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Research Article

Fuzzy Logic Approach For Warping Problem In 3D Printing

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Abstract:

The most common problem encountered during 3D printing –especially working with ABS material- is the warping problem. Starting from the corners which caused by cooling of the printed object and resulting the faulty production of the model. One way to solve this problem is making the production on a heating surface. While the production continues on the heated bed, PID (Proportional Integrated Derivative) control keeps temperature of heated bed stable. Another method to fight this problem is covering the entire printer in a closed box and making the environmental temperature steady during the production. Some other methods and researches exist on this problem. Purpose of this paper is to find an alternate solution with fuzzy logic to the problem mentioned. Current environment and produced part's temperature used as input, and the temperature of heating bed controlled as output parameters. A PIC 18F45K22 used as control unit, heater connections of a Prusa i3 printer were disabled and connected to the control unit. An infrared heat sensor was used to read the input values. In this way both the temperatures of environment and the printing part were been able to read with the same sensor. The warping amounts of both classic way (PID) and fuzzy logic controlled prints were compared.

1. Introduction

Additive manufacturing, which is more colloquially referred to as 3D printing, is quickly approaching mainstream adoption as a highly flexible processing technique that can be applied to plastic, metal, ceramic, concrete and other building materials [1] 3D printing is a misnomer. It is actually 2d printing over and over again. And uses the technologies associated with 2d printing. 3D printing methods with polymers are called with various names. Such as; SLA (Stereolithography apparatus), DLP (Digital light projection), CLIP (Continuous liquid interface production)[2], SLS (Selective laser sintering), FFF/FDM (Fused Filament Fabrication / Fused Deposition Modeling), LOM (Laminated object manufacturing). [1] One of the materials used in FDM printers is ABS (Acrylonitrile Butadiene Styrene) which has a respectively big coefficient of thermal expansion value. Because of that, the temperature must be steady during the production process. Otherwise warping of printing part may cause troubles or even the failure of production. [3] There are a couple ways to fight with warping problem. One of them is to envelope the entire printer with a box. So the temperature inside the printer will not be affected from external temperature changes. That way the rapid temperature changes on print will be eliminated. Some academic studies have been made to change the coefficient of expansion value of ABS by adding some other materials [4] or by revolutionary algorithms to change the slicing methods to prevent warping [5]. Also some researchers are working to build alternate heat bed platforms to get more stable heating and less energy consumption [6]. In this study heat bed temperature was manipulated with Fuzzy Logic approach to prevent warping.

2. Material And Methods

Most heat bed platforms used on 3D printers control the temperatures with PID method. And take feedback value with a thermocouple. In applications even with a stable heat bed temperature, warping may occur. It is inevitable to think environmental temperature change is the reason. In this study environmental and printing part temperatures were tracked to control temperature of printing part. Fuzzy logic systems come forward as the best method to control a system with multiple inputs [7].

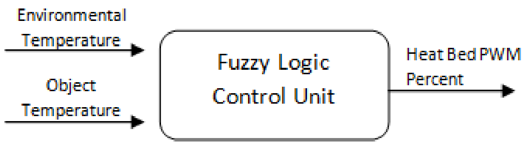

Figure 1. *Diagram for 2 inputs 1 output Fuzzy Logic Control System*

Input and output parameters have to be converted into linguistic expressions. This is called as fuzzyfication. Input parameters were picked as °C, and output parameter was picked as the percent value of PWM applied on heat bed platform which consumes about 100W power. Using 3 linguistic values as Low, Medium and High makes a Fuzzy Control System (FCS) less complicated during fuzzyfication [8].

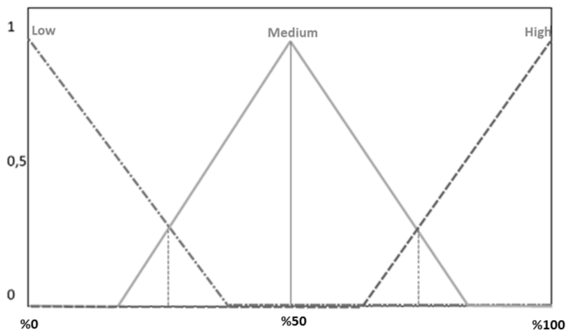

Figure 2. *Fuzzyfication triangles for output*

While working with linguistic values, a rule set has to be decided to define the relationship between inputs and outputs. At this point personal experiences come up and expert opinions define those rules. A couple of rule sets have been tested and finest results were obtained with the rule set in Table 1. (Low, Medium and High words represented with initials on the table). To make the FCS working, a Microchip PIC

Table 1. *Rule Set for Fuzzy Logic Control System*

		Environment Temp.		
		L	M	H
Object Temp.	L	L	M	H
	M	H	M	M
	H	M	M	L

18F45K22, to read the input values a MLX90614 infrared heat sensor were used. Both the input values were been able to read with a single sensor. The schematic of circuit can be seen in Figure 4. MLX90614 heat sensor mounted on the extruder and placed as close as possible to the nozzle.

