Joint and Structure Design of a Legged Hopping Robot

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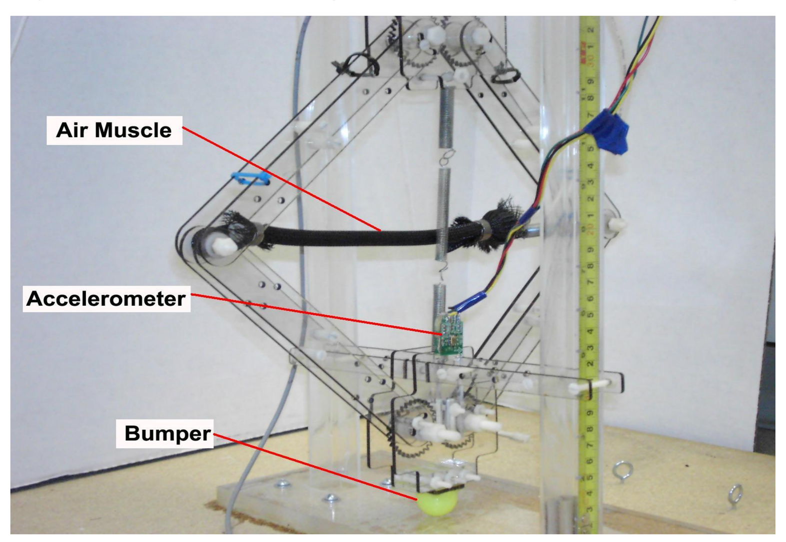
Project Overview

RoboPogo™, is a new robot designed to bounce and flip through uneven terrain and for entertainment purposes. The hopping motion is powered by pneumatic McKibben Actuators, also known as Air Muscles, that contract when pressurized and have a high power to weight ratio. The objective of this project is the design of the **structure and rotary joints** for the RoboPogo™, with emphasis on reducing frictional energy losses. The kinematics of the hopping robot requires 3 sets of platforms constrained to move as straight line mechanisms. A kinematic configuration was developed that provides the desired motion with purely rotational joints and without energy losses associated with gears used in prior versions. In addition, a new joint was developed based upon the Smith Rolling Hinge and which is analogous to the human knee joint. The potential for this joint is reduced frictional losses and ability to withstand high compressive loading.



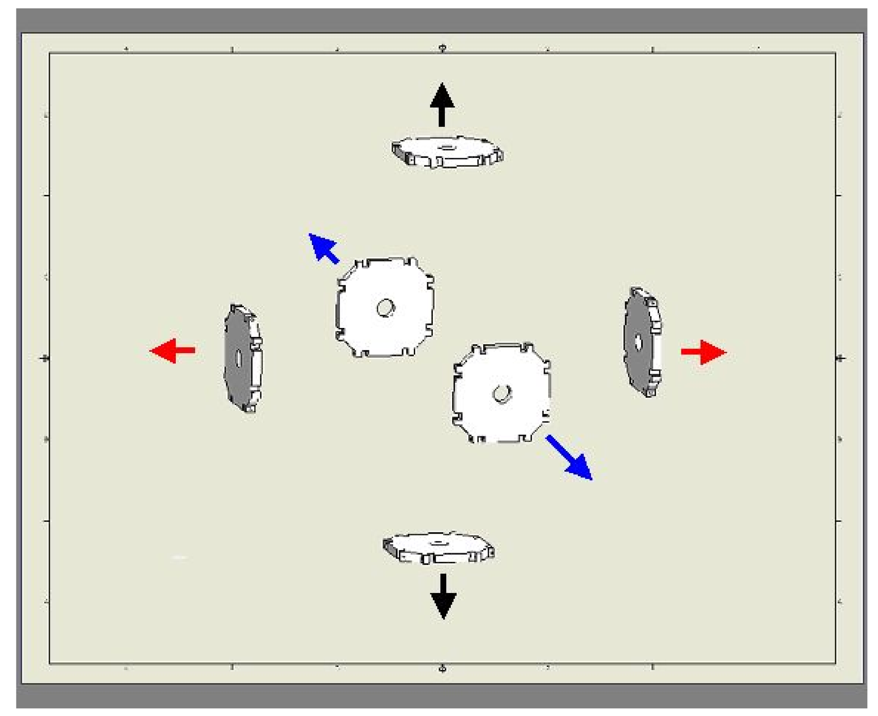
2D Version of Robopogo ™ with Air Muscles

Air Muscles will expand and contract the structure, allowing it to hop, while weighted wheels (not shown) on either side of the structure will spin, giving Robopogo™ the angular momentum to flip.

