iSUM: Investigation of 3D Physical and Computational Models of Self-Uprighting Behavior in Pill Millipedes

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Pill Millipedes play a vital role in humid forest ecosystems, functioning as decomposers and indicators of environmental health, thereby supporting biodiversity. One of their most interesting behaviors is curling into a tight sphere when threatened and later self-uprighting once the danger has passed. However, recent observations at our school, located near the Wang Chan Forest, revealed a significant decline in their population following nearby construction activities. Past research suggests surface conditions can influence their locomotion, yet due to challenges in controlling live specimens, many aspects of their self-righting mechanism remain poorly understood. To address this, we present an interdisciplinary approach combining biological observation, physics-based modeling, and engineering design. Through detailed video analysis, we identified a three-stage flipping mechanism: Stage 1 (leg-ground contact), Stage 2A (successful flipping via ground reaction force), and Stage 2B (unsuccessful oscillation due to over-relaxation). We replicated this behavior using computational simulations and physical experiments. A 3D-printed model—constructed with a rigid filament shell, silicone tissue, and embedded magnets—was developed to mimic biomechanical properties and test flipping dynamics. Our results show that an opening angle of 309.35° and a ground slope of 20.10° optimize self-righting by minimizing the required impulse. Statistical analysis using a chi-square test confirmed strong correlations between experimental and simulated data. These findings advance our understanding of millipede biomechanics, offer valuable insights, and potentially contribute to eco-conscious construction design and bio-inspired robotics

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