Beyond Touch and Go: Evolving Bipedal Walking Maneuvers for a Spacecraft on Stilts to Explore Asteroid Surfaces

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Motivation

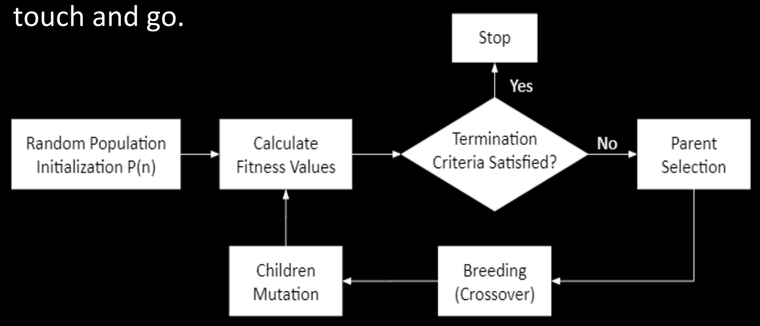
There are 2 million asteroids in the solar system that vary in shape, size, composition and origin. These small bodies can provide critical insight into the origins of the solar system. Sampling the surface and subsurface of these bodies is one of the best ways possible to attain this insight. Current missions can only perform touch and go and have only been able to collect a few samples from a small body. This is because the surface of an asteroid has many unknown risks that impacts landing and mobility.

Concept

The SPIKE (Spacecraft Penetrator for Increasing Knowledge of NEOs) craft is a unique spacecraft that is a hybrid lander and flyby spacecraft with one or more booms to hop to places on an asteroid. The first model (shown above) consisted of a single boom. This is an extension of that project. With this we hope to expand on the spacecrafts design, landing and mobility.

Method

This study aims to use Evolutionary Algorithms to optimize the number of booms to facilitate 'walking' over the asteroid surface. The resulting designs can consist of multiple booms to help understand mobility in low-gravity conditions and provide new pathways for exploration beyond touch and go.



Evolutionary Algorithms

The purpose of an Evolutionary Algorithm is to perform stochastic search in high-dimensional search space to find near-optimal solutions. The process is outlined below.

Step 1

Initialize a population with random parameters

Step 2

Calculate a value that pertains to how they do in testing

Step 3

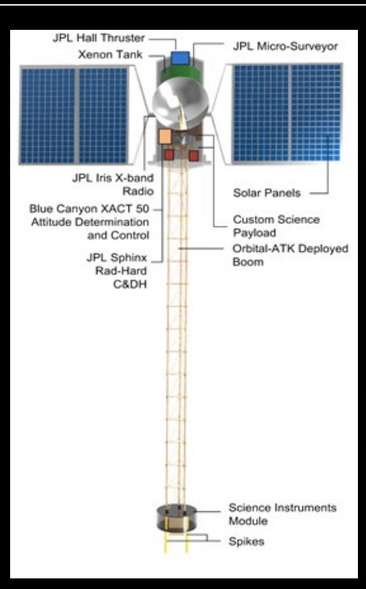
Determine if the optimal solution is found, if so stop here. If not select 2 "parents" with the highest fitness value

Step 4

"Breed these parents, mixing up their genes

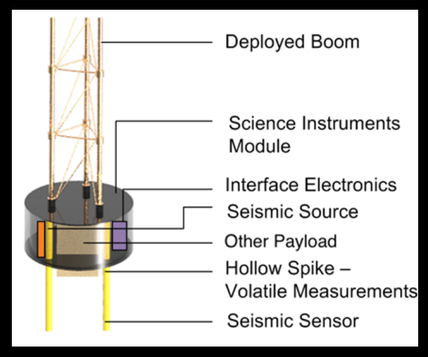
Step 5

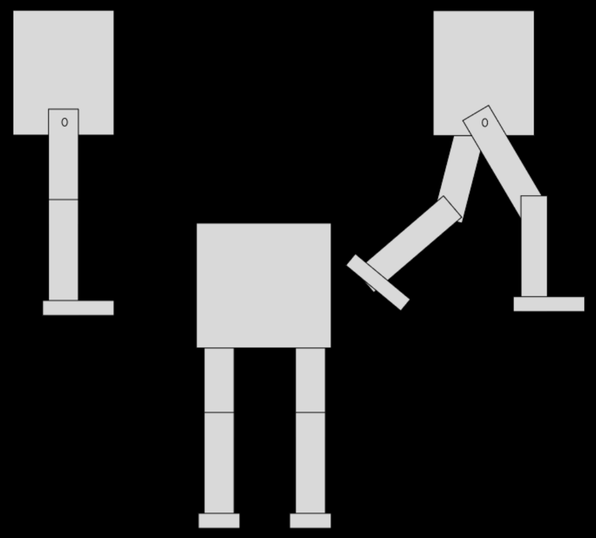
Mutate them if need be then repeat at step 2.



Original Design

This design consists of a singular boom with movements like that of a pogo stick. It has a bus, solar panels and is propelled by xenon fueled solar-electric Hall thrusters . It is based on JPL Micro Surveyor.





Two-Legged Design

This design is more like a bottom half of a humanoid, consisting of two booms or "legs". It has 3 links that connect the body (bus), legs (booms) and the feet (the bottom of the booms). The movement could mimic human crawling, walking, as well as hopping.

The Booms

The boom or the legged portion of the spacecraft can be instrumented to perform science. This enables the spacecraft to move from location to location on an asteroid, while doing important science. In the original design, the boom can analyze subsurface volatiles and organics, as well as, conduct seismology. The payload of this is equipment is seismometers, cameras, and other instruments that will be designed to access >10 cm beneath the surface of the asteroid. We plan on incrementally introducing these sophisticated science instruments into the two-legged design. The challenges includes modelling the interaction of seismic instruments with the asteroid regolith during various stages of the crawling, walking or hopping maneuver while limiting damage to instruments and keeping the gait-physics relatively simple. Beyond simulation experiments, the team plans to validate the evolved low-gravity walking-gait controllers using robotic hardware in the laboratory.

Evolutionary Experiments

Gravity: 1 m/s² Generation 1 Time: 3 seconds

Gravity: 1 m/s² Generation ~200 Time: 8 seconds

Gravity: 9.81 m/s² Generation 1 Time: 3 seconds

Gravity: 9.81 m/s² Generation ~200 Time: 1.5 seconds