Collisional diffraction in serpentine self-propulsion

Jennifer M. Rieser[1], Perrin E. Schiebel[1], Arman Pazouki[2], Feifei Qian[1], Zachary Goddard[1], Andrew Zangwill[1], Dan Negrut[2], Daniel I. Goldman[1]

[1]Georgia Institute of Technology,[2]Califoria State University, Los Angeles, [3]University of Wisconsin, Madison

Limbless locomotors such as snakes gracefully navigate through a wide range of varied terrain, from tall grasses to debris-littered forest floors to the yielding sandy substrates of the desert. Despite the seeming simplicity of this movement, the interaction with the ground coupled with intermittent obstacle collisions can give rise to complex dynamics. To begin to understand the mechanics and control underlying even relatively simple locomotor-obstacle interactions, we study the dynamics of an open-loop snake-like robot moving through a model heterogeneous terrain in which a row of five evenly-spaced pegs, oriented perpendicular to the robot's initial direction of motion, extend vertically upward from a firm, flat surface. To sample all possible interactions, the robot begins each experiment in the same initial configuration and is placed at different positions within a region with lateral and longitudinal dimensions set by the peg spacing and distance travelled in one undulation cycle. We find that, despite uniformly-sampling all possible collisions, the robot preferentially emerges from the peg array along one of a few rotated directions of travel, and that the distribution of rotations depends on the obstacle spacing. Numerical simulations agree with experiments and allow for a more thorough exploration of this dependence, which we find is surprisingly well-fit by the functional form expected for wave fields. Simulations further reveal that collisions with the head dominate this reorientation, and that the duration of these collisions set the amount of rotation. A simple model shows that the duration of the collision is set by the impact location on the peg and the phase of the wave at impact. This suggests that collision-induced rotations may be able to be controlled by managing the details of the interaction with the head.