Hinge and Structure Requirements

- To created stable surfaces to mount stabilization actuators and bumpers, we wanted to create a structure with 3 sets of platforms constrained to move in a straight line without changing orientation. Specifically the whole mechanisms must have only one Degree of Freedom.
- Strong connections and joints between each platform to absorb impact on the bumpers and if the robot should not land directly on a platform.
- Maximum interior space to allow room for payload and Air Muscles
- Joints with no or minimal friction because there are so many joints, a small amount of friction in each hinge would sum up to a large energy loss.

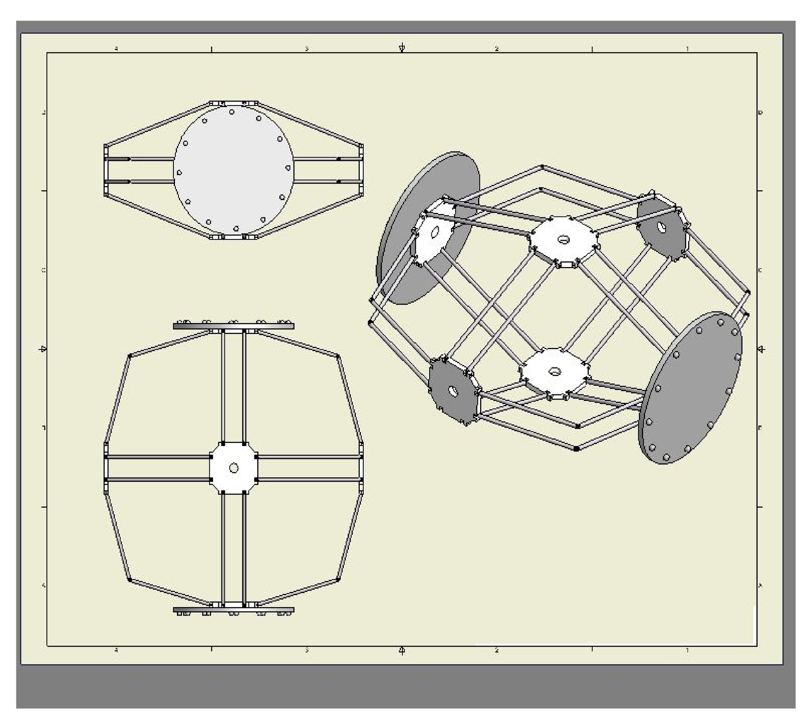
Kinematic Design



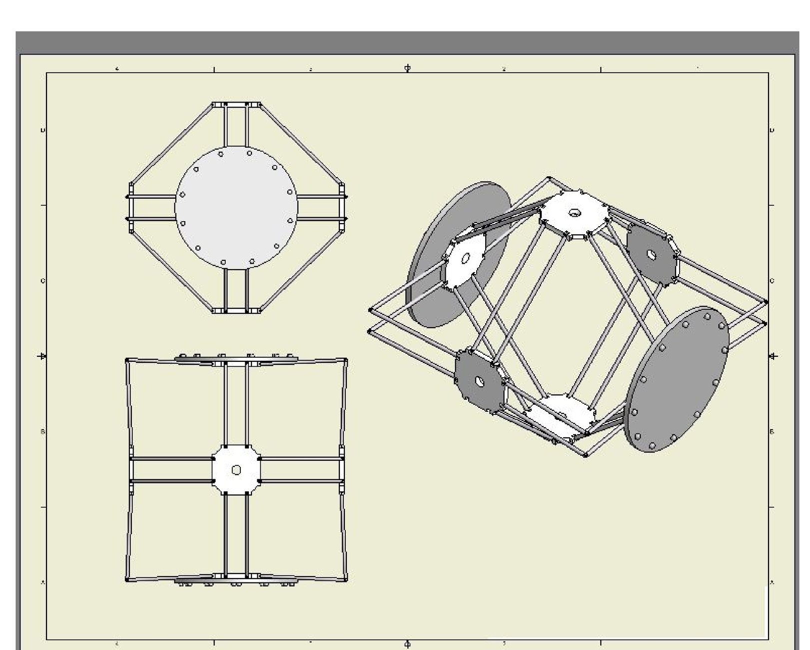
Desired Motion

3 sets of **platforms**. The platforms in each set move parallel to each other, while each of the sets move perpendicular to each the other sets

To kinematically constrain each platform to motion to a single degree of freedom, and to keep the middle of the robot open, each platform had to be attached to all 4 of the platforms around it. With this configuration, two sets of platforms expand, while the other set of platforms contracts.



