PUUREfab

PLASTIC UPCYCLING USING ROBOTIC EXTRUSION

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EMERSON STOLDT estoldt@andrew.cmu.edu

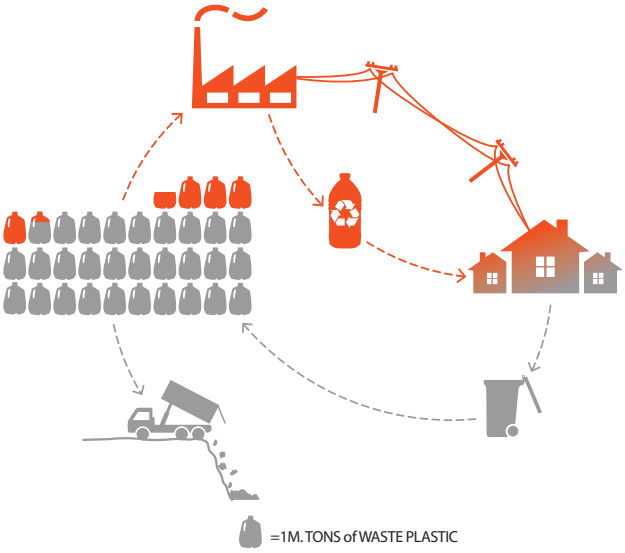
To investigate and develop a new method of working with recycled plastics in fabrication and design.

PROMPT:

Each year, upwards of 33.6 million tons of plastic are labeled as "waste" by the American populous. About **6.5%** of that waste plastic is recycled, and roughly **7.7%** is combusted in waste-to-energy facilities, leaving **28.8 million tons** of plastic per year that end up in landfills if left unused. Of the plastics that are recyclable and reusable, the most widely used are #1 polyethylene terephthalate (PET, used for synthetic fibers and water bottles), and #2 high-density polyethylene (**HDPE**, used for jugs, bottle caps, water pipes).

The current applications for using recycled plastics in fabrication and design are fairly limited, on a small scale, plastics that are the plastics (such as ABS, HDPE, or PET) are shredded and formed into pellets, and then either extruded into filament to be used in existing 3D printers, or injection molded into small parts and pieces of larger components. At a large scale, recycled HDPE is melted into sheets and either used directly as sheets in construction, or then heat formed from a sheet into components for construction. These methods of fabrication using recycled plastics are the norm because of their affordability and straightforward processes, yet each method leaves some complexity to be desired.

On the large scale, what can be produced by forming sheets of recycled plastic with molds and forms is fairly limited by the nature of a mold, because all geometry must be simple enough to release from a mold. At the other end of the spectrum, on the small scale, while what is produced through 3D printing can be extraordinarily complex, size is extremely limited. Producing anything equally complex on a



FACTS:

HDPE (high density polyethylene) is very dense and **chemically, UV, and impact resistant**, and because of these properties, is one of the most widely used and recycled plastics. It is downcycled into plastic lumber, tables, chairs, and almost any other **durable** plastic product in demand that can be molded or formed.

It has a service range from **-82° C** to **129° C**

Because of its durability and strength, HDPE products can take upwards of **100-200 years** to decompose in landfills.

large scale with 3D printing is time and labor-intensive, as well as a relatively expensive process.

For most, 3D printing at a large as a methos of processing recycled plastics scale has been deemed inefficient due to the cost of acquiring machinery, the technical knowledge required to effectively and safely run a robot, and the simplicity and cost-effectiveness of the already existing systems for fabrication using recycled plastic. Some independent designers and labs, with the help of grant or private funding, have produced a handful of styles of robot-based extrusion that range from **Dirk Vanderkooij**'s application of recycled plastic extruded into furniture that sells for $700+ per chair, to a group called **Mataerial**, who fabricates by extruding and heating a two-part resin to produce supportless sculptural pieces. While both examples serve to prove that robot-based extrusion is technically possible, I will strive in my thesis to prove that **ROBOT-BASED EXTRUSION is a viable method of manufacturing with RECYCLED HDPE PLASTIC, and can be used to produce INEXPENSIVE components** that can be implemented directly into existing construction.

