Recycled Plastic to Performative Urban Furniture

Suat Batuhan Esirger[1], Muhammed Ali Örnek[2]

[1]Istanbul Technical University, Istanbul/Turkey · esirger17@itu.edu.tr
[2]Istanbul Technical University, Istanbul/Turkey · maornek@itu.edu.tr

Abstract: Critical changes in technology are improving communication and increasing connection goes between devices and with their surroundings. Humans increasingly expect to communicate with their devices and tools. The term "smart" has come to refer to anything that can *interact* with "others." Interactivity between devices, with users and with nature gives humans more opportunity. In contrast to recent research on developing interactive urban furniture focusing on recreational use of human computer interaction, this paper presents an empirical study that describes how smart mechanisms can be built for improving the performance of public spaces by 3D printing from recycled plastic.

Keywords: Performative design, urban street furniture, computer-aided design

1 Introduction

In design research, the boundaries between interactive, responsive and performative approaches are still not clear. Ervin (2018) defines 'control systems based on connected input and output sub-systems, in both machines and living things' as 'cybernetic'. Producing urban furniture systems only equipped with sensors and actuators does not make them cybernetic. These systems' *senses* should be programmed to be responsive according to gathered data. Performative systems should be more than just responsive and should aim to improve the performance and the quality of (urban) spaces.

According to Oxman (2009), performative design refers to the digital performative systems and the growing importance of sustainable design. Performative systems are becoming a central theoretical and developmental priority in digital architectural design. Yet, the related scholarship in the field only suggests developing interactive urban furniture for social purposes (TAKEUCHI & YOU 2014), or display purposes (HAGGAG 2018). In addition to that early work, this research suggests development that uses the proposed an urban furniture design for increasing the performance of the urban areas should be:

- Adaptable to various environmental conditions such as topography, climate, etc.;
- Easy to assemble and disassemble;
- Sustainable for recycling scrap plastics into 3D printing material;
- Modular: different polygonal structures, vertical and horizontal usage scenarios
  - **Shading** to provide shelter to users for sunny, rainy or snowy weather conditions,
  - **Noise reduction** in dense traffic areas,
  - **Optical separation** to create dynamic spaces in public areas,
  - **Structure** to prove a framework for vertical gardens or to display projections.

Journal of Digital Landscape Architecture, 5-2020, pp. 166-172. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-690-1, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537690018.

2 Research

In urban areas, parks and recreational spaces, semi-public places are insufficient or non-existent. According to recent studies, people need partition in these public spaces. This need comes from different forms of sensory inputs. The proposed system focuses mainly on visual and sound isolation using the adaptable modules.

Fig. 1: Concept visualization of proposed shading modules

2.1 Design

The main structural frame module is inspired by beehive-like stacking of 3D hexagon modules. In order to adapt the structure of the system to various urban areas, modularity has been one of the most important aspects of this project. Repeating modules make up the whole structural system and electro-mechanical systems, while allowing for the customization of the module sizes and functions. With the purpose of being easy to pack, unpack and transport, we designed the system be built with a rod and node system. Nodes are fabricated using additive manufacturing methods. Nodes and casings are 3D printed in order to reduce limited batch production costs and due to customization needs (mold, extrusion material, labour, transportation). A fraction of that has been spent on the 3D printing material with the use of existing 3D printers in our inventory, instead of investing in mould and plastic injection systems. The advantage of additive manufacturing has been wielded due to customization needs. While using plastics, environmental effects have been considered. In order to reduce plastic waste, all 3D printed parts have been printed from recycled ABS plastic.

The sound isolation module consists of 3-D hexagonal skeleton construction, sound-absorbent flexible textile, sound level sensor, processing modules and adaptive electro-mechanical parts. We use a sound level sensor in order to read environmental noise data. The on-module microprocessor processes sound sensor data and absorbent textile is stretched according to acoustic needs. The intensity of sound intensity value stretches the textile and creates a greater surface area to absorb more noise. Visual isolation modules come in two different configurations, which can be used on two planes: vertical (in order to isolate users and other unwanted visual elements) and horizontal (in order to use the system as a shading solution).

