CPS-Medium: Dense Networks of Bacteria Propelled Micro-Robotic Swarms

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Abstract:

The last decade has seen increasing studies on bacteria and other cells-integrated bio-hybrid microrobot. A major motivation of them is to apply such kind of microsystems into targeted drug delivery system. Although various fabrication techniques have been developed to improve the efficacy of the system, control of the bio- hybrid microrobot is severely understudied, especially at population level. This poses an challenge for further application of the bio-hybrid microrobots, such as targeted drug delivery engineering. Here, we present a way that uses the sensing function of the flagellated swimming bacteria on their environmental pH to realize drift control of bacteria-propelled micro polystyrene beads at population scale. Using a diffusion based microfluidic gradient generator, we calibrated a pH gradient profile that can drive the applied bacteria, Serratia Marcescens (S. marcescens), to accumulate in the middle of the tested channel, where the pH value is around 7.0. Tracking of the swimming bacteria allows us to find that the accumulation of bacteria around the neutral pH band is realized by biasing the flagellar tumble rate based on the swimming directions, whereas the tumble rate of bacteria is normally random and isotropic when there is no gradient. Subsequently, we studied the motion and distribution of a swarm of S. marcescens propelled microrobots under the calibrated pH gradient over time. The microrobot is fabricated by randomly attaching multiple bacteria onto a spherical polystyrene bead. Upon generation of the pH gradient, the microrobot swarm starts to drift towards the region with neutral pH, and the distribution of the microrobots stabilized after around 6 minutes for the given channel width. Our further analysis on the swimming trajectories of the microrobots under unidirectional pH taxis shows that, on average, the attached bacteria can provide higher forces when the bead moves towards their preferred directions, and they also steer the microrobot in a fashion that produces higher probability to orient to the preferred directions.

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