RFID 3D Printing Objects that Connote Information

Ken Fujiyoshi, Chihiro Fukai, Hiroya Tanaka, Jin Mitsugi, Jun Murai; Keio University; Fujisawa, Kanagawa Prefecture/Japan

Abstract

During the past century, a whole new world has been created: the digital world. Along with the development of computers, internet, mobile devices, and etc, the digital world has created a whole new reality for human beings. Combined with new sensors, nowadays, everything that can be observed digitally is stored online and is being used for marketing and other uses. In this research, we aim to combine the world of digital and physical by using RFID (radio frequency identifier) and 3D printing technology. In detail, we embedded RFID modules inside 3D printed object, and wrote its information after the object was fully printed. With this, we aim to enhance the interaction between the real world and the virtual world, bringing more rich data transition and data manipulation.

Introduction

Ever before computers or even the use of binaries were discovered, men had struggled to combine information together in various ways. Money is one example: a piece of paper represents a value, and the designs on that paper explains the value of the paper. Packaging is another example. What ingredients make up that food, until when they are fresh, how it should be treated.... These are all examples of attempts of human beings to connote information within objects. At the same time, including an information of own self is a mechanism seen in nature. These systems are implemented as DNAs, RNAs and other shapes of genes, making them copy-able from oneself. This self-generating system has been artificially developed as "self-assembly system", a technology to bring objects together and form itself with simple but robust system.

As examples above, many approaches were taken to achieve this goal of connoting information inside objects, and this is also the goal of this research as well: designing a method to connote information inside an object, and thinking about the interaction between the digital world and the physical world.

On the other hand, 3D printing, or additive manufacturing process, is becoming a popular manufacturing method, due to its quickness, simplicity of manufacturing process, and its reproducibility of digital data. Although the technology itself has existed from before, the development of the 3D printing itself and the expiration of the 3D printing related patents has allowed it to spread quickly[1]. Although the method has become very popular, problems still remain: 3D printing is not perfect and traditional manufacturing system still proves itself fit for manufacturing "real" products in some ways.

In this paper, we would like to propose the RFID 3D printer, a new approach to connoting information to objects by inserting RFID tags inside an object during 3D printing fabrication process, enabling the object to connote a "gene" of its own and also creating a fabrication method, unique to 3D printing.

Digital Fabrication and 3D Printing

At first, for humans, fabrication was something that was solely done by hand. By pounding a hard rock against a softer rock, people made sculptures, houses, and fire. As they evolved and as their hands became more dexterous, they began to develop tools to make something. First, it was something very practical and something very simple like hammer, but the tools developed as humans grew smarter, and by the mid 18th century, humans began to produce automated tools, known as machines. Even though the machines took over most of the fabrication process that was done by human beings, still, someone had to design the machine itself, and the machines were basically moved manually, requiring a skill to use machines. Digital fabrication is totally different compared to these "manual" fabrication methods.

Digital fabrication is a fusion of information technology and fabrication technology. Machines that were once controlled by human hand began to be controlled by computers, allowing a more accurate fabrication, and enabled humans to make something according to the data they produced. These Computerized Numerically Controlled machines, or CNC for short, allowed the manufacturing of objects just like the input data, but they still had few weakness: limitation of fabricate-able objects; loss of most part of the material; long fabrication time. 3D printers cover these weaknesses that CNC machines and other computer controlled fabrication objects had: they can fabricate "almost" exactly as the 3D input user that the user has selected; they use only the least materials needed for the target object; they are quick(compared to CNC and other manufacturing processes).

The mechanism of 3D printing itself is very simple. First, the input 3D data is sliced into thin layers. Then, the machine moves along and inside the target object, slice by slice. While moving, the machine either extrudes a material or processes the material in some way, making it hard. When the machine moves to the next layer, the layer before becomes a basis of the next layer, making the material to pile up each other, making the target object after countless piling up of the materials. Since the mechanism itself is very simple, many combinations of materials and fabrication methods to harden them has been developed. The most common materials are plastic materials such as PLA and ABS, synthetic / chemical fiber such as nylon, plaster and metal. Since the fabrication method of 3D printer adds the materials to make objects, it is also called as additive manufacturing, making a distinction from subtractive manufacturing, or other manufacturing methods, which basically includes scraping or carving the materials to make the target object (Figure 1).

