Rubber Bands, the Ultimate Botball Actuator
Jeffrey Hsu
Nease Robotics - Ontic Development Group Team 10-0055
hsus@msn.com
GCER 2010
For publication in the conference proceedings and to be given as a talk during the conference

Rubber Bands, the Ultimate Botball Actuator

Every year, Botball has a designated kit. This kit contains all of the motors, servos, and materials a Botball robot is allowed to be constructed with. Most teams will simply use the standard Lego and metal components for their robots. In doing so, they often miss the unique properties of the additional materials in the kit. The largest lost opportunity is the powerful rubber band. Although they can easily distract and entertain bored individuals, when utilized on a robot, rubber bands can be the ultimate Botball actuator.

1. Rubber Bands

Rubber bands, at their lowest level, are simply a band of rubber. However, this rubber material has elastic characteristics. After a rubber band is pulled or stretched, it is capable of returning to its original shape. This physical property of the rubber band allows the storage and release of energy, in the form of mechanical motion.

1.1 Rubber Band Elasticity and Spring Constant

This behavior of a rubber band matches that of an expanding spring. When a spring is pulled from its normal state, the material attempts to return to that original state. As a spring is pulled further from its normal state, the material opposes even more. A greater amount of force is necessary to pull the spring a greater distance. The behavior of the spring follows Hooke's Law and can be modeled by $F = -kx$, in which x is the displacement from the normal state or equilibrium position, k is the spring constant of the material, and F is force exerted by the material to return to its normal state. [1][2]

1.2 Rubber Band Wrapping

Rubber bands can be "wrapped" or overlapped to create a rubber band with smaller length and greater spring constant. This can be useful under many contexts. The act of wrapping allows an individual to adjust the rubber band's properties to the specific mechanism, potentially making it more effective.

1 Wrap (Single) 2 Wraps (Double) 3 Wraps (Triple) 4 Wraps (Quadruple) [4]

Rubber band wrapping is not limited to the styles presented here, however, these styles keep the displacement of stress and strain close to uniform among each rubber band strand. Other methods of wrapping, such as a cross or twist, often cause more stress on particular inner or outer strands, making deformation and fracture more likely.

2. Uses of Rubber Bands

Rubber bands, like any material, can be used in an infinite range of contexts and situations. However, there are particular mechanisms and designs where rubber bands are very advantageous.

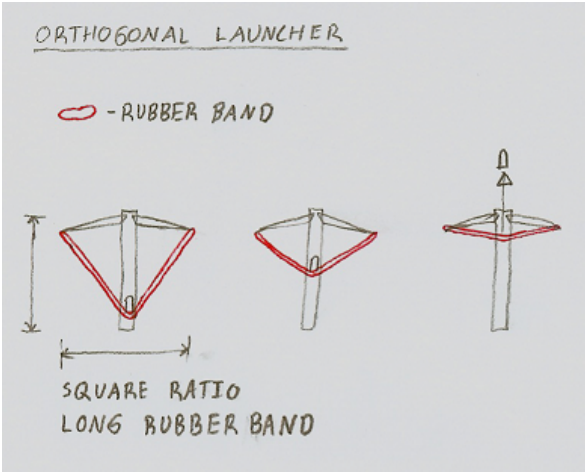
2.1 Launchers

The first mechanism should be very obvious. Nearly every individual in Botball has shot a rubber band at least once before, some have shots hundreds. Evident in a rubber band's ability to achieve a degree of flight, this energy is capable of launching other objects and projectiles as well. The projectile can vary based on the need and engineer who designed it. Rubber bands have enough power to shoot practically anything from small Lego axles to large baskets and grapples.

Launchers mainly come in two forms, based on the orientation of the rubber bands relative to the barrel of the launcher.

