Robophysical Model for Investigating Sand-diving in the Sandfish skink

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Abstract

Previous research on the burial pattern of the sand-swimming sandfish skink *S. scincus* revealed that the forelimbs are critical for successful sand-diving [1]. Sand-diving allowed the sandfish to bury itself below surface and occurred prior to sand-swimming. Unlike sand-swimming where propulsion is generated by a head-to-tail traveling-wave of body bending, sand-diving occurs through both undulatory body motion (typically 1-2 cycles) and a stereotyped pattern of limb use (and disuse). When all limbs were bound (taped to the body), the sandfish required 4-7.5 body undulations to fully submerge and had a higher failure rate than when the animal was not bound [1]. Building on these results, we seek to understand the timing and coordination of the sandfish's limbs and undulatory motion using a robophysical model. We tested a 3D printed servo-driven robot with four limbs, flexible wedge-shaped head, tail, and body. The robot measured 17 cm wide and 41 cm long. Using an air-fluidizable bed of a granular medium of poppy seeds, we investigated requirements for successful sand-diving. We used a stereotyped limb motion in tandem with a standing wave motion generated with one servo in the middle of the body. The limb motion is akin to a competitive swimmer's free stroke. The robophysical model can dig but not completely bury itself in the granular media. The aerated bed (defined as a state in which the air flows through the granular media but the material is not fluidized, see Qian et al, *Bioinspiration & Biomimetics*, 2015) decreases resistive forces so that the robot sinks, but still does not dive. Current experiments suggest that the head and neck play a role in starting the sand-diving process. This is in accord with previous research that showed that wedge-shaped robot heads with an angle greater than 120 degrees from the horizontal plane created a negative lift, enabling a sandfish robot (without limbs) to enter a granular medium after approximately 5 back undulations [2]. Maladen et al used low-friction 6mm plastic beads with no aeration. We found burying occurred between 2-20 body undulations depending on the level of aeration of the poppy seeds. Fewer body undulations occurred below onset of fluidization and bubbling. Updated versions of our model will include a head with greater freedom of motion which will improve the depth of the robot's initial dive. Additional servos will be added starting at the base of the head to allow for the wave form to travel from head to tail, which will more accurately model the traveling body wave undulations of the sandfish.

REFERENCES

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