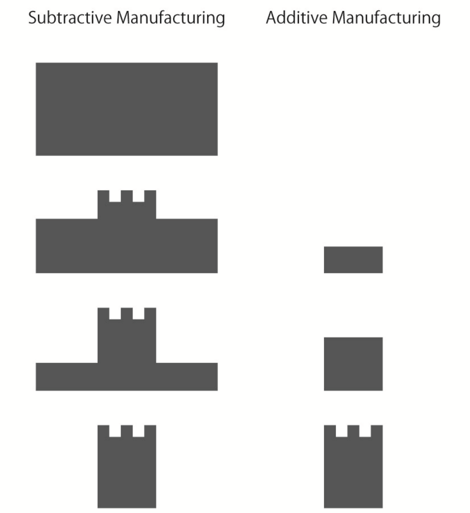

***Figure 1**.Additive manufacturing and subtractive manufacturing*

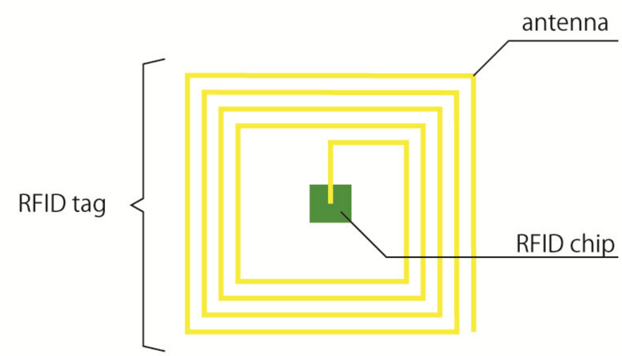

***Figure 2**.RFID tags*

The largest weakness of the 3D printing is the low-efficiency when producing objects in large quantities. The amount of money and time for fabrication needed for fabricating one product is same even if you try to produce 1000 of them. On the other hand, if you produce a metal mold with subtractive fabrication, although the fabrication of the first product will cost a lot, the cost taken for each product will become lower as much as you make them. This critical weakness has made 3D printer to be used only during development stage, and never for the actual manufacturing of the product. For this reason, a unique product or fabrication that could only be done with additive manufacturing is needed.

RFID

RFID is part of Near Field Communication (NFC) technology. NFC is a bandwidth which is open for anyone to use. Technology that uses radio waves but does not communicate at large scales are basically NFC. Microwave ovens, some remote controllers, IC card tags, Bluetooth, FeliCa are all examples of NFC technology used in our everyday life. Compared to communication bandwidth used for mobile phones and other stable communication radio wave protocols, NFC's communication area is quite limited: they are usually below few meters.

Although there are many technologies within NFC, the most uniqueness feature that RFID has is how RFID does not need any external battery to make it work. All that is needed to make RFID work is a RFID chip to communicate and an antenna to fly its communication (Figure 2). The RFID chip is driven by the electromagnetic induction that is generated when the RFID is being read. This allows RFID to work independent from other electronic devices, making it a best technology to combine with 3D printing.

RFID 3D Printer

The most difficult part of using RFID tags with products is the introduction of RFID implementing system to manufacturing process. Since RFID itself is a product, they are treated as a "part" but unless the manufacturer chooses a modules with a large antenna, they will have to position the tag closer to the shell of the product compared to other electronic parts and devices. To do this, the implementation of RFID has to be done against the outer shell, making the whole manufacturing process to be redesigned considering this process.

Using 3D printing, RFID can be easily "added" by printing on to the inner shell surface. At the same time, this is a process technique that is best implemented with 3D printing, or the additive manufacturing, for the reasons above, and also in order to use RFID in its most unique way - embedding it inside an object.

Experiment Environment

The experimentation of the RFID 3D printing system was done based on Orion Rostock delta 3D printer[2], a 3D printer that manipulates its extrusion head with three beams from three directions, each associated with an axis pillar. By moving up and down along the axis, the three beams justify a unique position of the head (Figure 3).

The largest advantage of using a delta 3D printer is its extensibility. Since each of the axis are manipulated just like the other, the axis are easy to customize, and due to this customizability of the beams, the extrusion head can be easily taken off and customized as well.

Figure 3*.Orion Rostock delta 3D printer (an official image from SeeMeCNC)*

Implementation

The implementation was done in three steps: making an mechanism to drop the RFID tags inside 3D printed objects; wire and assemble extrusion head; create a program that manipulates the 3D printer to extrude the RFID tags at the exact moment it needs to be.

First, we made a simple mechanism to drop the RFID tags. We adopted a cylinder mechanism of the revolver-like system assembled from three parts: the RFID magazine, revolver, and a guide. The RFID tags are stacked inside the magazine, and with the gravity, it falls inside one of the holes of the revolver. The revolver is rotated by a stepping motor, from the signal of the mother board of the 3D printer, rotating to allow the RFID go down the guide cylinder and to the target place. Since the only actuator needed is the rotation of revolver, which require very low torque, any motor can be used to make this mechanism work. Usually, stepping motors are used to develop 3D printers, so we chose stepping motor for the RFID 3D printer as well to keep versatility.

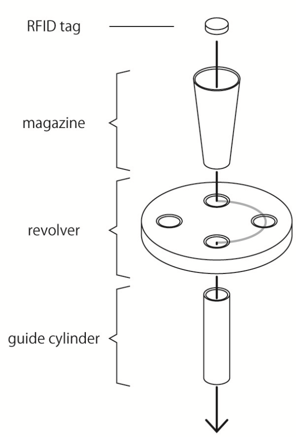

Figure 4*.Rotate & drop mechanism*

A program to drop the RFID tag is very simple: it just needs to rotate the revolver when it needs to at exact angle we chose. Since most of the 3D printers use G-code as an input command, and we chose to implement the movement to drop the RFID tags with G-code as well, again to keep versatility with other 3D printers.

