Maker: Candy Crane Robot

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Title- Maker: Candy Crane Robot

Abstract:

Candy Crane is a custom-made robot that looks like a traditional tower crane and is used to pick candies by the young users for fun and for learning mechatronics product design. The tower structure (Mast) is made from either aluminum C-channels or plastics made from 3D printer. Two 12V DC motors and several limit switches are used to control the movement of the crane. A miniature crane to be held by the user is equipped with a linear potentiometer and rotary potentiometer and is used to control the movement of the big tower crane wirelessly through a blue tooth module. An Arduino microcontroller is used as a master to send the movement commands from the miniature crane to the Lego Mindstorms' NXT Brick mounted on Candy Crane. The NXT Brick serves as a slave to relay the commands to drive the DC motors to place the hook to proper location. Once the hook is in the right position, the user can send the hook down to pick up the candy of his/her choice. The user can learn mechanical design, electronic design and programming from the mechatronic toy.

1. Introduction

Hands-on mechatronic design activities have been proven to be a very effective tool to inspire engineering students to stay focused on their study, to make connections to real engineering work, to understand the multidisciplinary nature of product design and the importance of teamwork and collaboration. Project based hands-on projects provide students with valuable hands-on experience and allow them to take responsibility for their successful implementation of the project from start to finish within a reasonable time frame [1-7].

The objective of this Candy Crane project is to provide a hands-on opportunity for the mechanical engineering students to practice concurrent engineering, to learn the intrinsic relationships among mechanical design, electronic/electrical design, and software design. It is intended to give the students an example of systematic concurrent engineering approach to product design. The advancement in computer technology and semiconductor electronics has created a new product design field called **mechatronics**. Mechatronics treats product design as system design that requires the tight integration of mechanical components, electrical/electronic systems, industrial design ideas, computer-control systems, embedded systems, and intelligent software into the product design and development processes[8-9].

Candy crane is one of the projects that utilize the popular Lego Mindstorms' NXT Brick[10] as one of the two controllers. The other one is Arduino Mega microcontroller[11]. The Lego NXT brick is chosen because many middle school and high school students are already familiar with the system. So they can build the Candy Crane as an extracurricular activity to learn the importance of multidisciplinary approach in early ages. However, NXT brick has only three 9-V DC motor ports and four I/O ports. It somewhat limits its applications for projects that requires high voltage motors and more I/O ports. To extend the use of NXT brick to control 12-V DC motors, a 12-V DC motor controller from HiTechnic[12] is used to interface with the NXT brick. The Candy Crane project has two major subsystems: a larger crane system and a small crane system called Emulator. The user uses the small crane (emulator) to control the movement of the larger crane. The larger crane is controlled by an NXT brick and the small crane is controlled by an Arduino microcontroller. Communication with the NXT brick and the Arduino microcontroller is through Bluetooth communication technology.

2. Candy Crane Design Project

It started as a challenge to a group of experienced students, who had worked in the mechatronics technology center at the college for two year, on whether they can build a functional Candy Crane one month before the 2012 New York Maker Faire. It was later adopted as one of the design projects in a capstone course called machine design in the mechanical engineering technology department's associated degree program. Students take the machine design course in the fourth semester. The materials cost for the project is about $400.

The Candy Crane project utilizes the popular Lego Mindstorms' NXT Brick as a controller. NXT brick is equipped with three servos ports and four I/O ports. Since the Candy Crane's Slewing Unit and Trolley Unit need stronger DC motors to drive them, a 12-Volt DC motor controller from HiTechnic is used to drive two 12-V DC motors. To measure the exact angle that the slewing unit has turn and the exact distance that the trolley unit has moved, optical encoders were used for both the 12-V DC motors. I/O Port one of the NXT brick is used to send the control signal from the NXT brick to the DC motor controller. That leaves only three I/O ports available for interfacing with external sensors or switches. A small candy crane called emulator is used to remotely control the movement of the Candy Crane through an Arduino microcontroller and a blue tooth module. The project has three major components: mechanical design, electrical/electronic design, and software design.

3. Mechanical Design

The mechanical design includes design of crane base, the tower (Mast), the Slewing Unit (tower rotation unit), the Jib (horizontal beam), the trolley unit, and a claw unit. The main concern for the mechanical design was the rigidity and aesthetics of each structural unit.

