MTRL 466: Engineering Project I

Department of Materials Engineering

The University of British Columbia

PROJECT PROPOSAL REPORT (Group 2)

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Executive Summary

Fused Deposition Modelling (FDM) or 3D printing is a type of Additive Manufacturing (AM) that is slowly becoming more and more popular with the manufacturing industry [1]. FDM creates objects by using a converted digital model and continuously adding layers of deposited material to the object. This method of AM has the potential to be a main mode of commercial manufacturing as “rapid prototyping” is eliminated [1]. Parts and products are being made more efficiently, and therefore can be inherently cheaper.

Currently, the underlying dilemma with FDM is when a print run is unsuccessful, and obvious defects are formed through failure. Determining one key method to detect failure during FDM that ideally stops the print run is the purpose of this design project. Minimizing capital costs through reducing material waste as well as printing time is the project objective.

This proposal will provide sufficient information and specifics on how the team will meet their project objectives, ensuring that the overall project goal is achieved. The project definition and related technicalities will be reviewed along with a more in-depth explanation of the teams’ goals and objectives. A project schedule as well as a communication plan will help to ensure that the initial, weekly and overall goals are met. A risk assessment was also conducted which lays out any foreseen threats at this point which may help plan for any setbacks along the way. Furthermore, a list of technical resources required for this project are described along with a detailed budget of the expected costs. Finally, safety concerns associated with carrying out this project are outlined in the ladder part of the report.

Problem Definition

The use of 3D printers is rapidly evolving from printing prototypes to printing end use products and parts, but one of the main obstacles of using additive manufacturing to make end use products is that the part rejection rate of 3D printed objects is significantly higher than the rejection rates of other manufacturing processes [2], meaning that a large volume of material is wasted, making the cost of production per part higher than it should be. To make use of this technology in large scale manufacturing processes, the part rejection rate must decrease and there must be proof that the parts can function according to industry standards and that the materials used will maintain their desired properties on the parts printed [3].

The focus of this project is to identify a non-contact technology compatible with a variety of fused deposition modelling (FDM) printers for detection of defects during an FDM print run.

Technical Review

Defects:

As identified in the Problem Definition, the focus of this project is to reduce the rejection rate of parts created by the Fused Deposition Modelling Process. To do this, we must first define a defect or in other words identify why part rejection occurs. Errors in FDM that result in part rejection can be due to a number of issues such as "Misalignment of the print-bed or nozzle, clogging of the nozzle, depletion of printing material or disrupted material flow, lack or loss of adhesion to the print bed, and vibration or shock (from the printer or another source) [4]." These specific errors have also been classified into five different categories. These include: "detachment of the part from the print bed, missing material flow (e.g: blockage in extruder head), deformed objects (e.g: collapsed bridges or overhangs), surface errors (e.g: smooth model but roughly printed part), and deviation from the model (in terms or size or appearance) [4]". Currently there is research being done to reduce and detect print errors in FDM, one of these methods is outlined below.

Previous Solution:

The method that will be explored is optical error detection with the capacity to detect detachment, missing material flow, as well as deformed objects. All three of these error types are able to be detected as optical sensors are able to pick up on horizontal movement of the part as well as uneven vertical growth. In the case of a deformed object, "this error class has features from the error classes of missing material flow and loss of adhesion from the print-bed and therefore can be detected utilizing methods designed for them [4]." Outlined in the paper entitled *Vision Based Error Detection for 3D Printing Process* the setup consisted of multiple cameras working alongside an "auxiliary thresholding algorithm [4]". This algorithm has the capacity to receive the footage from the optical cameras and "segment the digital image into binary images with a clear distinction between the object and the background [4]." The particular camera setup that was used in this application was the "Playstation EyeCam camera with an OmniVision chip of the resolution of 640 pixels by 480 pixels [4]" chosen for its high resolution and relatively low price. To ensure that only relevant footage was obtained the layout of the printer was carefully measured, important pieces such as the print head were identified, and the video frame cropped.