The vertical visual isolation system uses sensory proximity data in order to determine the distance of the moving subjects (pedestrians, animals, cyclists and likewise transit objects and beings) and adapts accordingly. This module consists of 3-D hexagonal skeleton construction, opaque shading panels, proximity sensor, PIR sensor, processing modules, motor and adaptive electro-mechanical parts.

The horizontal isolation module aims mostly to satisfy the need of changing shading demands. The horizontal mesh of adaptive modules is structurally supported by vertical 3-D hexagonal skeleton construction. During the day, shading performance of these modules adapts according to the sunlight intensity data taken from sensors. The light intensity value is measured by an Arduino-based circuit, which changes the openings of the umbrella-like mechanism, which in turn changes the open-closed ratio by motor movements for optimising shading performance. The semi-transparent shading panels are directionally adjusted using electric servo motors, according to the commands from the microprocessor unit. This module consists of 3-D hexagonal skeleton construction, semi-transparent shading panels, light intensity sensor, PIR sensor, processing modules, motor, and adaptive electro-mechanical parts.

2.2 Prototyping

After the design process, we focused on the manufacturing of the modules. We manufactured a prototype of the proposed modules to explore the possible errors and issues regarding production, assembly and durability and to test the system's functionality according to the changing environmental conditions. The main purpose of manufacturing joints from recycled plastic is "to be an efficient means of converting waste polymers into usable using Fused Deposition Modelling (FDM) based manufacturing processes and could be instrumental in reducing waste output from the use of this popular form of 3D printing technology" (MOHAMMED et al. 2017). "In recent years, FDM technology has become one of the most widely-used rapid prototyping methods for various applications." (DUDEK 2013). FDM technology refers to an additive manufacturing method that enables building objects by "selectively depositing melted material in a pre-determined path layer-by-layer" (3D HUBS 2020).

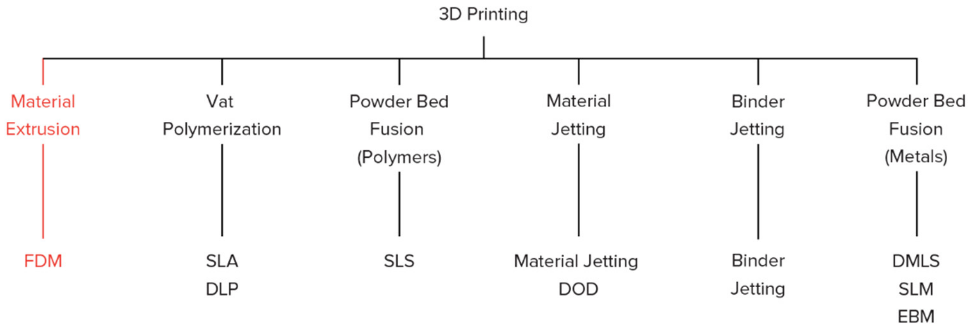

Fig. 2: Chart showing the 3D Printing methods and techniques (3D HUBS 2020)

The manufacturing equipment we used on this project are:

- Plastic shredder,
- Filament extruder,
- Spooler,
- FDM 3D printer (Ultimaker 3).

The plastic shredder is a tool for shredding plastics into small granules in order to ready them to be extruded. The device has slow rotating steel blades that fragment the plastics into little pieces, that are then discarded for recycling. For this project, we focused on ABS plastic, which is commonly used for everyday objects and has a higher melting point and higher impact resistance compared to other polymers (PLA, XT, nGen are the other common FDM materials). Then, these shredded plastic pieces are mixed with unused ABS granules to produce new filament (FDM type 3D printing material). We used 2.85 mm filament diameter, which was easier to manufacture.