The C-channel, the angles, and the connectors, etc come from the TETRIX® MAX Starter Set from PASCO[13]. Many college and high schools have used TETRIX materials for their projects.

Figure 3.1 shows a CAD model of the candy crane base. Figure 3.2 shows a CAD model of the tower (mast) of the candy crane. Figure 3.3 shows a design of the jib (horizontal component). Figure 3.4 shows a CAD model of the candy crane assembly and a physical prototype. Figure 3.5 is a CAD module of the emulator and a physical prototype of the emulator printed out from a 3D printer. Most component files used in the design are provided by PTC[14].

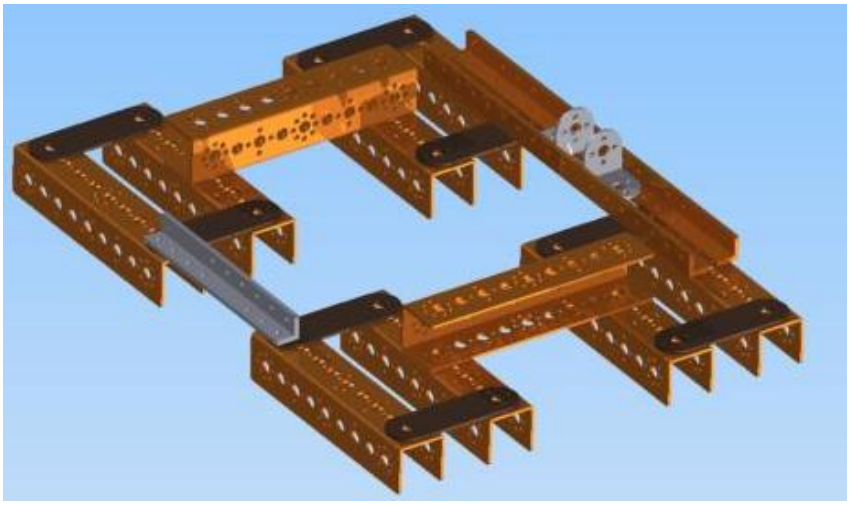


Figure 3.1 A CAD Model of the Base of Candy Crane

Figure 3.2 A CAD Rendering of the Tower (Mast) of Candy Crane

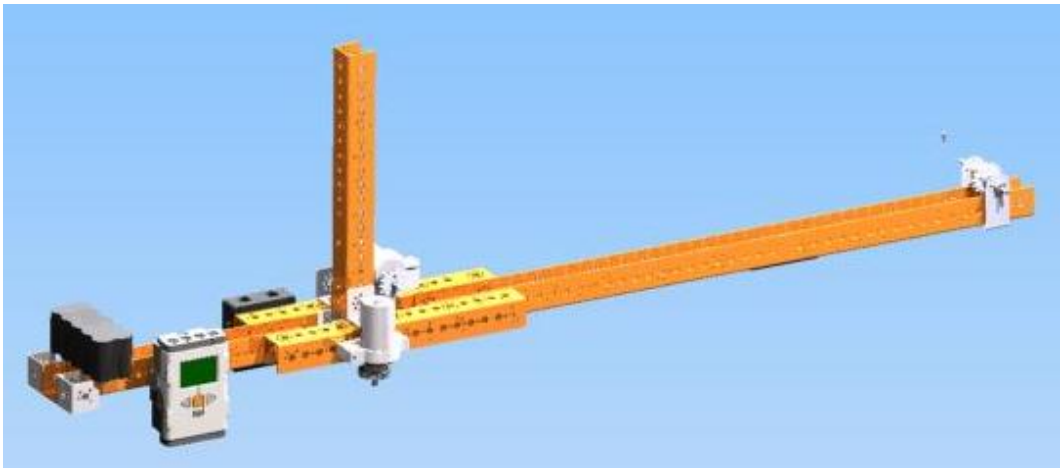
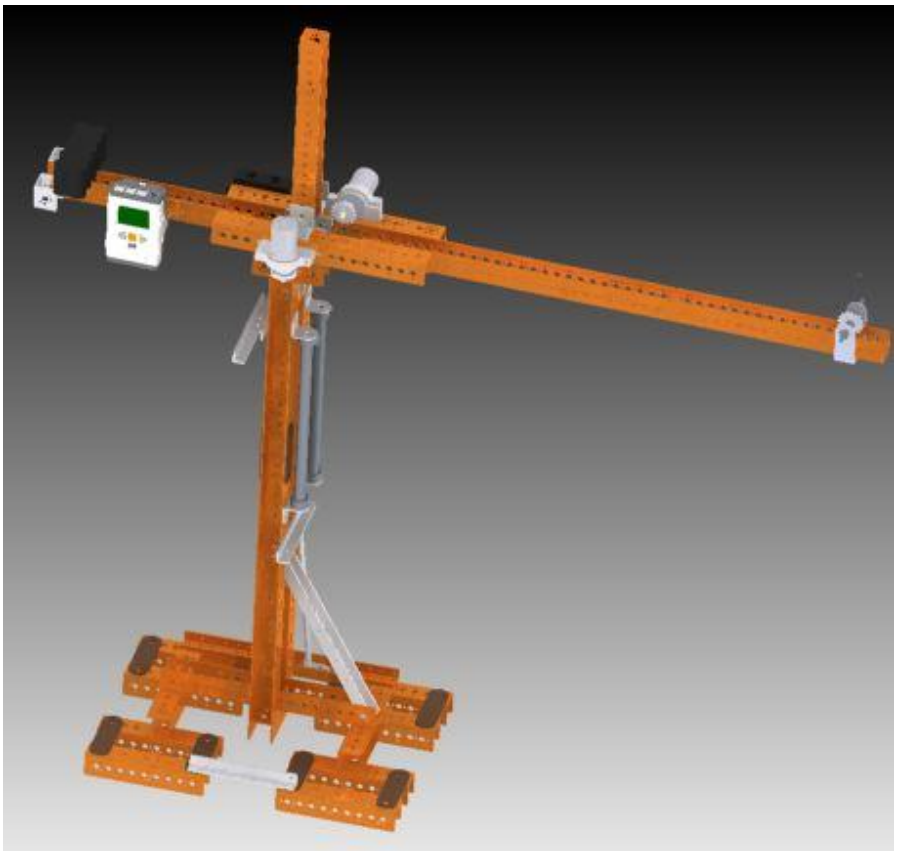
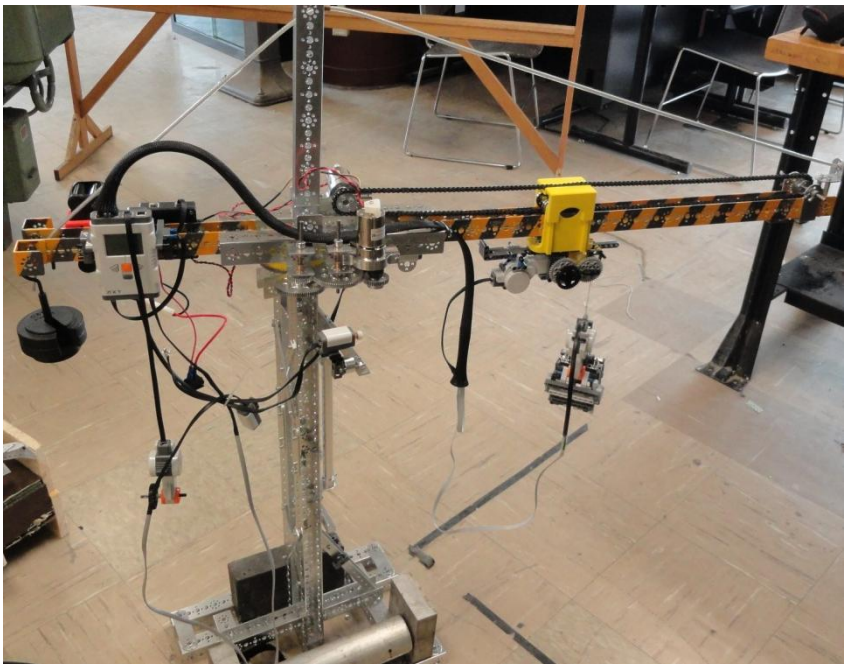


Figure 3.3 A CAD model of the Jib (Horizontal Beam)