To identify whether the print was successful or not, the differential images (in this case the difference between three images) were generated. For this method during "an error free print the object does not change its horizontal location but will only grow vertically [4]." In the event of a horizontal movement in the differential images, an error is detected and will likely result in the part needing to be discarded. To test the accuracy of this method the machine was first run several times properly to ensure that no errors were detected. This was then followed by the printing of two different faulty test objects. The first sample was examined "with 5 objects printed without cutting the filament flow in order to ensure that no false positive detection occurs and with 5 objects printed with the filament flow cut off mid-print in order to ensure positive recognition of the failure detection [4]". From this, "four out of five objects [were] correctly classified as failed (80% detection rate for material flow failures) [4]." The second sample was examined by printing a triangular object with a very small base "10 times undisturbed with the object toppling over randomly 6 times [4].” Out of the six failed objects “four objects [were] correctly classified as failed resulting in 60% detection rate for object detachment [4].” Several times a part was classified as a “temporary failure [4]” during the print run however this was “corrected within a time span of 30 to 90 seconds [4]”. To improve this process the authors suggested that the algorithm be further developed for “resilience against lighting changes, [and] marker mis-detection [4]”.

Potential solutions:

At this point in the research we have not deemed any solutions inappropriate, and will continue to look for creative solutions that align with the Project Objectives and Quantitative Goals section of this report. An existing technology that will be explored in further reports will be Acoustic Emission detection [5]. On top of that, there are some possible technologies that may or may not have been previously used to monitor FDM that will be explored. Some of which are (but are not limited to) non-contact dimensional or depth sensors such as sonar and light, olfactory sensors, and thermal sensors. With further research, we will determine any issues or reasons why certain existing technologies are not feasible (too expensive, low precision, etc). Solutions will be evaluated via comparing sensor methods by type, precision, as well as what defect types and and defect size ranges they can detect.

Project Objectives and Quantitative Goals

As described in the project definition, materials are often wasted as the produced object does not match the envisioned design, during an unsuccessful FDM print run. FDM failures cause time delays and produce an excess of wasted material as different types of defects are formed, ultimately increasing capital costs. To combat this problem, it is important to determine the 3 most common types of defects that occur when 3D printing. Once this is established, defining a defect-detecting method that can easily recognize these specific types of defects can be achieved.

The project objective therefore is to minimize material waste and time spent during a single FDM 3D-print run using one type of sensory method. The type of sensory method is not fixed yet as that is the variable we are manipulating. There are however constraints that will be followed more strictly. The method chosen should allow for the cost to be under $300.00 CAD, as well as be a non-contact process. This means that if a defect is being created during a print run, the sensor should be able to detect it and stop the process automatically without user interference.

By the end of November, the aim is to have one working idea established and a feasibility study of the chosen solution complete, ensuring the objectives, variables and constraints are met.

Initial Project Schedule

The preliminary schedule for this project is outlined in the table of tasks below. See table 1. The start of each week has the milestone objective highlighted. The sub tasks below the milestone objectives have been assigned to various group members. The goal of this schedule was to have each group member contribute 6-8 hours of work a week.

As this is a preliminary schedule, it is likely to change over the course of the semester. In the event that tasks take more or less time than expected, work will be redistributed evenly again. Furthermore, complications may arise which will add unforseen tasks. This table will be updated accordingly.

Completing all these milestones at the scheduled time will lead to a successful solution for this project.

Table 1 - Table of Tasks to be Completed

Task	Week	Completed by	Comments
Initial literature review complete	1	All	Milestone
Problem definition	1	Isabela & Clement	
Defining relevant terms	1	Catherine & Sofia	
Research already existing solutions	1	Jenna & Aleisha	

List of all possible solutions	2	All	Milestone
Research all possible defects	2	Sofia & Catherine	
Begin writing proposal report	2	All	Was divided
Preliminary proposal report written	3	All	Milestone
Complete writing preliminary proposal report	3	All	Was divided
Finalized proposal report and continued research	4	All	Milestone
Finish final copy of proposal report	4	All	Was divided
Familiarize with physical FDM printer (if available)	4	All	Group activity
Research defect size ranges	4	Catherine, Sofia & Isabela	
Research sensors (prices/precision/existence)	4	Clement, Aleisha & Jenna	
Top three solutions chosen with week 4's research	5	All	Milestone
In depth comparison of functionality of top solutions	5	Sofia, Catherine & Isabela	
In depth comparison of economics of top solutions	5	Clement, Aleisha & Jenna	
Preliminary presentation and midterm report completed	6	All	Milestone
Prepare presentation	6	All	To be divided
Write report	6	All	To be divided
Practice presentation	6	Half the group	Half the group will present
Completed presentation and midterm report	7	All	Milestone
Present	7	Half the group	Half the group will present
Complete midterm report	7	All	To be divided
One solution chosen	8	All	Milestone
Use in depth comparison to choose optimal solution	8	Catherine, Isabela & Jenna	Collaborative effort
Clearly define which defects this solution can detect	8	Clement, Aleisha & Sofia	
Top solution finalized with in depth research ongoing	9	All	Milestone
Estimate reliability of the sensor	9	Catherine, Sofia & Isabela	With help from others
Top solution assessment	10	All	Milestone
Determine placement of sensor	10	Jenna, Catherine & Sofia	
Perform LCA of solution	10	Aleisha	
Research social impacts of solution	10	Clement & Isabela	
Preliminary report and presentation complete	11	All	Milestone
Prepare presentation slides	11	All	To be divided
Write preliminary final report	11	All	To be divided
Complete project successfully	12	All	Milestone
Present final presentation	12	Other half	Other half the group will present
Turn in final report	12	All	