Figure 5*.Example of printed object*

After the printing, by assigning the RFID tag with a unique ID and uploading its information online with the assigned ID, the object and its information is now paired and available (Figure 6).

Discussion and Future Works

There has been many researches on designing interaction between the digital world and physical world. In this chapter, we will introduce InfraStructs[3], a research that uses 3D printing and aims to enclose information inside an object just like this research, and discuss about the possible future work and application of this research.

InfraStructs

InfraStructs is a research done by Karl D.D. Willis of Carnegie Mellon University and Andrew D. Wilson of Microsoft Research. It combines image processing, 3D printing and Terahertz scanning technology. By varying the density or material inside an object, the Terahertz scanning reads that difference between objects, resulting as an visual “bits”, allowing the program to distinguish the information that is embedded. The most unique point of this research is how the technology does not allow the changing of the information once it is embedded.

In this research, although the images provided shows that the prototype objects were made by 3D printers, it does not necessarily have to be 3D printed. As long as the layer of the information does not exceed the limits of Terahertz waves, the technology can be implemented with any other fabrication methods.

Compared to InfraStructs, using a RFID tag is a very simple way to implement the embedding of the information to objects, but since both technology allows small amount of information to be embedded, although the InfraStructs method itself does not allow changing of the information, it is assumed that the actual information embedded inside the object will be only an ID of the object. Still, the position recognition that InfraStructs method might be able to integrate combined with RFID tags will allow detection of the status of object in addition to the information of the object.

Future Works

Although this paper covers RFID tags being printed, in order to make the RFID 3D printer to work on any object, more work has to be done. First, we need to experiment how far away the RFID tags can be read from, and how the shells of the object effects the communication of the reader and RFID tag. Based on this experiment, an auto RFID tag placement program against 3D objects has to be made in order to allow the users more easy manipulation of the system.

Secondly, we need to create a RFID reader / writer in order to allow the users to write and read RFID tags directly after the printing of the object, which is something fundamental this system. The making of the database has to be done simultaneously along with the making of the object itself, and without a total system to print and write RFID tags, the users will be able to tamper the information of the object.

In addition to the indispensable requirements listed above, there are some possible future works to this research. One possibility of printing an antenna for the RFID chips directly on to the object. Earlier research[4] has shown RFID antenna printed onto a paper, and with the combination of filaments from conductive materials and 3D printers, there is possibility that the same can be done against 3D objects.

Another approach is using the electric produced from an electromagnetic induction seen in RFID and designing an isolated circuit inside an object. There has been an attempt to turn on a LED light using the power supplied from a smartphones when it hovers over the object[5].

Conclusion

In conclusion, the RFID 3D printer enables users to embed information inside objects with the combination of RFID technology and additive manufacturing method. The method offers an unique implementation that can only be achieved by additive fabrication.

By pairing the information of physical objects and digital data, the interaction between physical and digital world will be enhanced, which will ultimately lead to the world of internet of things, a world where everything is connected to online and can be manipulated or checked from the internet[6].

References

[1] Chiristopher Mims, "3D printing will explode in 2014, thanks to the expiration of key patents" [Online], Available from: http://qz.com/106483/3d-printing-will-explode-in-2014-thanks-to-the-expiration-of-key-patents/, [Accessed: March 5, 2014]. (2013)

[2] RepRap Wiki. "*Rostock - RepRapWiki"* [Online], Available from: http://reprap.org/wiki/Rostock, [Accessed: February 9, 2014].

[3] Willis, K.D.D., and Wilson, A.D., "InfraStructs: Fabricating Information Inside Physical Objects for Imaging in the Terahertz Region," *ACM Trans. Graph.*, ACM (2013), 32, 4, 138:1–138:10. (2013)

[4] Yang, Y., Rida, A., Vyas, R., and Tentzeris, M., "RFID tag and RF structures on a paper substrate using inkjet-printing technology," IEEE Trans. Microwave Theory and Techniques 55, 12, pg. 2894-2901 (2007).

[5] Takara Tomy A.R.T.S., "LumiDecoNail" [Online], Available from http://www.takaratomy-arts.co.jp/specials/lumideco/, [Accessed: June 10, 2014]. (2014).

[6] Sanjay Sarma, et al. "The Networked Physical World Proposals for Engineering the Next Generation of Computing, Commerce & Automatic-Identification," Auto-ID Center, Available from: http://www.autoidlabs.org/uploads/media/MIT-AUTOID-WH-001.pdf [Accessed: February 9, 2014]. (2000).

Author Biography

Ken Fujiyoshi is currently taking his bachelor's degree at the Faculty of Environment and Informational Studies. He is a member of Hiroya Tanaka Laboratory, a lab whose theme is to create interface and interaction between digital and physical world with digital fabrication and other technologies from the perspective of design.