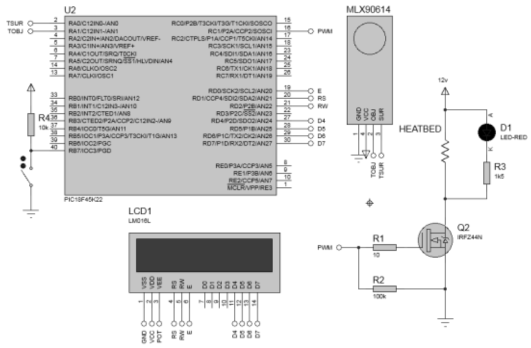

Figure 4. *Schematic circuit of FCS*

Both PID and Fuzzy Control codes were included in the program of microcontroller. Because at the start of print there is no object to track its temperature. Naturally prints started with PID control only and switched to Fuzzy Logic when first layers of printing were completed. Switching between control methods done manually in every test. The cartesian 3D printer used in study can be seen at Figure 3. Connections of heat bed were removed and connected to FCS circuit.

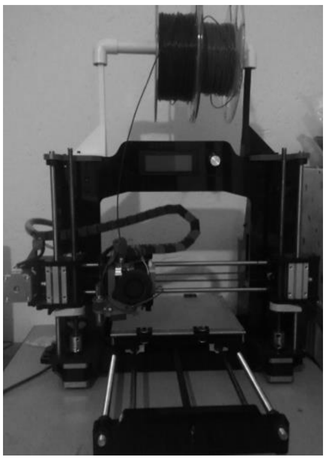

Figure 3. *FDM 3D printer*

3. Results

Ten test objects have been printed with each control method and same (front left) corner of every print was marked. Sideway pictures of printed parts were collected.

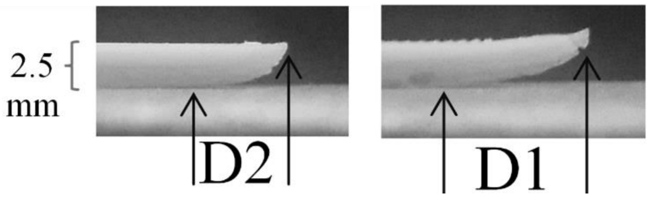

Figure 5. *A sample of test prints*

Dimensions of test objects were 50x50x2.5 mm. Warping amounts (D1 and D2 in Figure 5) were calculated by proportioning measured height of object from pictures and known height of object. Calculated amounts of warps were noted into Table 2.

Table 2. *Warping Amounts of Test Prints*

	PID (D1)	FLC (D2)
Test 1	9.2mm	5.3mm
Test 2	8.4mm	6.2mm
Test 3	7.7mm	5.7mm
Test 4	8.1mm	6.4mm
Test 5	7.2mm	7.1mm
Test 6	9.1mm	7.6mm
Test 7	8.5mm	5.6mm
Test 8	7.9mm	6.2mm
Test 9	8.0mm	7.3mm
Test 10	7.6mm	5.9mm
Average	8.1mm	6.3mm

4. Conclusion

Average warping amounts show that Fuzzy Logic Controlled prints have %22 less warping than PID controlled prints. Adding a thermal camera system to track all temperatures (environment, printing part, nozzle and heat bed temperature) in FDM printers might be the interest of a further study which will give more control on printing process and also warping problem too. This kind of studies set a guideline for industries and scholars study on FDM technologies.

References

[1] Stansbury, J. W. & Idacavage, M. J. (2016). 3D printing with polymers: Challenges among expanding options and opportunities. Dental Materials, 32(1), 54–64.https://doi.org/10.1016/j.dental.2015.09.018

[2] Tumbleston, J. R., Shirvanyants, D., Ermoshkin, N., Janusziewicz, R., Johnson, A. R., Kelly, D. DeSimone, J. M. (2015). Continuous liquid interface production of 3D objects. Science, 347(6228), 1349–1352.https://doi.org/10.1126/science.aaa2397

[3] Weng, Z., Wang, J., Senthil, T., & Wu, L. (2016). Mechanical and thermal properties of ABS/montmorillonite nanocomposites for fused deposition modeling 3D printing. Materials & Design, 102, 276–283.https://doi.org/10.1016/j.matdes.2016.04.045

[4] Wang, S., Hu, Y., Song, L., Wang, Z., Chen, Z., & Fan, W. (2002). Preparation and thermal properties of ABS/montmorillonite nanocomposite. Polymer Degradation and Stability, 77(3), 423–426.https://doi.org/10.1016/S0141-3910(02)00098-8

[5]Guerrero-De-Mier, A., Espinosa, M. M., & Domínguez, M. (2015). Bricking: A New Slicing Method to Reduce Warping. Procedia Engineering, 132, 126–131.https://doi.org/10.1016/j.proeng.2015.12.488

[6] Rictor, A., & Riley, B. (2016) Optimization of a Heated Platform Based on Statistical Annealing of Critical Design Parameters in a 3D Printing Application. Procedia Computer Science, 83(Ant), 712–716.https://doi.org/10.1016/j.procs.2016.04.157

[7] Mehmet Nuri ÖDÜK. Ph. D. Thesis (2010). Konya – Selçuk University Graduate School of Natural and Applied Sciences SELÇUK ÜNİVERSİTESİ.

[8] Derrouazin, A., Aillerie, M., Mekkakia-Maaza, N., & Charles, J. P. (2017) Multi input-output fuzzy logic smart controller for a residential hybrid solar-wind-storage energy system. Energy Conversion and Management, 148, 238–250.https://doi.org/10.1016/j.enconman.2017.05.046