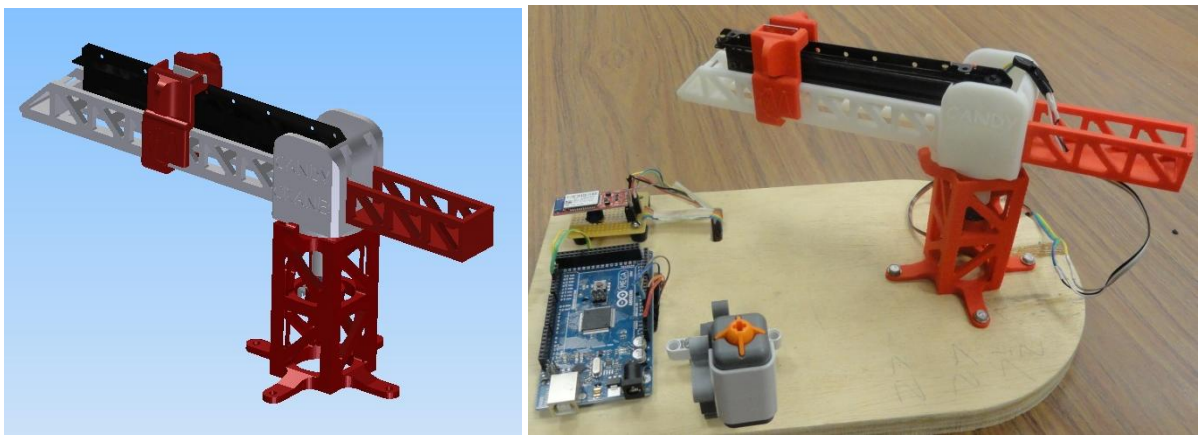


a) A CAD Model of the Candy Crane Assembly



b) A Candy Crane Prototype

Figure 3.4 Candy Crane



a) A CAD Model b) A Physical Prototype with its Control unit

Figure 3.4 Emulator

4. Electrical/Electronic Design

The electrical and electronics design includes circuit design that includes the use of candy crane controller, emulator controller, touch sensors (limit switches), and wireless communication system. Figure 4.1 is the circuit design for the candy crane system.

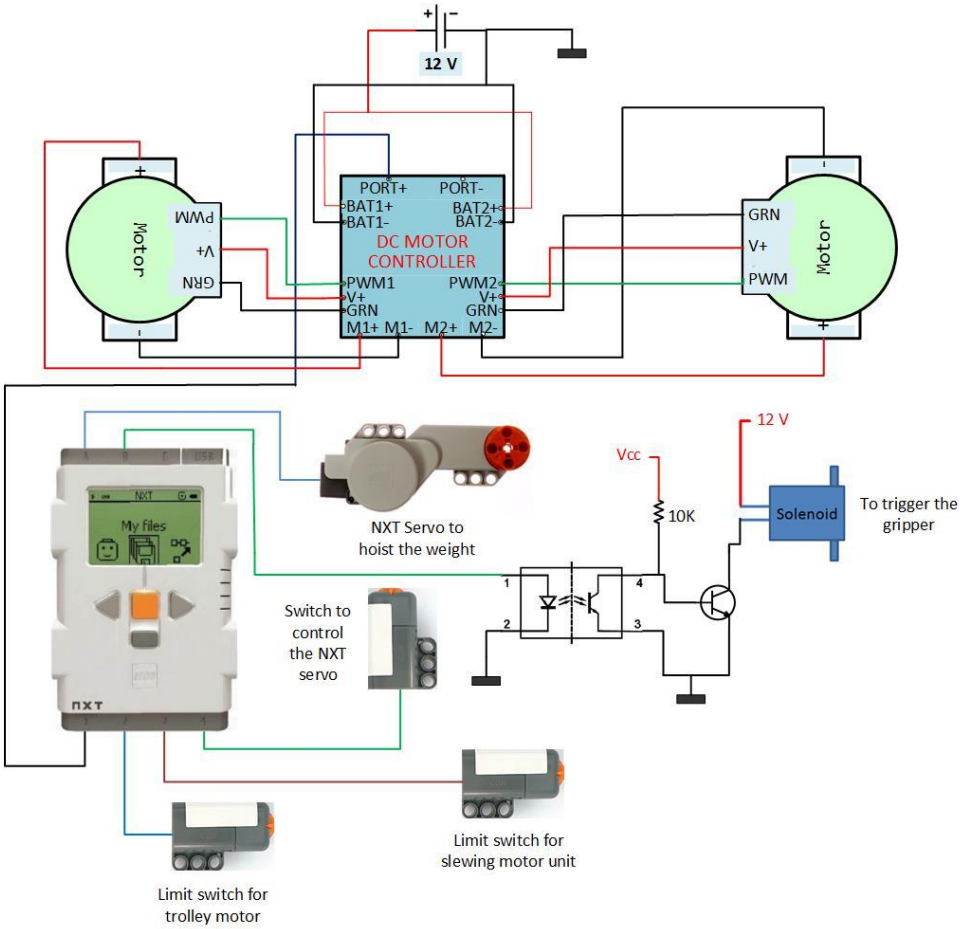


Figure 4.1 Circuit Design for Candy Crane

Figure 4.2 is the circuit design for the hand-held small remote control unit called emulator. Candy crane and emulator communicate through a built in Bluetooth in the NXT Brick and a Bluetooth module from Sparkfun[15] mounted on the emulator.

