Self-Righting Shell for Robotic Hexapod

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Getting flipped is a problem

Most terrestrial locomotion methods rely on appendages that are on the "bottom" of the body. This makes flipping a significant failure mode for animals and machines.



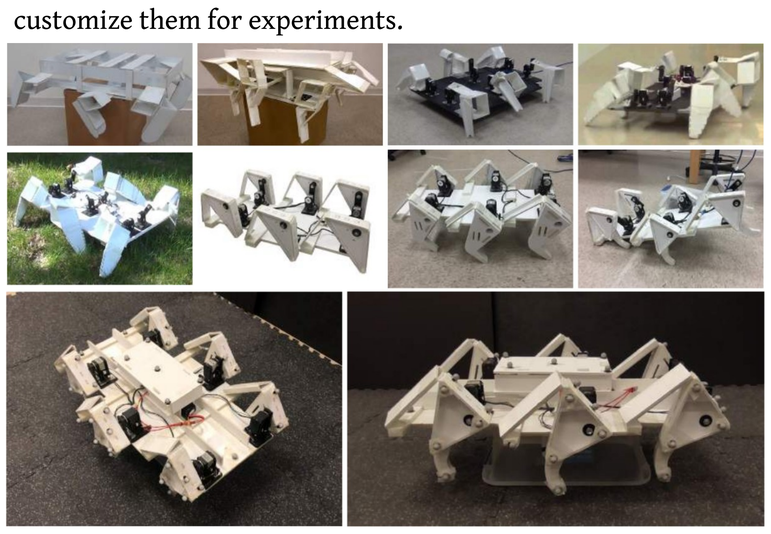
from Chen Li, *et.al.* ***Cockroaches use diverse strategies to self-right on the ground***, J. Exp. Biol. 222 (15): jeb186080 (**2019**)

Can flipping be addressed without any additional DoF or code?

We show a systematic approach to create a passive design that self-rights on flat ground.

The BigANT Robot Family

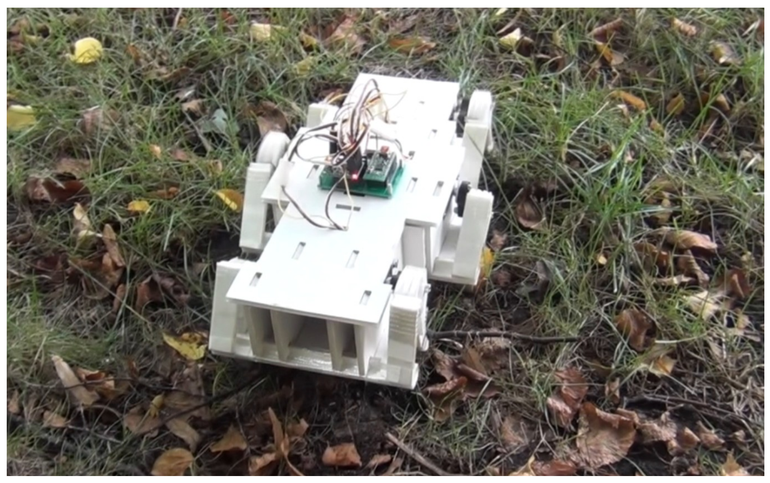
The BigANT robot family grew from a student project to scale up the Bekeley RoACH robot design to 1m scale. For the past 10 years we have developed and improved the BigANT family of robots. BigANT allowed us to explore rapid fabrication of robots. The entire chassis is made out of two materials – foam-core (poster-board) and fiber reinforced tape. It costs <$20 and takes a day to build. This allows us to rapidly build robots and customize them for experiments.



The Educational MediumANT

MediumANT is an educational robot designed to be build by high-school students[1]. The BoM is <$200 US; all parts but one cut foam-core; the remaining part is easy and fast to 3D print and is not tolerance sensitive.

