Claytronics Demo: A Novel Latching Mechanism for Macroscale Robots

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Abstract

One of the challenges in implementing modular robotics is an efficient robust latching mechanism. We show a latch based on electrostatic adhesion. The latch is self-aligning, requires only a small battery, quickly engages and disengages, and can hold ≈ 0.5 Newtons per square centimeter of latch area. In this demonstration we use the latch to join two prototype cubic robots, each of which is 30 centimeters on a side.

Introduction

One of the long term goals of the claytronics project (Goldstein, Campbell, & Mowry 2005) is to develop a modular robotic system which can scale to millions of units. One of the main challenge to achieving this goal is the development of a simple, robust, and effective inter-module latching mechanism. In this demonstration we explore the effectiveness of a latch based on electrostatic attraction. The potential advantages of an electrostatic-based latch are that it has no moving parts, is self-aligning, and uses very little power. While our long term goal is to create sub-mm robots, we demonstrate our latch using macro-scale robots.

The inspiration for this latch design originated in our work on a very large helium filled cubic robot which we called a giant helium catom (GHC) (Karagozler *et al.* 2006). The GHC, shown in Figure 1, was designed to allow us to explore nanoscale phenomena at the macro-scale. At the nanoscale, the surface-area to volume ratio increases; which in turn increases the ratio of the surface-area to weight. The GHC is filled with helium which gives it to a huge surface-area to weight ratio, resembling the physics down at the nanoscale, where weight is less important and area dependent forces, such as drag, are dominant.

The adhesion mechanism in the GHC uses electrostatic forces generated by the flaps attached to the faces of each cube. Each face has four flaps, each of which is divided into two regions. Each region acts as an electrode made up of thin aluminum foil, which is coated with a dielectric material (mylar). The dielectric material prevents electrical contact between two flaps. Adhesion is achieved when the flaps between two adjacent catoms come together and the adjacent regions are oppositely charged.

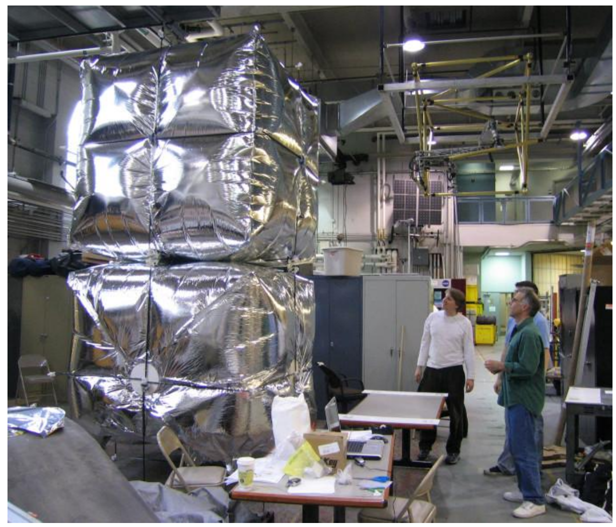
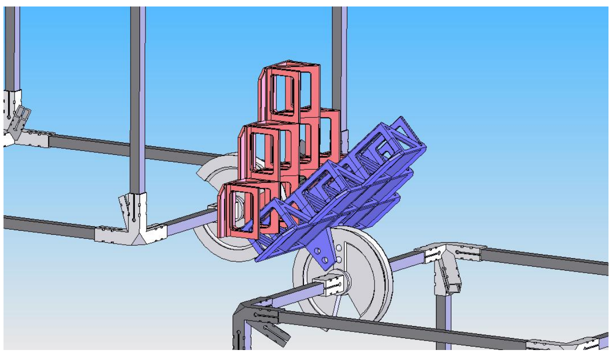


Figure 1: Giant helium filled catoms.

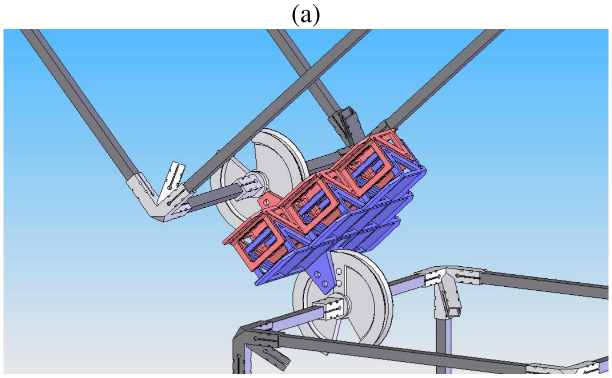
Figure 2: Corrugated flaps

In our experiments we found that when the flaps were charged, even when a good seal was created between the flaps, that the flaps would peel away from each other. In retrospect, this is easily explained by the fact that the flaps were made of flexible material. The flap material needs to be flexible so that two adjacent flaps can conform to each other, decreasing the distance, and thus increasing the electrostatic force between them. However, this flexibility also limits the amount of adhesion that can be generated because the edge of the attracted regions can easily be separated with almost no force. This peeling effect then propagates through the entire region, eventually causing the entire surface to snap off.

Although the normal forces necessary to separate the two electrodes are very small (due to peeling), the amount of shear force created by the friction between the electrodes is extremely high. To make use of shear forces, we designed flaps that have corrugated electrodes where each strip of dielectric coated conductor is normal to the flap surface. Thus, when the flaps come together, the shear force created by the electrostatic adhesion holds the flaps together. The following figure 2 shows two example designs. The flaps shown have a sawtooth-shaped plastic frame that helps them align as they engage.



(a)



(b)

Figure 3: Flaps (a) engaging and (b) latching

Demonstration Overview

We demonstrated the effectiveness of electrostatic latches using two prototype cubic robots with a side length of 1 foot. The robots were built from carbon fiber rods. On each face of the catom, 4 flaps are mounted. Flaps were built using corrugated plastic frames covered with aluminized mylar. The robots move around each other in a three step process. First, each robot moves the proper flap out from the face. If the robots are arranged as in Figure 3a, then each flap must move $45°$. If they are aligned with each other, then each flap is rotated $90°$. When the flaps come into contact with each other each robot excites the electrodes attached to its flap. This causes the robots to adhere to each other. Then, in the final step, the robots move the flaps back to their original position (see Figure 3b). The robot which is not bound to anything else will move into the desired position. In our actual demo, only the fixed robot moved its flap.

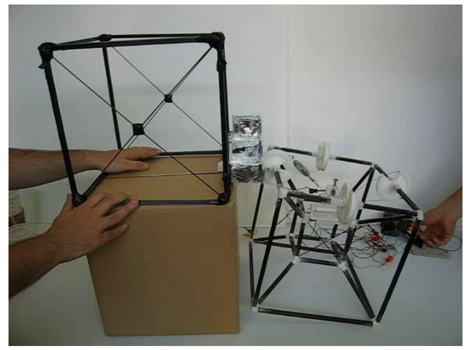


Figure 4: Catoms latching

Figure 4 shows the robot prototypes latched together with the lower robot being pulled up to mate with the robot on the box. We used three 'C' batteries to charge the flaps. The charging circuit scaled the voltage so that the voltage difference between the two flaps was 450 volts.

Acknowledgments

This work was funded by Carnegie Mellon University, the National Science Foundation under grant number CNS 0428738 (ITR: Synthetic Reality), and Intel Corporation.

References

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