Risk Assessment

Access to technical resources is seen as one of the greatest risks for this project. This is due to the fact that additive manufacturing has only recently moved from being a method for rapid prototyping to being a manufacturing process. This means there is very limited research and exploration into ways to reduce part rejection and material waste in an FDM printer. Adequate knowledge on the background of this project can be gained but with regards to actual solutions the scope is limited. Due to this, not all possible routes can be explored (primarily because they are not known) and the solution found even though suitable, may not be the best case. To reduce the risk associated with this, the group plans to periodically seek input from our sponsor with regards to any solution or direction we decide to undertake. This way we are sure to obtain some technical expertise to supplement the research we do.

Technical Resources, Budget and Safety

Technical Resources:

As the project relies fully on the use of the FDM printer, it is important that the team understands how defects are formed, and in doing so, become experts in the printer process. Understanding the ins and outs of printer through sessions with technical experts and advisors that have used it in the past would be greatly beneficial. It would be ideal to have these sessions and become comfortable with the printer as soon as possible. As mentioned previously in sponsor meetings, a designated TA for the project has been selected and thus, they would be the team's primary resource for this request.

Budget:

The budget for the expected solution should be no greater than the cost of the printer, with the solution budget estimated at approximately $300. The team currently has not identified our final solution and so the details for the equipment needed cannot be specified.

Safety:

In regards to safety, understanding the operating procedures of the specific FDM printer would be the most important. As this is a resource provided by the department and we want to minimize material waste, it is important the all team members are trained properly in the use of the device.

Communication Plan

The agreed methods of communication within the group are Facebook Messenger and Google Docs. The chat platform on Facebook Messenger allows for easy communication in terms of deadlines or quick announcements and reminders. This platform and “when2meet” will be simultaneously used to schedule extra group meetings when the need arises. To communicate in terms of research documents and reports, Google Docs proves effective as a centralized location where all files and documents can be accessed and edited. This way each team member can adequately input and follow the progress of the projects and changes can be effectively tracked as well.

To communicate with our project sponsor, we are using emails and the UBC Wiki platform. The wiki is generally to host research papers that have been referenced in the project and the weekly minutes so they are made accessible to the sponsor on a UBC managed page, conforming with university privacy laws. Emails sent to the sponsor usually have all group members copied or the content and response will be posted on the group’s online chat room. This way everyone is on the same page and kept in the loop. Minutes will be taken for every meeting, group and project sponsor alike, as this is another way to track progress.

References and Appendices

[1] Wong, Hernandez, and Aldo, "A Review of Additive Manufacturing," *International Scholarly Research Notices*, 16-Aug-2012. [Online]. Available: https://www.hindawi.com/journals/isrn/2012/208760/. [Accessed: 21-Sep-2019].

[2] C. Sinclair, "MTRL 466: Design Project 2019"

[3] "Additive manufacturing: scientific and technological challenges, market uptake and opportunities," *Materials Today*, 29-Jul-2017. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1369702117301773. [Accessed: 21-Sep-2019].

[4] F. Baumann and D. Roller, "Vision based error detection for 3D printing processes," *MATEC Web of Conferences*, vol. 59, p. 06003, 2016.

[5] H. Wu, Y. Wang, and · Z. Yu, "In-situ monitoring of FDM machine condition via acoustic emission."[Online]. Available: https://msse.gatech.edu/publication/IJAMT_FDMmonitor_wu.pdf?fbclid=IwAR30Hj__iaIY1Le6LNCbPbL7Of969dvuIeQJN21G3owit4eTOrZ4yNTnZ5s

[6] C. Wiltz, "With HoloLens 2 Microsoft Focuses on Mixed Reality's Time to Value," *Design News*, 27-Feb-2019. [Online]. Available: https://www.designnews.com/design-hardware-software/hololens-2-microsoft-focuses-on-mixed-realitys-time-value/164385451960335. [Accessed: 21-Sep-2019].