Robot structure collapsed

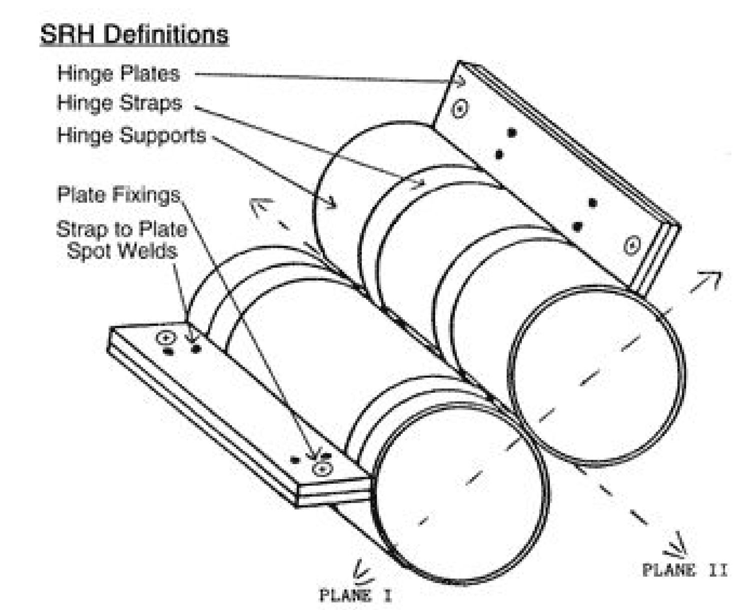


Robot structure expanded

Hinge Design

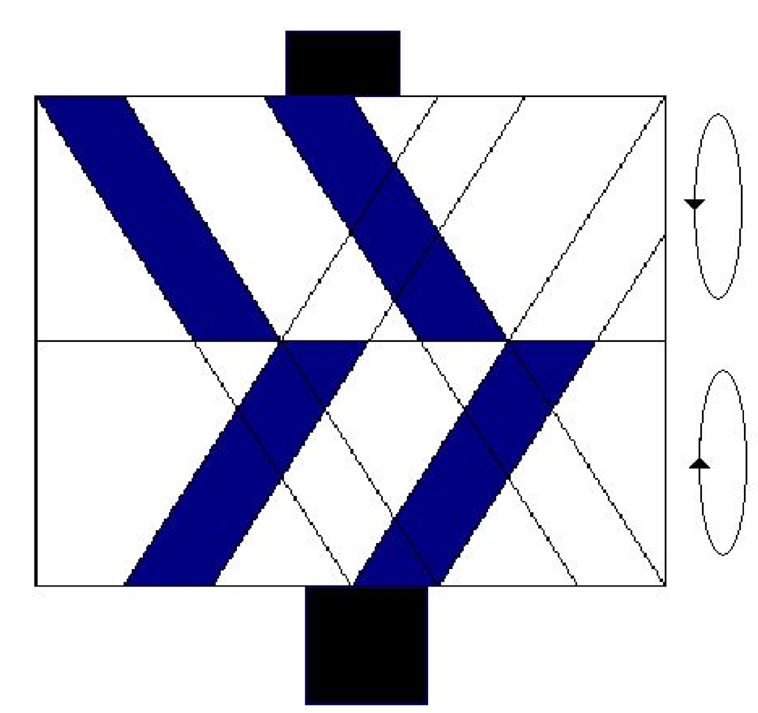
Smith Rolling Hinge

The first operational version of the structure was built with standard pin type hinges. However, an alternative hinge design is concurrently being pursued to reduce the frictional losses in the motion of the structure. This new hinge is based upon the Smith Rolling Hinge; which is a hinge with 4 hinge straps that keep two hinge support cylinders rolling tangentially with respect to each other. Using such a hinge would mean no energy lost to friction. However, the hinge was stable and solid in plane 1, but not very much in plane two. Loss of rigidity in any joint would cause each plate to loose its 1 dimensional constraint