2.1a Orthogonal Launchers

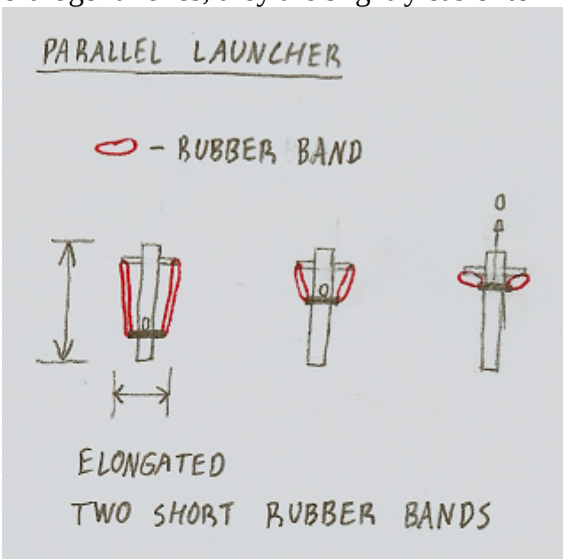
Orthogonal launchers consist of rubber bands perpendicular to the barrel, similar to that of a crossbow, ballista, or slingshot. Perpendicular launchers are capable of high tension bands, but rely heavily on the structural integrity of the frame. Certain flexing and bending of the frame reduces the effectiveness of a launch. Orthogonal launchers often take up a large amount of space on a single plane, making them difficult to use or incorporate on smaller robots.



*This picture shows the release of a projectile on an orthogonal launcher. The red loop represents a rubber band. Note that the mechanism is roughly square and the rubber band must stretch a long distance. [5]

2.1b Parallel Launchers

Parallel launchers consist of rubber bands parallel to the barrel, similar to spring loaded guns and weapons that use expansive materials like air or explosives. Parallel launchers use the energy from rubber bands more effectively due to the barrel and rubber band being inline with each other. This design often requires a larger hammer component, to carry the projectile. This often results in a very elongated frame, requiring a strong mount to the robot frame to prevent bending. Since parallel launchers are relatively smaller than orthogonal ones, they are slightly easier to incorporate in a small robot.



*This picture shows the release of a projectile on a parallel launcher. The red loop represents a rubber band. Note that the mechanism is very elongated and uses two small rubber bands for balance. [5]

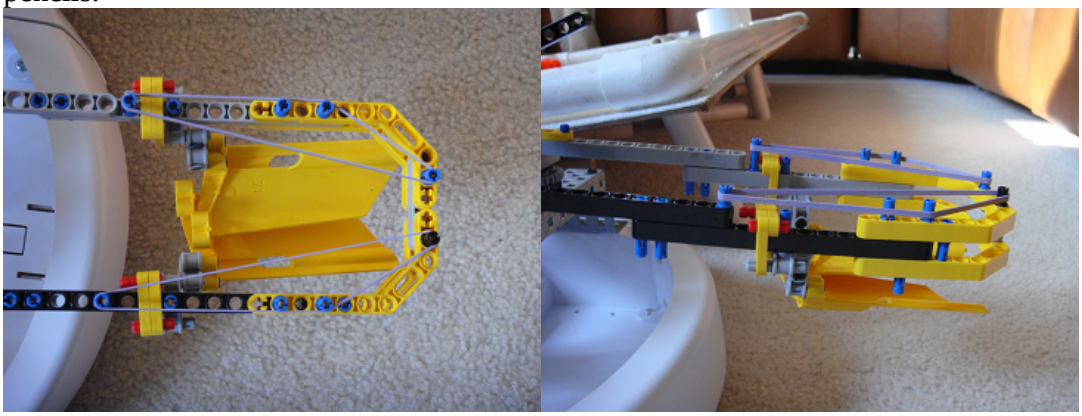
2.2 Claws

Rubber bands can greatly improve the effectiveness of robot claws, especially those with slick plastic Legos as grips.

2.2a Claw Assists

Rubber bands can be easily added to an existing claw to improve its grip. There are two main approaches to this, either increasing the friction between the claw and object, or increasing the force of the gripping mechanism.

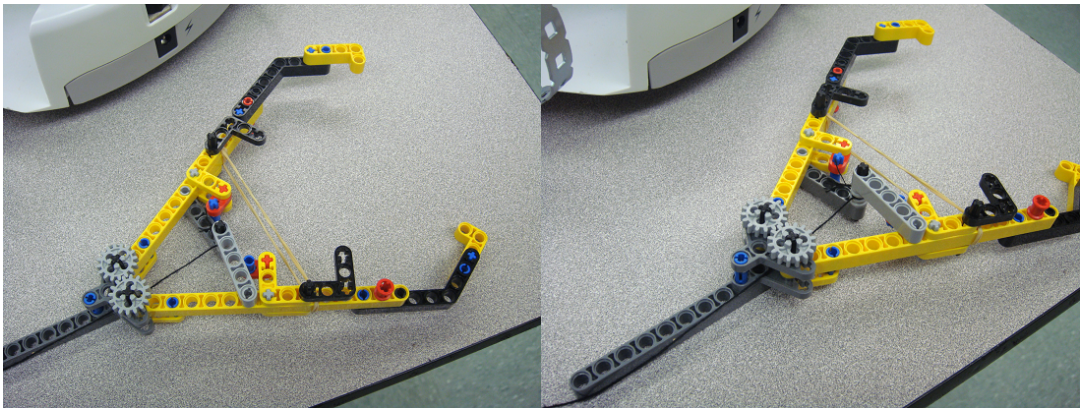
Rubber bands can be wrapped or intertwined in a claw to change the gripping surface that comes in contact with game objects. Rubber typically provides more friction than LEGO plastic, especially when gripping slick game objects such as PVC, plastic cups, and pencils.