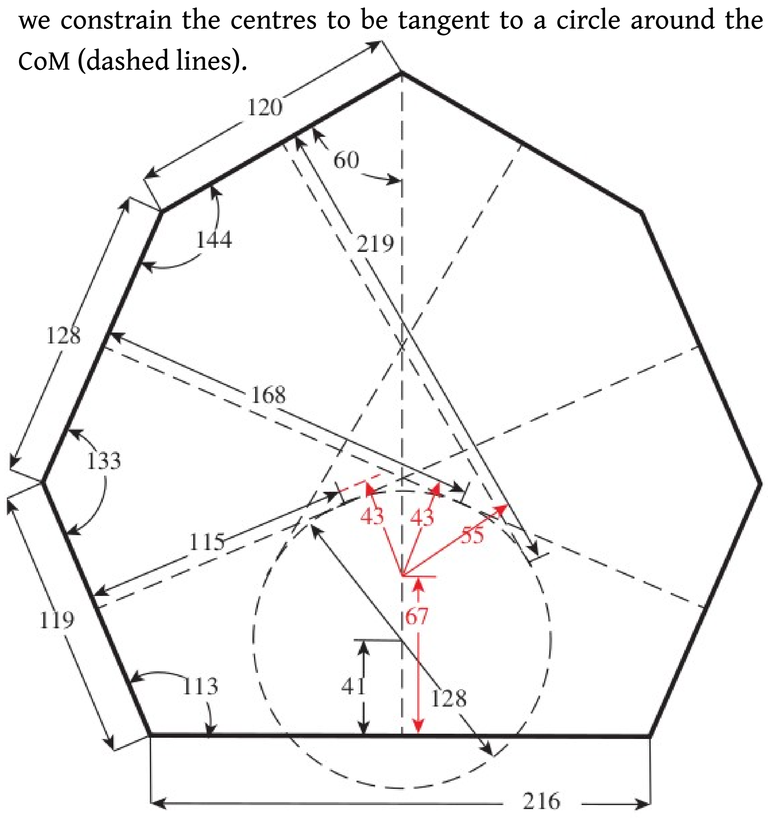
We used MediumANT as a test bed for demonstrating how to build a shell that makes a robot always right itself if it is on flat ground. It is based on modifying the original chassis[2] to allow a carefully designed roll cage shell to be attached.



[1] see https://mileggedrobot.eecs.umich.edu under MEDIUMANT
[2] tutorial http://tinyurl.com/buildMedANT

Starting from a 2D solution

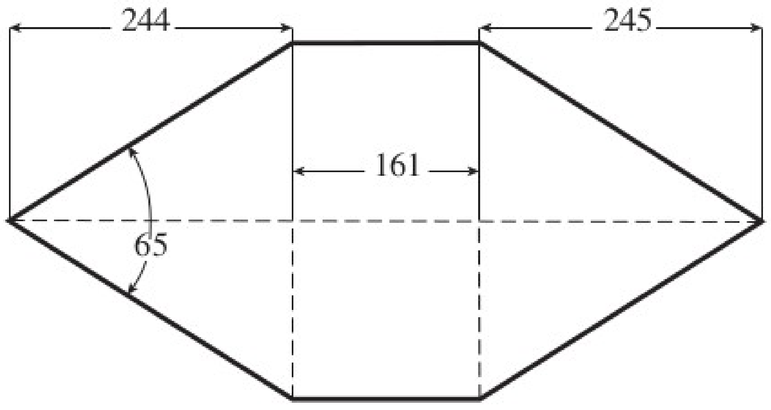
First, we stabilize roll, the robot's most common mode of flipping. We make the following simplifying assumptions:
1) On a flat plane, a face produces a force at its centre.
2) The shell itself is weightless.
3) The shell is bilaterally symmetric
Since we would like all the faces to have a minimal lever arm, we constrain the centres to be tangent to a circle around the CoM (dashed lines).



In practice, the weight of the shell moved the CoM up from 41mm to 67mm, leading to smaller lever arms (red arrows) but these still ensure the shell will induce rolling the robot back to an upright position allowing it to stand on its feet.

Extending to 3D

In the horizontal plane, previous work [Han2021] has shown that a narrow tip can help a robot maintain orientation as it encounters obstacles. We added this feature to our design with the following requirements:
1) Front and hind faces of horizontal projections must produce moments that roll (in world frame; yaw in body frame) onto the central self-righting prism.
2) The horizontal projection of the shell is 4-fold reflection symmetric.



