6.4212 Project Proposal Fall 2022

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Motivation

Rock skipping is a highly dynamic and relatively complex task that can be performed easily by many humans. Using motion planning and perception tools learned in this class, we plan to make a program which can use the IIWA robotic arm to sling a rock across a surface that mimics the behavior of water. With hope, we can maximize the number of skips that the rock displays to gain insight on rock skipping and motion planning.

Project

To reiterate, the exact project deliverable is utilizing the IIWA robotic arm to throw a rock with the intended goal of maximizing the total number skips across a simulated water-like surface. This will be achieved in two main sections mentioned below. In addition, we have a stretch goal (depending on time) of developing a perception system to choose a desirable rock shape over a set of generated geometries. We will use pydrake to develop simulation and trajectory.

First, we will need to set up a simulation in Drake that consists of a surface that mimics the behavior of water. Specifically, we will need to implement our own multibody force element to model the interaction between the rock and surface of the “water”. The magnitude of this force will be determined using a paper on rock skipping dynamics that is mentioned in the prior work section of this proposal. Overall, this will be a rather tricky project as it encapsulates the entire dynamics of the rock skipping problem. As a result, this will take a lot of trial and error to determine the exact configuration. For example, we may need to model the surface of the water as a hydroelastic surface since the amount of force that should be applied is determined by the compliant contact of the rock and surface. Ultimately, we will need to execute and tune these potential ideas in simulation to find the one that works most realistically. We also need to create the rock with a desired elliptical shape (flat and high level of surface area). We can generate this shape by using the primitive ellipsoid shape in SDFormat which is easily parsed by Drake. To test our simulated environment, we will simplify the problem by launching the rock with a particular initial velocity (not using the robotic arm). This will enable us to fine tune the simulation before diving into the mechanics of the arm.

With the desired simulated environment, our next task is to manipulate the rock and throw it. First, the robotic arm will need to determine ideal grasping points in order to pick up and toss the rock. Our current impression is that grasping the sides of the rock will optimize the arm’s ability to flick the rock such that it only spins along a given axis (the flat side will remain on the bottom). Once the rock is grasped along its major axis, the robotic arm will have to fling the rock with high angular velocity in an attempt to skip it. Trajectory will be generated to optimize the angular momentum of the rock and horizontal velocity, while considering the actuation limitations of the IIWA arm. Over the course of the project, it will be interesting to uncover how planned trajectory and rock shape affect the number of skips possible. For example, if we choose the wrong rock, do we get less skips? Similarly, if we don’t fling the rock fast enough, do we get less skips? We hope to answer these questions. For this project, it's important to note we assume an abundant number of camera perspectives.

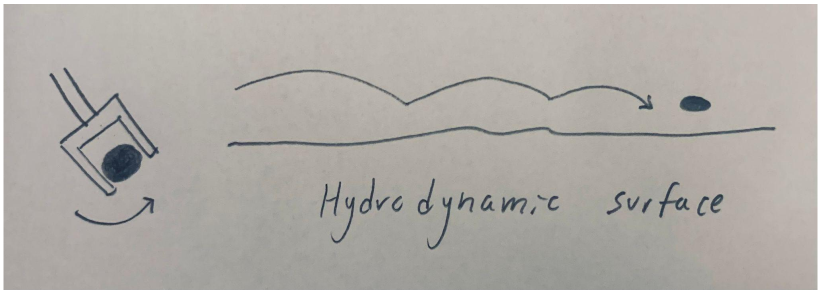

Figure 1: Rock flung and skips across a hydroelastic surface.

If we have enough time given the short timeframe of the project, we have a stretch goal of developing a perceptive system for choosing optimal rock shape. Our proposed setup would be to have a predetermined number of rocks with constant shapes. So, for example, we would have 3 rocks: one spherical, one rectangular, and the desired elliptical shape (we will have already implemented). This setup is displayed in Figure 2. We will be able to use the same SDFormat to generate these additional shapes. Our program would determine the desired rock based on a point cloud's estimated normals. Specifically, we will create an objective function that optimizes rock shape by evaluating the major and minor axis of the point cloud. Every action from this setup is executed using a finite state machine.

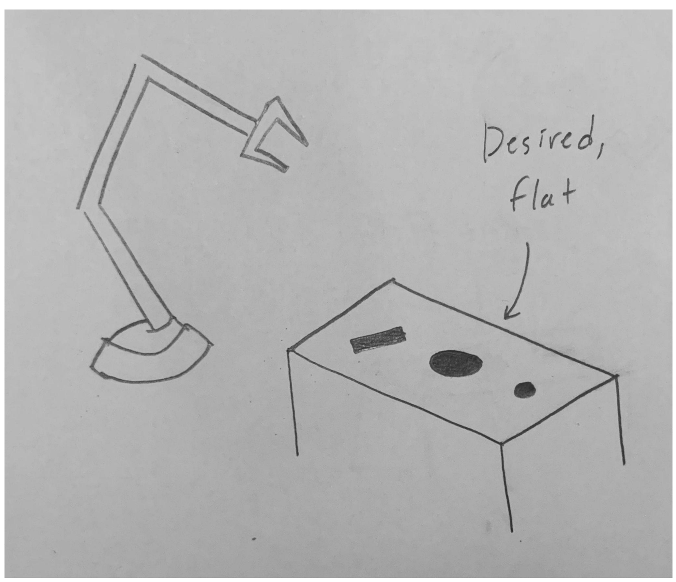

Figure 2: Rock and arm stretch goal layout

Prior Work
There has been limited prior work done to uncover optimal trajectories for motion planning of rock skipping. Similarly, no robotic system has been built to execute the task of rock skipping. However, work has been done to investigate the dynamics of rock skipping. We can leverage these studies to inform our project. The most notable example can be found here.

Timeline

October 30th:	Understand the dynamics of rock skipping Learn how to utilize tools in Drake to develop our project
November 7th:	Get simulation set up
November 15th:	Incorporate dynamics into simulation Start developing throwing trajectory
December 2nd:	Throwing trajectory done