*In these pictures of a Landrum Middle School robot, the robot claw uses Lego pieces to scoop under objects and purple rubber bands to grip them. [3]

A rubber band can also be used to assist the gripping motion of a claw. By wrapping it around the claw, a rubber band's tension can provide additional gripping strength from a motor or servo in one direction. This facilitates a tighter grip without involving a physical redesign of a claw's size or gearing.

A rubber band by itself can also be used to power a mechanism in one direction. This is especially useful when a team is running out of motors and servos on a robot. If the claw only needs to grip or lift an object once, a rubber band can be used to power the mechanism instead of forfeiting a valuable electronic actuator.



*In these pictures of a Nease High School grapple, the rubber band powers the gripping motion of this airborne claw. When the string is pulled, the rubber bands will shut the grapple and grip a target. [4]

2.3 Rubber Band Assists

This rubber band technology can be very crucial for robots that span long distances or carry heavy loads. Rubber bands can compensate for the weight of an arm or appendage, decreasing the apparent weight to a servo or motor attempting to move it. This allows for greater control and precision of the arm. In the context of a long, overhanging arm, the rubber bands are placed vertically, to cancel out some of the force due to gravity. Without the rubber bands, a servo attempting to lift the arm may be highly stressed or incapable of moving the arm. The servo is dedicating a large amount of movement simply to keep the arm in a hanging position. The rubber band assist removes the need for a servo or motor to maintain the stability of the mechanism.

3. Rubber Band Maintenance/Snapping Point

3.1 Maintenance and Use

When using rubber bands, be aware of its approximate life span. Over time and use, rubber bands lose elasticity and begin to tear. The rate of degradation heavily depends on the tension at which the rubber band is used, the tension at which a rubber band is stored, the number of times a rubber band returns to its normal/un-stretched state, and the rate of releasing tension in a mechanism. A Botball builder should be aware of the limitations and maintenance necessary for the use of rubber bands.

In general, rubber bands used in claw grips are relatively static and stored at low tension, meaning that they do not have to be replaced often. On the other hand, the rubber bands used in a launcher that are constantly straining and releasing must be replaced frequently. From experience, a launcher attempting to achieve extreme degrees of accuracy and precision must have its rubber bands replaced and monitored even more often to avoid degradation.

3.2 Snapping Point and Avoidance

Lastly, rubber bands should be used such that they will not approach their “snapping point”. This is the approximate tension at which rubber bands are extremely likely to tear and snap; rubber bands also have a tendency to lighten and pale in color at this point. If a mechanism requires a high amount of tension, instead of using a single rubber band at a long distance, a Botball builder should either use multiple rubber bands or a single wrapped one. By preventing snapped rubber bands, mechanisms will be more reliable, replacements will be more infrequent, and fewer rubber bands will be used over time.

4. Conclusion

Often overlooked, rubber bands can be a useful and versatile asset to a Botball robot. Since they are included in the standardized kit, a Botball team should make the most of them. The applications of rubber bands in this paper are only a few of many possible uses, and I encourage future Botball teams to discover more.

Bibliography

1. "Hooke's Law (physics) -- Britannica Online Encyclopedia." *Encyclopedia - Britannica Online Encyclopedia*. Web. 1 June 2010. <http://www.britannica.com/EBchecked/topic/271336/Hookes-law>.

2. Loomis, Kenneth. "All About Hooke's Law." *Hooke's Law*. Web. 1 June 2010. <http://asms.k12.ar.us/classes/physics/general/kenneth/hooke.htm>.

3. Pictures of Landrum Middle School 2009 Botball robots, Landrum Middle School. Personal photograph by author. 2009.

4. Pictures of Nease High School 2009 Botball robots and components, Nease High School. Personal photograph by author. 2009.

5. Diagrams by topic, drawn by author. 2010