompatibility and ease of control. Due to microrobots' small size, the medical imaging systems (MRI, X-Ray and ultrasound) have been investigated to localise them. The control strategy, however, depends on the type of microrobots and the medical interventions. The untethered microrobots are used in closed-loop control schemes, whereas microswarms are designed based on predictive modelling. The microswarms are therapeutic agents which are made of a collection of magnetic nanoparticles (MNPs).

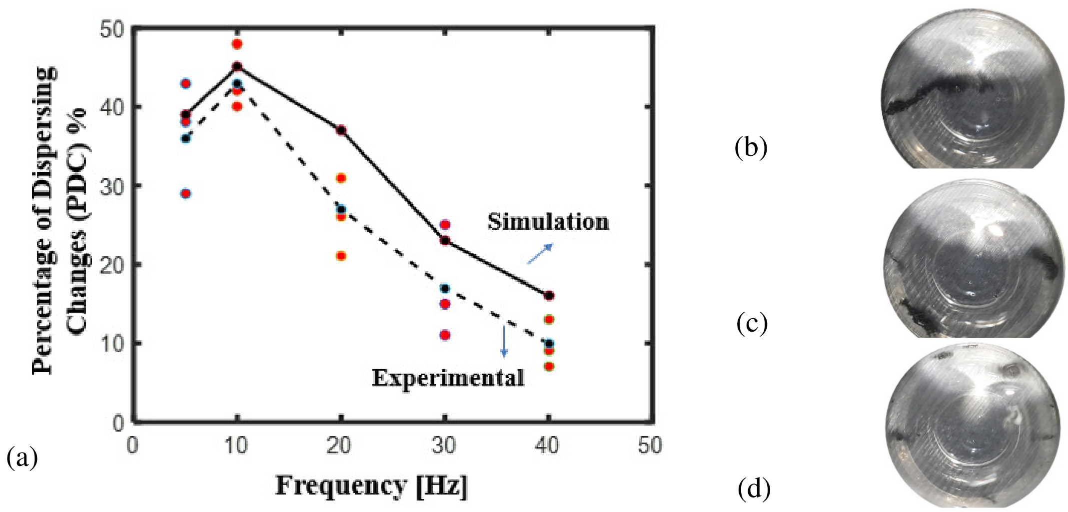

Figure 1(a) shows the compersion between the simulation platform and the experiment results for microswarm creation [1], (b) Rotating magnetic field of 25 mT Fr. 10Hz, (c) Rotating magnetic field of 25 mT Fr. 20Hz, (d) Rotating magnetic field of 25 mT Fr. 30Hz.

Results and discussion

Predictive modelling is used both in collaborative (human-assisted) and feedforward applications. Using mathematical modelling, we have developed a simulation platform (based on discrete element modelling) to predict microswarm shapes and their separation. The platform is validated using experimental data and shows acceptable results [1, 2]. Different parameters have been studied to show their effects on microswarm formation. We showed that in case the initial dispersion is below (<0.12) or above (>0.25), generating the nanoparticle-based microswarm fails. Fig. 1 shows the simulation and experimental result comparison, and Fig. 1 (b-d) shows that the particle disintegrates at a higher frequency (10 to 30 Hz). To guide these microswarms in the vascular network in a dynamic environment, we developed user-in-the-loop interventions [3]. The study on microswarm steering showed that fluid velocity is the most influential parameter. Therefore, we also modified the guidance region for the microswarm to optimise the particles reaching the target.

References

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