In this process, several percentages have been tested throughout the manufacturing trials. 40 % shredded plastic and 60 % pure ABS granules have given the best results for our manufacturing process in terms of thickness consistency, layer adhesion, post-print warp percentage (Mohammed et al. 2017). The extruded filament is then spooled. During the process. filament diameter has been checked constantly by the device in order to achieve the optimal thickness tolerance. Once the process is done, the filament is checked then loaded into the 3D printer. We used Ultimaker 3 3D printer for manufacturing plastic parts. Ultimaker 3 (2018) is an open-source 3D printer, which has an open filament system and allows the printer to work with 3rd party materials. This includes but is not limited to the recycled filament that we produced. The printer has a heated build plate which is essential for printing with ABS material. It has side and back panels that helps heat to distribute evenly, improving the print quality. After the recycling process, the recycled and spooled filament used in Ultimaker 3 for printing the joints are used to hold the aluminium rods together. In addition, the housing of the sensor, microprocessor case and the linear servo adapters have been 3D printed on Ultimaker 3 with the recycled filament.

In order to make the system adaptable, we added various sensors and electronic elements with changeable properties to the design. A microprocessor (in this case, an Arduino Nano Development Board) reads the sensor data by and this microprocessor controls the motors in order to achieve the desired result.

Fig. 3: Photos on plastic shredding, filament extrusion and spooling process

Electronic bill of materials are as follows:

1) Servo motor
2) HC-SR04 Ultrasonic sensor
3) PIR sensor
4) TEMT6000 Brightness Sensor
5) Sound level sensor
6) Electronic Cables
7) Power supply

Fig. 4: Photos on assemble details of the module, sensors and mechanisms

Electronics are encased in watertight casings. Also, cables are mainly enclosed in the profiles in order to be preserved from environmental effects. These casings have been manufactured from ABS with 3D printing technologies (Figure 4).

All the plastic parts that have been used in the system are 3D printed. The material used in the 3D printer is recycled from old failed 3D prints and unused ABS plastic appliances. Plastics that have been chosen for recycling are shredded into tiny bits. Shredded bits than mixed with 40 % pure ABS pellets in order to have a sturdy polymer structure. After that, this mixture is extruded by a filament extruder in order to make it usable with 3D printers. Extruded recycled filament is then spooled and loaded onto the 3D printers.

In order to transform the servo motor's rotary movement into linear movement, an adapter is designed and manufactured by using FDM 3D printing technology. This part also fixes the servo motor on to the aluminium rods (Figure 5).

Elastic textile: Several textiles have been used and are still being tested on the physical prototype. Although elasticity and sound absorption are the key features, durability to environmental effects is also considered during material selection.

Aluminium profiles: Aluminium material is chosen for being lightweight and resistant to outside conditions. Two types of rods have been used on the system. The first profile is a pipe profile with 25mm radius and 1mm thickness. This profile is used to create the load-bearing structure of modules. Beside this profile, the square-shaped profiles are used to fix the servo motor and movement systems. This profile has 10 mm × 10 mm with 1 mm thickness.

Fig. 5: Photos of a noise absorbing module prototype

3 Conclusion and Outlook

This research presents an empirical study that describes how smart mechanisms can be built to improve the performance of public spaces by 3D printing from recycled plastic. One of the observed issues has been the sound-absorbent textile being also water absorbent. This water absorption reduces the textile material acoustic absorption skills. Also, wet textile gets heavy. This puts unnecessary load on the motors and structural system. This load might cause motor malfunctions, damage to the electronics and structural integrity problems in the future. In order to overcome this, we are planning to apply and test water repellent spray on the fabric. Another foreseen issue is vandalism. The testing prototype has not yet endured such action, but we are considering how to overcome this aspect at the moment.

After the field tests of acoustic modules, we aim to build both vertical and horizontal shading and visual isolation modules on 1:1 scale. The objective of this build will be to examine the material durability and usability by acquiring environmental and usage data.

For future development, we intend as of 10 to add mesh networking capabilities and environmental sensors in order to turn these modules into the "Internet of Things" modules. With these developments, our aim is to acquire environmental and usage data to make further adjustments to the system. Through the analysis of the usage data, more accurate usage scenarios can be constructed and optimized for intended usage.

Using alternative power sources for the system is also one of the future goals. For the shading modules, shading panels can be made from solar panels in order to generate the power needed in order to operate the system. This solution is integrated with power storing capabilities and can provide an added benefit of using stored power to charge user devices.

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