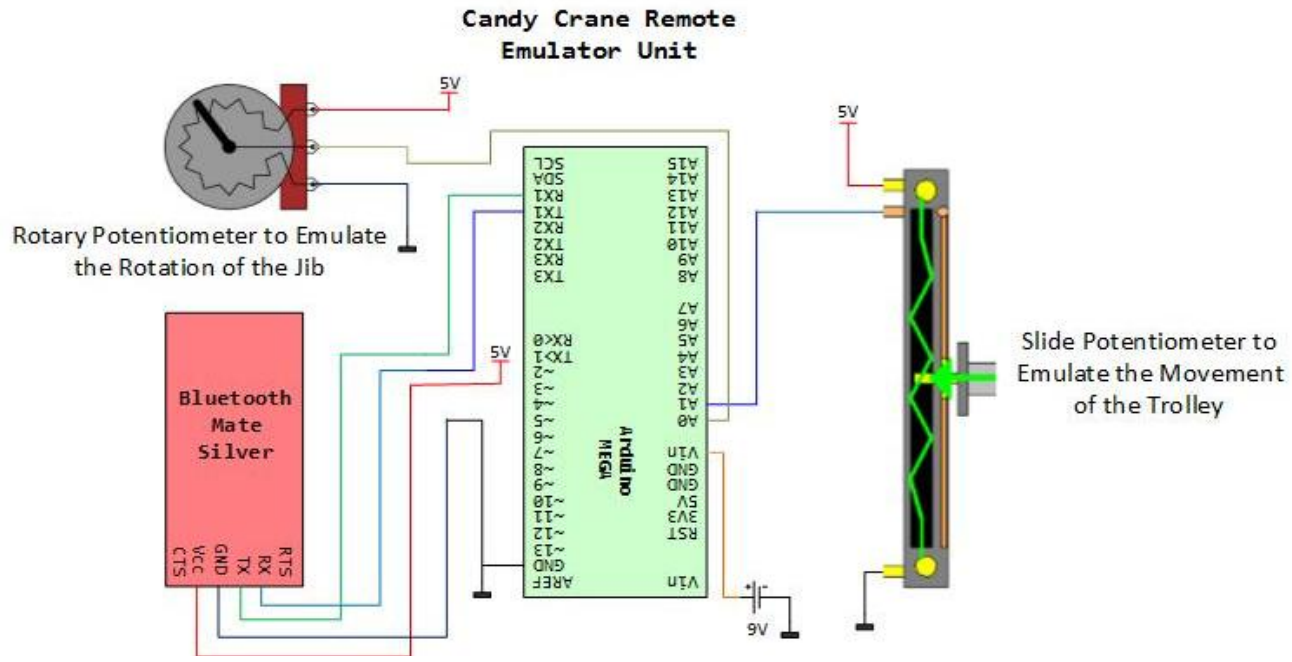


Figure 4.2 Circuit Design for Remote (Emulator) Control Unit

5. Software Design

The software design includes the development of candy crane control algorithms and source codes, extensive testing and fine tuning of the codes to meet desire results. Figure 5.1 shows a flow chart for program source code that runs on the candy crane. RobotC, a C language developed by the Robotic Academy of Carnegie Mellon University is used to create the program.

6. Test Drive and Outcome Assessments

The first Candy Crane was finished before the 2012 New York Maker Faire took place. It has attracted a lot of attention during the 2012 New York Maker Faire. For that it received an Educator of Choice award for the college. Figure 6.1 shows an improved Candy Crane in action in the 2013 New York Maker Faire. As part of a design project in the machine design course, it was the first time that students were exposed to multidisciplinary design activities. Survey indicated that although students enjoyed doing this type of projects but they lack proper electronic design and programming skills. To address this issues, the authors have proposed to create new courses in robotics/mechatronics in the mechanical engineering technology department to give students necessary exposure in electronic design and programming as they related to interfacing with mechanical systems.