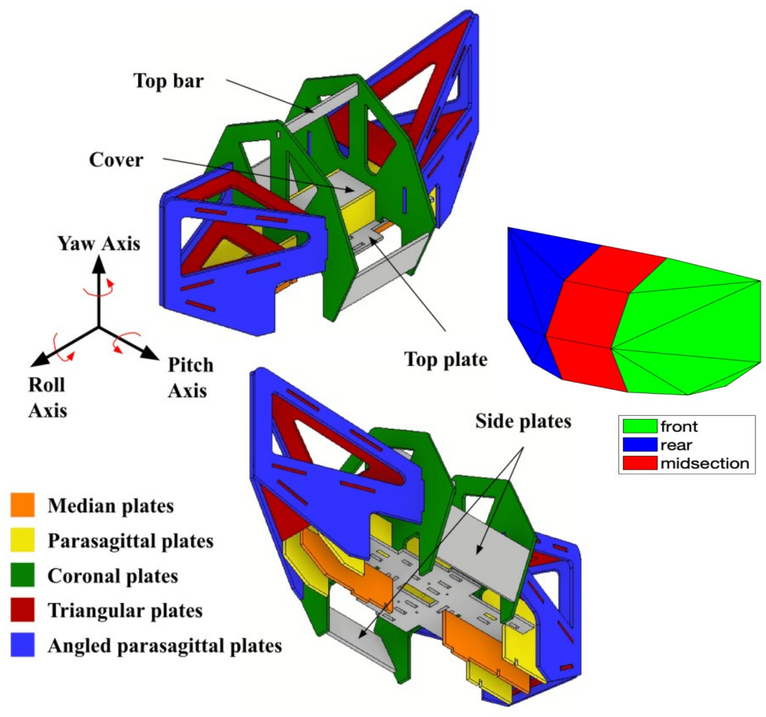
For the saggital projection, we required that the front have a raised slope reaching higher than the CoM, to allow the robot to passively climb onto steps.

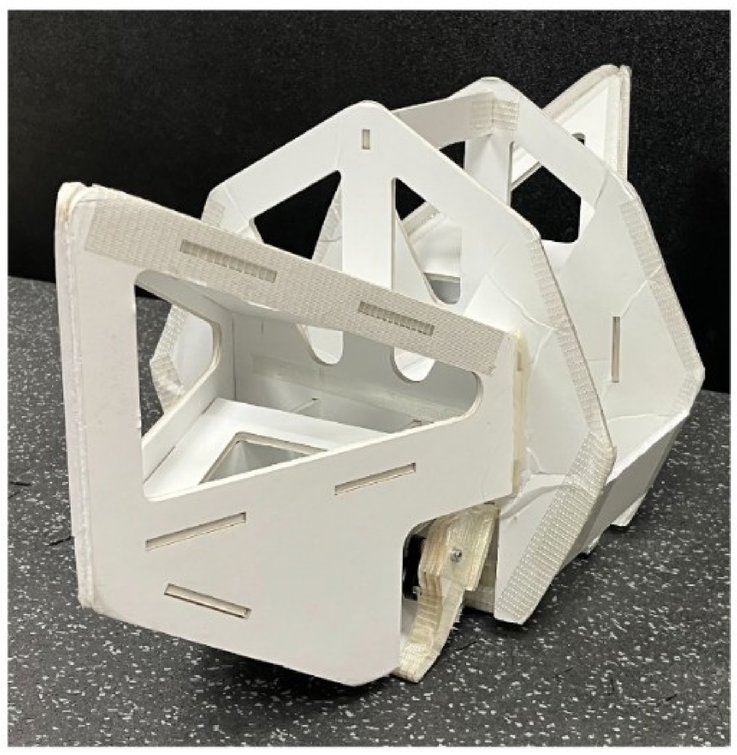
Intersecting the horizontal, saggital, and coronal projections produced a hull whose corners we needed to reach with sufficiently rigid structures.

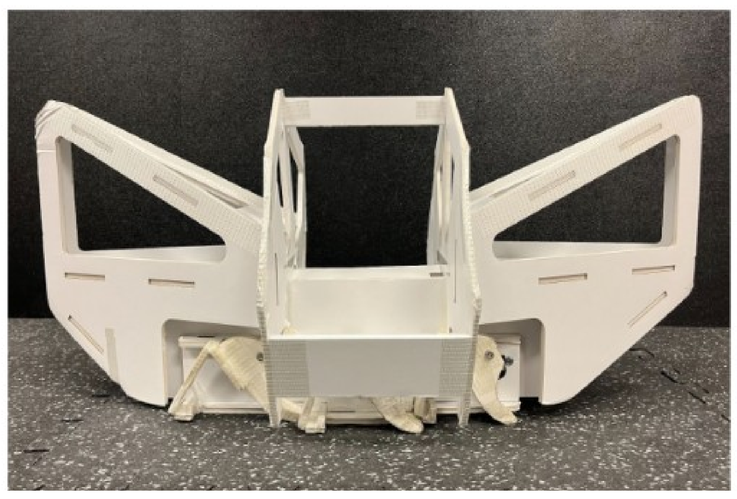
[Han2021] Han, et.al., *Shape-induced obstacle attraction and repulsion during dynamic locomotion*, IJRR, 2021

Realizing the Shell

The shell design method lead to a convex hull, which we manually tuned to reduce the number of faces and corners while still meeting all design requirements and assumptions.







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