Studying insects traversing large obstacles using a novel treadmill

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Insects can traverse natural terrain filled with obstacles comparable to or larger than their body size. A major challenge to understanding locomotion in such complex 3-D terrain is to create tools for controlled, repeatable, lab experiments with systematic parameter variation. Existing terrain testbeds only allow observations at small spatiotemporal scales (~10 body lengths, ~10 stride cycles) with low spatial resolution (~5% pixels representing the insect). Here, we present a new terrain treadmill to enable high-resolution observations of insects moving through large obstacles over large spatiotemporal scales. The treadmill consists of a transparent outer spherical shell rigidly connected to a concentric, solid inner sphere with reconfigurable terrain modules, and motors that rotated the outer sphere to keep the animal centered on top. To demonstrate its performance, we tested locomotion of discoid cockroaches (*Blaberus discoidalis*) through cluttered and sparse pillar obstacles. The treadmill elicited sustained locomotion for up to 25 minutes (2500 strides) and over 100 m (2000 body lengths) in single trials. For cluttered pillars, narrow gaps resulted in significant body-pillar contact, and the animal almost always traversed by rolling through the gap. By contrast, for sparse obstacles, body-pillar contact reduced due to wider gaps and the animal's use of antenna to detect and avoid obstacles. For both cases, apart from walking and running, behaviors like antennal sweeping, body rolling/turning, pillar climbing were observed. Our terrain treadmill increased the limits of experimental duration, distance, and spatial resolution and opens doors to studying behavior in complex terrain.