7. Conclusion

The Candy Crane is fun to make and it presents a crucial element in engineering education that is learning by doing. It helped students to realize the importance of multidisciplinary approach

and collaboration. It gave students valuable experience working in teams. Proper scaffolding courses in robotics/mechatronics are needed to help students to really implement the current engineering philosophy in their design work. The details on how to construct the Candy Crane from mechanical design, electronic design, and programming will be made available in www.mtccitytech.org.

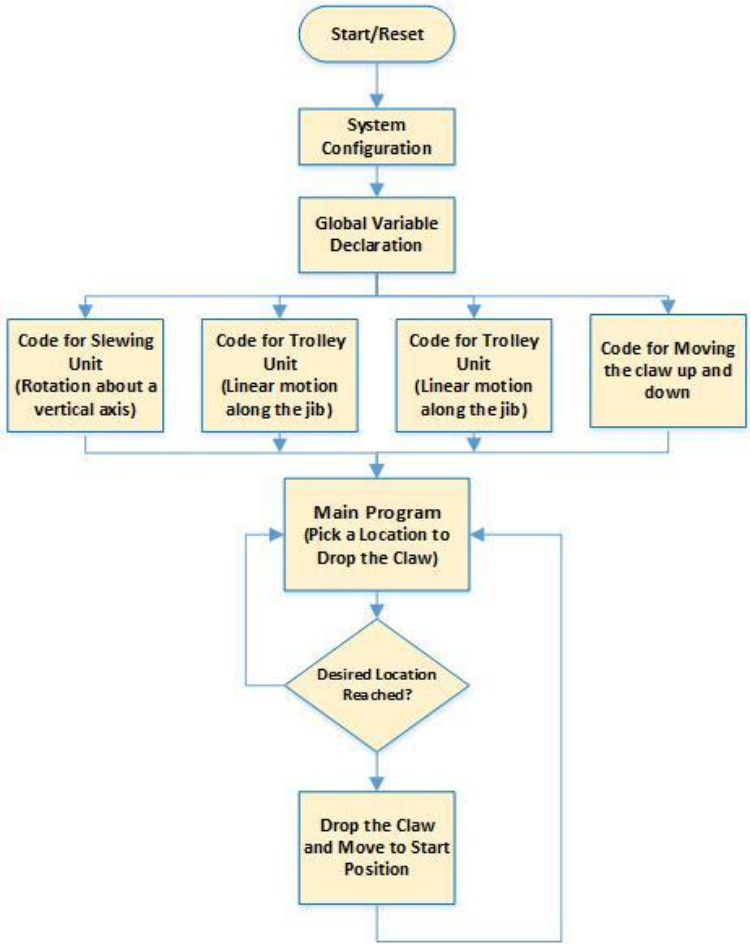


Figure 5.1 Candy Crane Controller Program Flow Chart

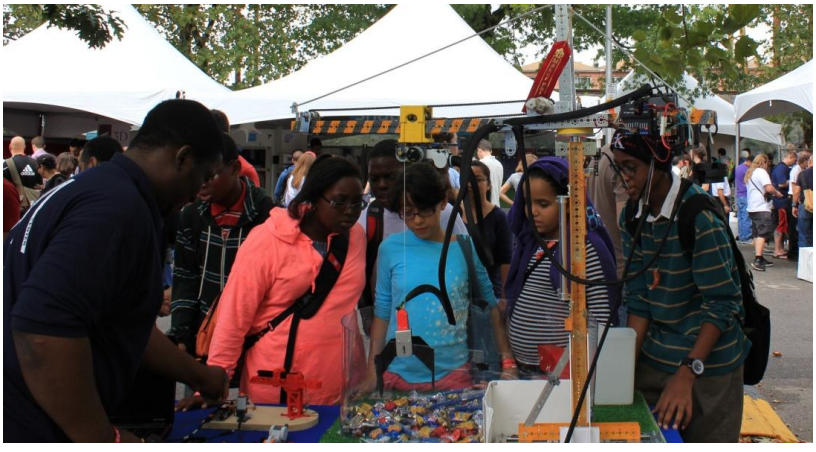


Figure 6.1 Candy Crane in 2013 New York Maker Faire

8. Acknowledgements

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