GOALS AND OBJECTIVES:

- To develop and fabricate an extrusion tool for the 7-axis robotic arm that melts and extrudes waste HDPE plastic, driven by HAL Robot Programming & Control and controlled by a custom built arduino platform.
- To design and produce components using this process test the limitations of the extrusion tool that are inexpensive and can easily be implimented into existing construction.

METHODS:

The extrusion head tool for the robot arm will be based on a scaled-up version of desktop pellet-to-filament extruders such as the **Filabot Wee**, which is designed as an alternative solution to buying spools of filament for 3d printers.

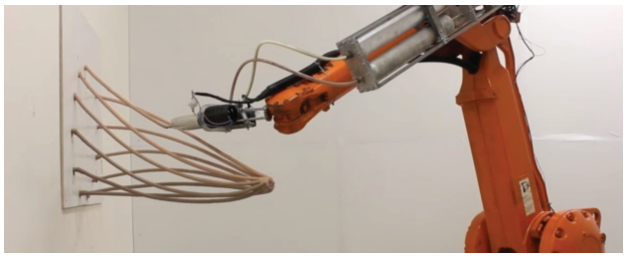
The tool will consist three main parts; the extruder head, the driver board, and the hopper. The hopper is a large reservoir for HDPE pellets to be loaded in to, and will remain open so that more material can be added to the hopper while the tool is in use. The extruder head has three main parts; an interchangeable extruder tip, a metal heating chamber which is wrapped by the heating element and contains and an auger which will slowly turn to drive material through the heating chamber and out the extruder tip.

The driver board, located in between the hopper and the extruder head will be programmed on an arduino board

PRECEDENT:

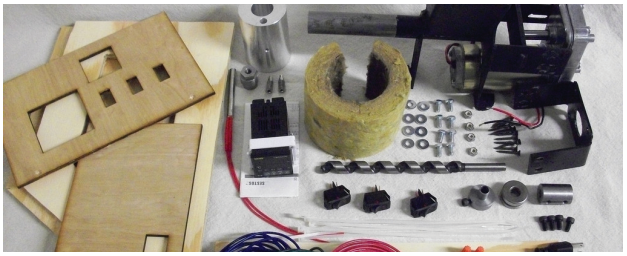
DIRK VANDERKOOIJ

"Endless Chair"
Expensive designer furniture produced by robotically extruded recycled plastic.
http://www.dirkvanderkooij.nl/



MATAERIAL

"Anti-gravity" supportless 3D printing using a robotically extruded proprietary two-part quick solidifying material.
http://www.mataerial.com/



FILABOT WEE

Kit for a desktop-sized extruder for creating filament for 3D printers out of plastic pellets.
http://www.filabot.com/

PLATFORMS TO BE USED:

- Rhinoceros 3D
- Grasshopper 3D
- HAL Robot Programming & Control
- 7-Axis CNC Robot Arm
- Arduino

to handle input/output from HAL in order to control when to extrude plastic. The arduino will control all aspects of the tool, including the heating element made of resistive wire, a thermistor to monitor temperature, a stepper motor to drive the auger extruder, LED indicator lights to display when the heating chamber is at the proper temperature.

Once the tool is developed and optimized for HDPE pellets, a workflow using HAL Robot Programming and Control will be developed in which the robot arm will follow toolpaths generated by grasshopper and HAL will output to the arduino via USB signaling when to run the extruder and when to stop.

This workflow will be created with the goal to produce components with recycled plastics through robot-based extrusion which will test the fabrication limits of the extrusion tool developed.

RESOURCES WITHIN CMU:

- Jeremy Ficca
- Josh Bard
- Zack Jacobson-Weaver
- Michael Jeffers
- Zach Ali
- Eric Brockmeyer
- Frank Melendez

DRAFT TIMELINE: