Building a 3D Micro-Manufacturing System using Digital Micromirror Device.

DESIGN DOCUMENT

Team sdmay20-30

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Engineering Standards and Design Practice

1. IEEE development standards
2. Digital design development standards
3. VLSI design development standards
4. Lab safety development standards

Summary of Requirements

1. Setting up a simple 3D printing platform, light source.
2. Establishing DMD Array to reflect UV light as a patterned light source.
3. Building an X-Y-Z Motorized System to make sure the stage can move layer by layer.
4. Designing the Graphical User Interface to upload the file which users want to print by our 3D printer.
5. Focusing on how to design a driver that could transfer the pattern from the GUI to DMD.
6. Testing our product and making continuous improvement.

Applicable Courses from Iowa State University Curriculum

EE 201. EE 230. EE 311,EE 332, EE 432, EE 531, Cpre 281. Cpre 288, Coms 228, Phys 221, Phys 222, Coms 227, Chem 167

New Skills/Knowledge acquired that was not taught in courses

1. SolidWorks
2. CreationWorkshop
3. LabVIEW
4. DLP
5. Stereolithography
6. Budget management

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1 Introduction

1.1 Acknowledgement

We would like to thank our advisors Meng Lu and Liang Dong for technical assistance and support. We would also like to thank our student advisor Le Wei in advance for helping to guide our team.

1.2 Problem and Project Statement

This project aims to build and demonstrate a 3D lithography system by using the existing digital mico - mirror array and the inverted microscope in our lab. 3D lithography system is important in many fields, for example, it could be used to develop microscale biorobots, microfluidic devices, and metamaterials.

The project consists of three major tasks for us:

1. building an X-Y-Z Motorized System.
2. developing the GUI for users to generate patterns and integrate the system.
3. Testing and examining our products, then making continuous improvement.

The output of our design:

1. Well - worked 3D lithography printer.
2. Functional 3D lithography system.

1.3 Operational Environment

The 3D printer must be placed and operated in an environment at room temperature without strong light since different lights will affect the intensity and focus of the UV source to interfere with printing accuracy. Avoid direct contact between the skin with the liquid in the print container.

1.4 Requirements

1. Setting up a simple 3D printing platform, light source, etc.

2. Establishing DMD Array to reflect UV light as a patterned light source.

3. Building an X-Y-Z Motorized System to make sure the stage can move layer by layer.

4. Designing the Graphical User Interface to upload the file which users want to print by our 3D printer.

5. Focusing on how to design a driver that could transfer the pattern from the GUI to DMD.

6. Testing our product and making continuous improvement.

1.5 Intended Users and Uses

Our design is intended for various users:

1. Manufacturing applications:

   Mass customization, Rapid prototyping...

2. Medical applications:

   Bio - printing, Medical devices...

3. Industrial applications:

   Soft sensors and actuators...

4. Sociocultural applications:

   3D selfies, Art, Education...

1.6 Assumptions and Limitations

Assumptions:

1. Up to 95%, accurate microstructures can be performed.
2. Easy to perform for users.
3. High-intensity UV light source may increase the efficiency of the printer.

Limitations:

1. The surface texture is generally too rough.
2. It is difficult to 3D model.
3. Machines are generally too slow.
4. Generally a few colors.
5. The size of the printed object must be smaller than the size of the platform.

1.7 Expected End Product and Deliverables

Expected End Product:

1. Optical imaging system.
2. GUI.
3. X-Y-Z Motorized System.

Expected End Deliverables: (Under the circumstance of COVID-19)

1. Build up essential parts required for testing and printing.
2. Trying best to produce products for demonstration
3. Semi-auto control system, automate the control system as much as possible.
4. Final Presentation
5. **Final poster**
6. **Final report**

2. Specifications and Analysis

2.1 Proposed Approach:

1. Set up the system.

a. Built up the platform using every resource we can find in the Lab, and some of them may not be very suitable for the system, for example, the optical scope and projector base.

b. Test the spectrum of DLP projector and find out it can cover 420nm

c. Find Out the "Formlabs"3D printer on Dr. Dong lab uses 420 nm light sources. The light from the projector can cure the resin but the curing time and the depth of rein need further testing.

d. Roughly add a lens between the projector and resin tank position and test the focus distance.

2. The motorized-stage "MP-285" is ready for operation.

a. The motorized-stage is ready for printing tests. The stage can be controlled by the Labview program and ready for modifying.

2.2 Design Analysis

We will create a sample GUI and it worked. Because we want our users to upload a file from the interface and we can make that happen. We want to find a suitable DMD array to be continued because the DMD array is the key element to generate a suitable pattern for lithography. A suitable DMD array can be identified by computer easily, but we get the DMD array from the projector, it's a little bit expensive.

2.3 Development Process

We made tests on MP285 by using Labview(move right, move left, move up, move down), and all the tests passed. Another thing is to control DLP4500 by using Labview, we can upload one pattern at one time by hand. But we are making a 3D printer, there are many patterns we need to upload to the DLP4500, so we are working on reprogramming the driver of DLP4500 on Labview. Besides, we make some tests with hardware and software together. First, we set up the whole system. In the system, we need to make sure the position of each device is suitable. What we do is to make sure every device in the system works simultaneously. Once we upload a single pattern to DLP4500, the MP285 will adjust the position of the resin(horizontal) to make sure it prints a single layer. After we finish the printing of the single layer, we need to adjust the position of the resin(vertical) to make sure it prints another single layer. Repeat the above steps to generate the 3D model.

We have been working on learning the slicing software for our 3D DLP UV printer during this semester. The software we used is creation workshop beta 13, we could open the STL file which is downloaded from a public resource successfully in creation workshop. In our test, we used the STL file of a thingiverse as the 3D model, the thingiverse was shown in the 3D viewing window where we could rotate around and view every angle of the model. After that, we are trying to slice our model by the button in the top left. For now, we had a couple of tests to slice a 3D model, but we still have some problems while testing in the creation workshop. Besides, we have successfully cut the model to slices horizontally. In addition, since the previous models were fundamental models such as boxes, gears and tires, we created some complex models and tried to cut them to slices in different angles such as bicycle, plane and house.

We made adjustments to the optical lens of dlp4500. After the optical lens, the pattern was warped. Also, test resin's cure position, and cure time. Design the building head base on our MP285. We calculated the depth of resin exposed to the UV light. Design the resin fill platform for further improvement. Still working on the optical platform to improve the alignment.

2.4 Conceptual Sketch
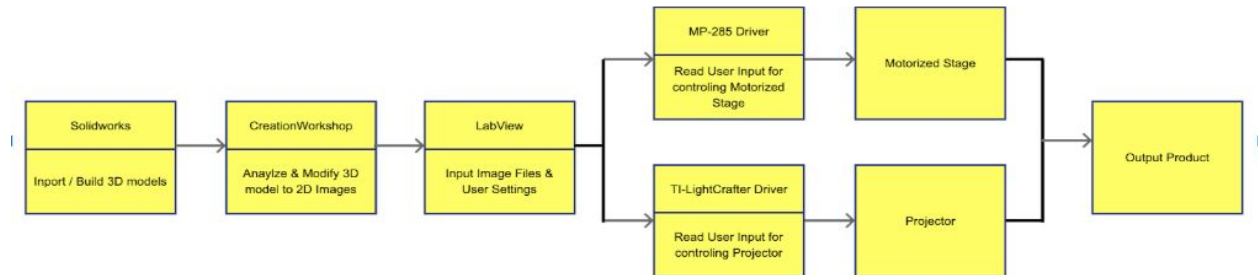
3. Statement of Work

3.1 Previous Work And Literature

Wu, C., Yi, R., Liu, Y., He, Y. and Wang, C. (2016). *PDF*. [ebook] Daejeon, South Korea: IEEE, pp.2155-2156. Available at: https://ieeexplore.ieee.org/document/7759338 [Accessed 2 Nov. 2019].

This article shows a way to build a 3D printer by using a delta structured platform. It shows the mechanical structure, control module and a prototype of delta DLP 3D printer. One aspect from this article that is similar to our project is to build a X-Y-Z Motorized System and platform to make sure the stage can move layer by layer(From bottom to top).

de Beer, M., van der Laan, H., Cole, M., Whelan, R., Burns, M. and Scott, T. (2019). *Rapid, continuous additive manufacturing by volumetric polymerization inhibition patterning*. [online] ScienceAdvance. Available at: https://advances.sciencemag.org/content/5/1/eaau8723 [Accessed 3 Nov. 2019].

This article describes the chemical technology for 3D printing called photolithography, which is a process used in microfabrication to transfer patterns into substrate. In our project, the photosensitive material exposed under UV light will change their properties to "print". The photoinitiator can create reactive species (free radicals, cations or anions) when exposed to radiation (UV or visible). The photopolymer

(light-activated resin) can change its properties (become hardened polymeric material in our project) when exposed to light.

3.2 Technology Considerations

The strengths: We could implement a structure that the platform can be moved both vertically and horizontally, we hope we could use a delta structure in the future.

The weakness: When one of my team members was working on a UV LED, he found that the 4500's Light engine design had different versions, so the shape of the LED board was a little different. Based on what we met, we are going to try an external LED, we basically mount the LED outside.

Trade-offs: The major trade-offs was to use a new projector instead of the old one in the lab, we ordered a new projector from TI, and we need to change the light source to only UV lights. In this way, we could save plenty of time. We also found that we could reduce Voxel size by adding two optic shims in the light engine. It is a good way to get the suitable pattern from the projector.

The projector "DLP-4500" requires a device lock.

    a. As we researched on the internet and asked the TI company. We didn't get a functional Labview code for the printer. We decided to fo the printing tests by using the provided driver and automated the process by mock manual control in the future.
    b. We can use the official driver with the account signed in. But it doesn't work on the Labview, so we are still finding solutions for the driver of DLP4500 on Labview.
    c. There is also a problem for its driver, it's the time interval between two patterns uploaded to the DLP4500.
    d. The TI products have a high-level security system that requires their product to connect only with the computer with authorization, which makes modifying the official driver hard to accomplish.

3.3 Task Decomposition

i) Setting up a simple 3D printing platform, light source, etc.

ii) Establishing DMD Array to reflect UV light as a patterned light source.

iii) Building an X-Y-Z Motorized System to make sure the stage can move layer by layer.

iv) Designing the Graphical User Interface to upload the file which users want to print by our 3D printer.

v) Focusing on how to design a driver that could transfer the pattern from the GUI to DMD.

vi) Testing our product and making continuous improvement.

3.4 Possible Risks And Risk Management

Possible risks	Risk management
System is fragile	Wrapping box to secure the System
The light is harmful to eyes	Manipulating with goggles
The process of cure will generate harmful gas	Required masks to avoid harmful gas

3.5 Project Proposed Milestones and Evaluation Criteria

Milestones:

28/9: Define project goals and design schematic.

13/10: Identify parts.

25/10: Motorized stage prototype.

01/11:DMD array projector prototype.

29/1: Learn how to use Creation Workshop to build 3D models.

11/2: Build up the functional system.

22/3: Build up the motorized-stage system.

20/4: Semi-auto control system.

Evaluations:

1 The schematic must be met the requirements of the project

2 Parts used must fit within budget

3 Stage prototype should move smoothly and along X-Y-Z axis

4 DMD array should reflect Uv light as patterned light source

3.6 Project Tracking Procedures

Use Slack to track our conversation beyond meeting time.

Post what we have done and what problem we meet during our work.

Write Weekly reports and hold weekly meetings through Zoom.

3.7 Expected Results and Validation

We aim to build and demonstrate a 3D lithography system by using the existing digital mico - mirror array and the inverted microscope in our lab. The expected results should be Well - worked 3D lithography printer and a Functional 3D lithography system.

One way to confirm a high-level performance is to see if our 3D lithography printer can print vivid products which are required by our clients.

Due to COVID-19:

Our team doesn't have much progress since the current process is running slower than scheduled. Due to the coronavirus outbreak, we are not able to go to campus (and lab). That caused our hardware building process to be delayed, and we are not able to test our software. Which also slows down the process of software and the whole process. The following topics are discussed and accepted by our client and advisor.

1. Build up essential parts required for testing and printing.

2. Trying our best to produce products for demonstration

3. Semi-auto control system, we will automate the control system as much as possible.

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

Time	Tasks
Oct. 2019	Setting up simple 3D printing platform, light source, etc.
Nov. 2019	Establishing DMD Array to reflect UV light as patterned light source.
Dec. 2019	Building a X-Y-Z Motorized System to make sure the stage can move layer by layer.
Jan. 2020	Still working on 3D Motorized Stage. Calculate cure speed and and Building head position.
Feb. 2020	Designing the Graphical User Interface to upload the file which users want to print by our 3D printer.
Mar. 2020	Focusing on how to design a driver which could transfer pattern from the GUI to DMD.
Apr. 2020	Testing our product and making continuous improvement.
May. 2020	Final presentation and document about our product.

System block diagram
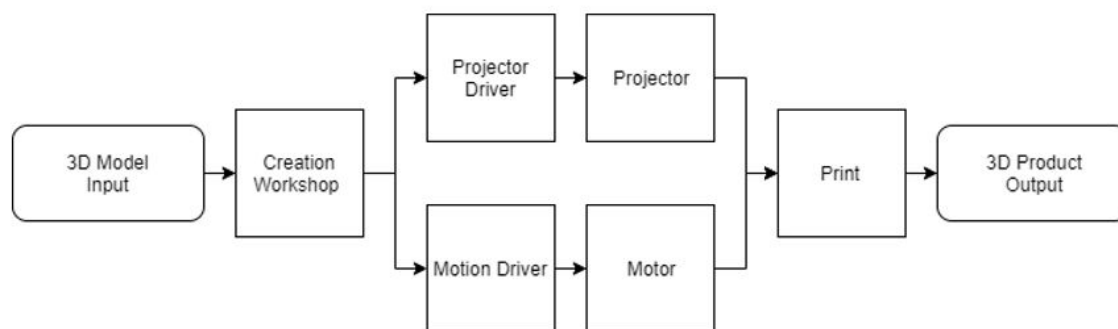
4.2 Feasibility Assessment

The realistic projection of our project is to create a three-dimensional object in our realistic world. We may not have the ability to implement our design ideally, this is because the property of our materials is not ideal, but at least we could print out a three-dimensional shape of what we want.

The State foreseen challenges of our project is to minimize our inaccurate printing.

4.3 Personnel Effort Requirements

Task#	Task details	Hours
1	Digital Micromirror Devices Array	Total: 126
1.1	Collect relevant materials	12
1.2	Design the prototype of DMD	15
1.3	Replace the UV light of projector	14
1.4	Revise and set up the driver of DMD	25
1.5	Test the pattern of UV source	10
1.6	Design a packing box for the projector by solid works	25
1.7	The open interface for DMD by GUI	20

1.8	Fixed projector on the table	5
2	X-Y-Z Motorized Stage	Total: 107
2.1	Collect relevant materials	12
2.2	Design the prototype of motorized stages	20
2.3	Set up the driver of the stage	30
2.4	Test and revise the driver by GUI	30
2.5	Connect the motorized stage to projector	10
2.6	Fixed motorized stage	5
3	Photolithography	Total: 97
3.1	Collect relevant materials	12
3.2	Decide chemical materials for Photoiniator and Photopolymer	20
3.3	Test the functions of Photoiniator	30
3.4	Test the functions of Photopolymer	30
3.5	Fixed on the printer	5
4	Final Test	30

4.4 Other Resource Requirements

1. Need a Power supply for our new projector,
2. Need a 420nm LED.
3. Need a DLP 3D printer GUI from TI, etc.
4. MP-285 motorized-stage.

4.5 Financial Requirements

Power supply	AC current with 9A	$ 17,49
Projector	DLP-4500	$ 1299
LED	420nm	$ 35.5
Motorized stage	MP-285	$ 0 (Available on the lab)

The total cost we need is $ 940.99

5. Testing and Implementation

1. DLP projector testing

2. UV light source replacing implementation

3. Projector protector design & implementation

4. Projector driver configuring

5. Motorized stage implementing & configuring & testing

6. LabVIEW coding & configuring & testing

5.1 Interface Specifications

Our project uses LabVIEW as our programming platform. We use the driver plugins of the hardwares and programming the system using block diagrams.

5.2 Hardware and software

For hardware testing, we use the official drivers provided by hardware companies- LightCrafter testing program for the DLP projector and MP285 testing program for the motorized stage. For software testing, we use LabVIEW code and dervicer plugins.
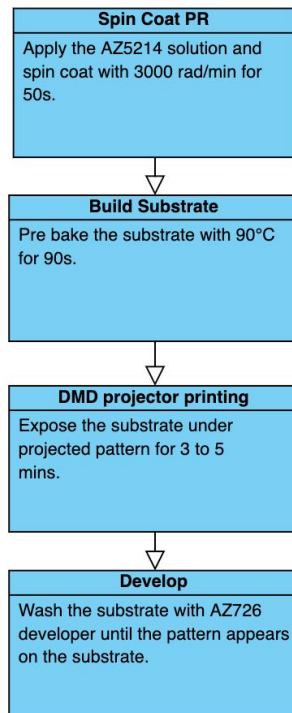
5.3 Functional Testing

During the UV light mounting process, we measured the light density with different focus distance and find the best position for the UV light source.

5.4 Non-Functional Testing

After we implemented the projector, we tested the time to print out a signal layer in many different environments.

5.5 Process

To test the DMD array, we made a substrate coat with AZ5214 and expose it to the patterned UV light to achieve 2-D massless lithography

Spin Coat PR

Apply the AZ5214 solution and spin coat with 3000 rad/min for 50s.

⇩

Build Substrate

Pre bake the substrate with 90°C for 90s.

⇩

DMD projector printing

Expose the substrate under projected pattern for 3 to 5 mins.

⇩

Develop

Wash the substrate with AZ726 developer until the pattern appears on the substrate.

To test the light source, we expose a resin droplet under our lightsource. After 10 min, the resin was cured.

To test the 3D printing, we input a patterned lightsource into a resin tank, and put the building head on the focus plane. Move the building head to finish the 3D printing.

5.6 Results

At this point, we finish most of the test. For the DMD-Array test, we can print a signal which means the DMD-Array is work, and it can generate the pattern which we want to print. We also do a test on the motorized stage, we use a driver to implement the motorized stage, it can move toward x-direction, y-direction, and z-direction.

We tested that our printer can perform 2-D lighthografhy on Silicon wafer (Az5214). Also, we tested that our lightsource were able to cure the 420nm Cure resin. Howerever, we still can't finish the actual 3D printing. The choice of optical lens and the focal plane distance require a large number of tests. Due to COVID-19, we were not able to find out the appropriate setup.

6. Closing Material

6.1 Conclusion

We tested that our printer can perform 2-D lighthograthy on Silicon wafer (Az5214). Also, we tested that our lightsource were able to cure the 420nm Cure resin. Howerever, we still can't finish the actual 3D printing. The choice of optical lens and the focal plane distance require a large number of tests. Due to COVID-19, we were not able to find out the appropriate setup.

6.2 References

Y. Pan, Y. Chen, C. Zhou, Fast Recoating Methods for the Projection-

based Stereolithography Process in Micro- and Macro-scales, in Proc.

Solid Freeform Fabrication Symposium, pp. 846-862, 2012.

http://www.ti.com/lit/ug/dlpu011f/dlpu011f.pdf#page61

Martin P. de Beer1*, Harry L. van der Laan2*, Megan A. Cole1, Riley J. Whelan1, Mark A. Burns1,3†, Timothy F. Scott1,2† Rapid, continuous additive manufacturing by volumetric polymerization inhibition patterning

6.3 Appendices