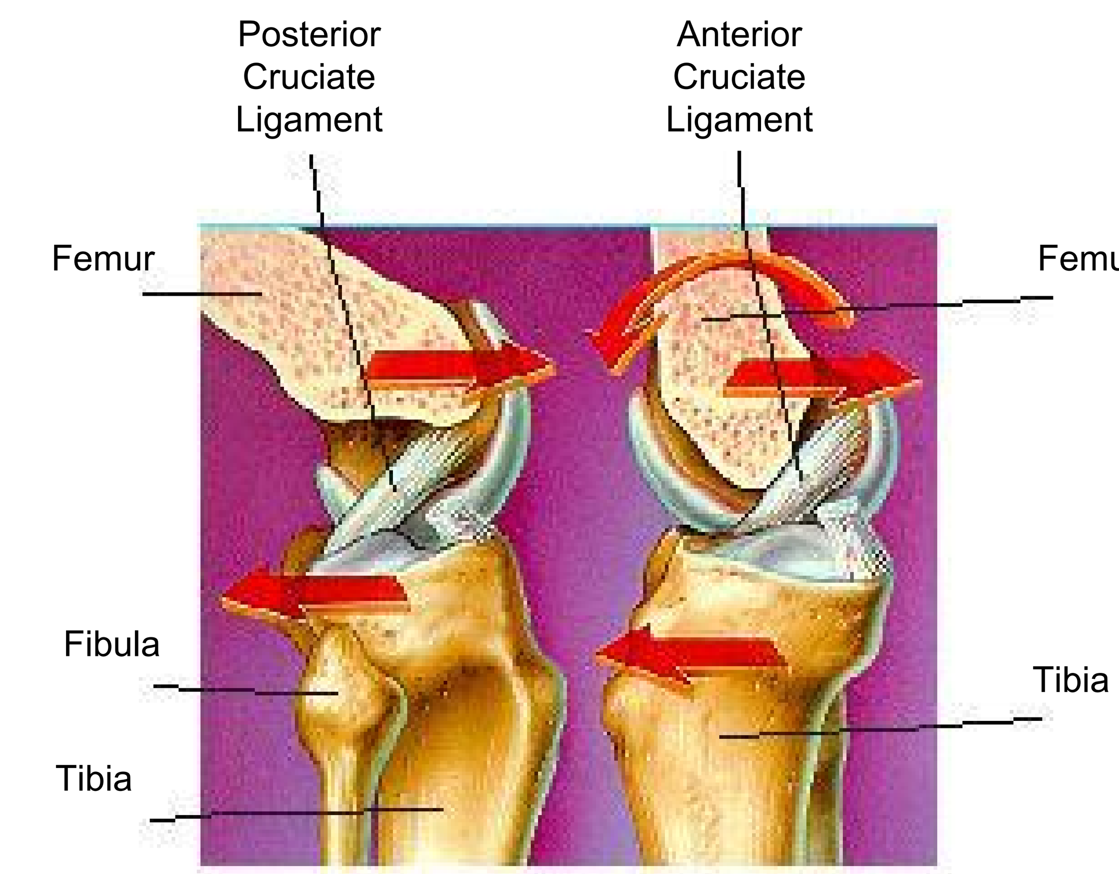
Hinge Modification

To strengthen the hinge in the plane II direction, the hinge straps were rearranged to run at an angle to each other. A strap can bear load only when in tension. By lacing the straps at an angle, each set of straps contributes to joint stability in both planes 1 and 2. This configuration offers more overall rigidity than a the original Smith Rolling Hinge.



Modified Smith Rolling Hinge: Blue straps are visible, white straps are hidden. The joint flexes about line AB.

The Modified Smith Rolling Hinge very much resembles the human knee hinge, where both are connected by straps that pass through the axis of rotation. Since both the Robopogo and the human knee need to absorb impact loading, we hope to learn from the knee joint design approaches.



Lateral View Medial View

Robot Construction

The connections between the 3 sets of platforms are pieces of Aluminum tubing because they are easy to construct with, are light and fairly strong. Using two tubes per connection give the structure greater stability.

To model the structure without having to build a modified Smith Rolling Hinge at each joint, and as a comparison between available hinges and the rolling hinge, we used Robart hinges. Steel dowels are press fitted into the 6 platforms through half hinge joints. The wholes of the half inch joints were made larger to fit the standard dowels.

References

1. Courier Products Limited. 2/18/06.<http://www.courprod.co.uk/hinge.htm>
2. "Knee Joint – Anatomy & Function." 4/3/2003. The Center for Orthopedics and Sports Medicine. 2/19/06. http://www.arthroscopy.com/sp05001.htm.

Acknowledgements

Thanks to: Nathan Delson, Chris Cassidy, Tom Chalfant