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Summary

We had originally discussed creating a pool game but discovered that a student last semester had already done a project. As a result, we threw around ideas for a similar game and decided on curling. Currently, there does not appear to be any curling games that actually take into account what affects a curling rock and just have the rock move in some kind of arc. We want to create a simulation that takes into account the coefficient of friction of curling ice, which is approximately .015 (less than Teflon) [1], as well as the linear and angular momentum of the rock. We also want to simulate the effect of brushing a rock, which reduces the coefficient of friction by melting the ice in front of the rock. We plan to combine these forces with accurate collisions to produce an accurate curling simulation. We will be programming the game from the ground up using Python, Pygame to handle events and PyOpenGL to handle rendering.

[2] The motion of a curling rock: Analytical approach

This paper takes previous work exploring what causes a curling rock to actually curl and works to create a simplified function that explains the phenomena. The result is a single formula that can predict the motion of a curling rock. The equation is $\tilde{x} = \frac{5}{2}\left(1-(1-y)^{\frac{3}{5}}\right) - \frac{3}{2}\tilde{y}$ where $\tilde{y} \equiv \left|\frac{y(t)}{y(t_0)}\right|$ is the displacement parallel to the direction of initial velocity and $\tilde{x} \equiv \left|\frac{x(t)}{x(t_0)}\right|$ is perpendicular to $\tilde{y}$ and is the horizontal displacement of the rock. $x(t_0)$ and $y(t_0)$ are the final positions of the rock. Using this function (Fig 1 in [2]) you can see that most of the curling of the rock takes place towards the end of its trajectory.

We plan to use this information to determine a general path for the rock which will be fine tuned depending on the coefficient of friction acting upon the rock, which when brushed will be lower and will cause the rock to move in a straighter trajectory, and if left alone will be maintained and cause the rock to curl more.

[3] 2-Dimensional Elastic Collisions without Trigonometry

The paper begins with elastic collisions in one dimension. Using conservation of momentum and kinetic energy in a collision they use algebra to find the final velocity of 2 objects in one dimension. Next the paper moves in to two dimensions. They follow 7 steps to find the values of velocity in vector form. They first find the unit normal, which is the direction between the two centers through the collision point and unit tangent, which is perpendicular to the unit normal at the collision point. Next they make the initial velocity vectors if it is necessary. The tangential velocity of the objects is the same after the collision so they separate the velocity vectors into scalar values in the normal and tangent directions using dot products. The next step is to find the new tangential velocity which is the same as the original. Then they find the normal velocities which is just a one dimensional collision in the normal direction so they use the formal for elastic collisions in one dimension. From there they find the normal and tangent velocity vectors by multiplying the new scalar value with the unit normal or unit tangent. They then add the normal and tangent velocity vectors to find the new velocity vectors of the objects.

This paper is useful for our project because we will need to produce 2 dimensional elastic collisions when the curling rocks collide with each other and without using angles reduces the amount of computations we need to do.

[4] The physics of sliding cylinders and curling rocks

The paper starts by first finding the equations of motion for sliding a cylinder along a solid surface and what would happen if the cylinder is rotated during the start of initial velocity. It is demonstrated that with rotation the cylinder curves in the opposite direction of the rotation on a solid surface, so if the cylinder is rotated counterclockwise it curves right and if rotated clockwise it curves to the left. The reason stated behind this is that there is a frictional difference between the front and back of the cylinder thus causing it to curve. They conduct some experiments and show that their theoretical path closely follows the results of the experiments. The paper then moves into the curling rock and its movement on ice. Using more math they find the distance a rock should deflect in the x direction but these numbers are the opposite of what are actual. They find that the more rotations the more the rock should deflect while in reality the more rotations the less the rock actually deflects. They also show that curling rocks on ice deflect in the opposite direction as cylinders on a solid surface. While the cylinders on solid surfaces seem to follow a constant deflection, curling rocks seem to take a sharper turn towards the end of their path going almost completely in the lateral direction. The paper then proposes the reason behind the curve is not because of front-back asymmetry in friction but rather left-right asymmetry in friction being one of the factors. This is shown that by itself can not explain the curl of the rock. Another one of the factors that the paper hypothesizes is that the ice melts due to the friction with the rock and the back of the rock has less friction due to the ice melting slightly from the friction generated by the front of the rock. This would reduce the amount of front-back asymmetry. The last hypothesis that the paper talks about is that the ice-rock friction collision is adhesive in nature which would cause pivoting about the slow half of the rock. This is backed by the fact that rocks may suddenly deflect from their path if they catch something on the ice, and the deflection is in the same direction as the rock is traveling.

This paper is useful for our project because if we were to model the simulation as a cylinder on a solid surface we will get rocks that curve in the opposite direction as would be accustom to the sport of curling. We will need to take this paper and other sources to try and hypothesize and simulate the curve of the curling rock. We may need to alter the surface properties of the rock and/or ice to get the proper movement that we are looking for.

Goals

1. Rendering curling rock and rink using Python, Pygame and PyOpenGL
2. Movement of curling rock using equation from [1]
3. Collisions Part 1 – collisions and transfer of linear momentum when rocks collide
4. Friction implementation to speed up or slow down rock along base trajectory
5. Rotation (curling) implementation to allow the rock to curl depending on coefficient of friction
6. Collisions Part 2 – transfer of angular momentum and resulting path correction when rocks collide

7. (Extra) Implementing gameplay mechanics - if the game is functional it can be scored by the players. If w have time we would like to implement scoring within the actual game)
8. (Extra) Raytracing effects – we would like to implement some ray tracing effects possibly including, shadows, reflections, cell shading, or caustics.

<u>Timeline</u>

4/15/10 – Completion of goals 1 and 2. 1 will be completed by Mark and 2 will be completed by Jeremy.

4/22/10 – Completion of goals 3 and 4. 3 will be completed by Mark and 4 will be completed by Jeremy.

4/29/10 – Completion of goal 5 which will be completed by both members.

5/6/10 – Completion of goal 6 which will be completed by both members.

5/12/10 – Bug fixes remaining from previous goals and possible implementation of goals 7 and 8, which will be completed by both members.

[1] Babcock, David. “The Coefficient of Kinetic Friction for Curling Ice.” 1996. <http://web.archive.org/web/19980216103851/aci.mta.ca/TheUmbrella/Physics/P3401/Investigations/CurlFricDDB.html>

[2] Shegelski, Mark R A. “The motion of a curling rock: Analytical approach.” *Canadian Journal of Physics, 78*(9), 857-864. 2000. <http://proquest.umi.com.libproxy.rpi.edu/pqdlink?did=252335111&Fmt=6&clientId=8470&RQT=309&VName=PQD>

[3] Berchek, Chad. “2-Dimensional Elastic Collisions Without Trigonometry.” 2009. <http://www.vobarian.com/collisions/2dcollisions2.pdf>

[4] Penner, Raymond A. “The physics of sliding cylinders and curling rocks.” 2000. <http://scitation.aip.org.libproxy.rpi.edu/getpdf/servlet/GetPDFServlet?filetype=pdf&id=AJPIAS000069000003000332000001&idtype=cvips&prog=normal>