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Large Area Projection Microstereolithography: Characterization and Optimization of 3D Printing Parameters

M. R. Ng, B. Moran, L. Bekker, N. Dudukovic

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Large Area Projection Microstereolithography:

Characterization and Optimization of 3D Printing Parameters

Melissa R. Ng

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Abstract:

Large Area Projection Microstereolithography (LAPμSL) is a new technology that allows the additive manufacture of parts that have feature sizes spanning from centimeters to tens of microns. Knowing the accuracy of builds from a system like this is a crucial step in development. This project explored the capabilities of the second and newest LAPμSL system that was built by comparing the features of actual builds to the desired structures. The system was then characterized in order to achieve the best results. The photo polymeric resins that were used were Autodesk PR48 and HDDA. Build parameters for Autodesk PR48 were found that allowed the prints to progress while using the full capacity of the system to print quality parts in a relatively short amount of time. One of the larger prints in particular had a print time that was nearly eighteen times faster than it would have been had printed in the first LAPμSL system. The characterization of HDDA resin helped the understanding that the flux of the light projected into the resin also affected the quality of the builds, rather than just the dose of light given. Future work for this project includes exploring the use of other resins in the LAPμSL systems, exploring the use of Raman Spectroscopy to analyze builds, and completing the characterization of the LAPμSL system.

Introduction:

One of the hardest problems that developers of machinery or measuring tools face is the ability to span several orders of magnitude. One example of this is a ruler. It is a fine tool for measuring the length of a banana or the diameter of a mug, but inadequate for finding the length of a racetrack or the width of a single hair. This new technology is all the more remarkable for this reason.

Large Area Projection Microstereolithography (LAPμSL) combines two traditional types of 3D printing – stereolithography (SLA) and digital light processing (DLP) – in a single technology that allows the production of parts with features that can span eight orders of magnitude. Like DLP printing, it projects a horizontal slice of a three dimensional object into a bath of photo polymeric resin which cures wherever the light touches it. Like SLA printing, it systematically moves the light back and forth across the resin. The end result is the projection of a moving image, like an animation, that is able to create microscopic features across distances. This allows the creation of objects that are both large in overall size and have feature sizes on the order of tens of microns.

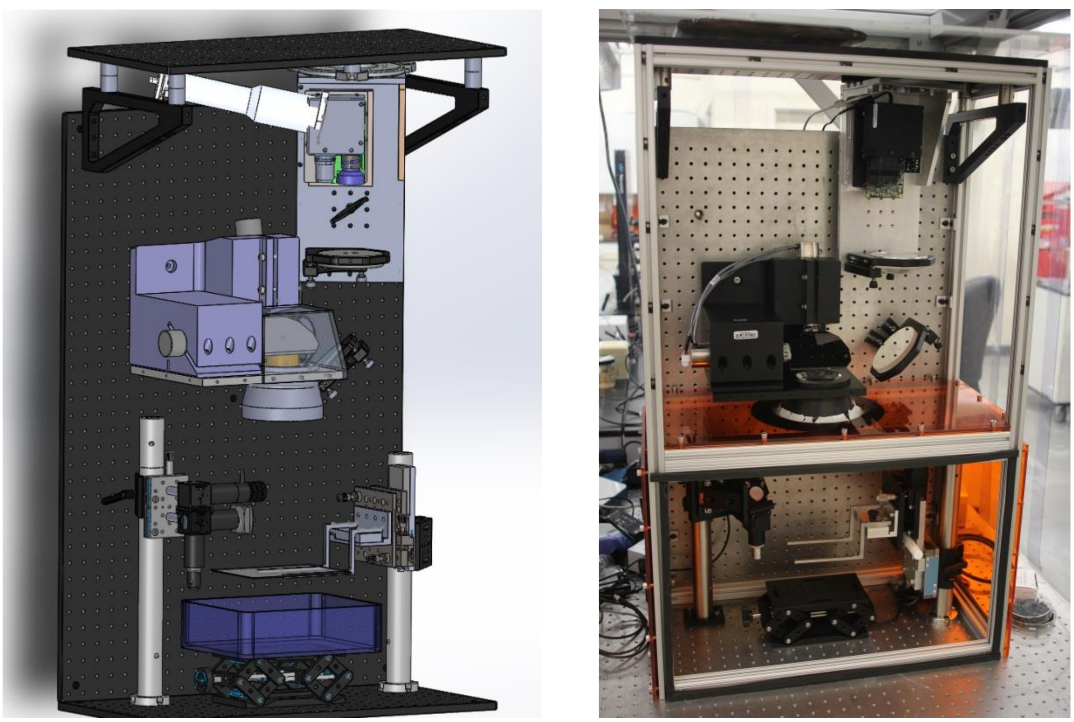

Figure 1: From right to left, a model of the LAPμSL system and the completed system itself.
Model and picture provided by Logan Bekker.

The majority of my work involved using the second and newest system that our group has developed (Figure 1) in order to determine if what we were printing was the same as what we meant to print. This evolved into a task to characterize the different resins for use in this system, and optimize the printing parameters for each resin.

Progress:

Most of our work was done by analyzing the features of a single test structure under different conditions. This was a small gradient lattice structure as shown in Figure 2. We picked this as our test piece for two reasons. The first is that lattice structures have many desirable properties and are often printed using SLA techniques. Secondly, this particular lattice structure allows us to test the resolution of features of different sizes.

Every sample was created and examined using the same method. First, the parameters that we wanted to test would be input into the software. The main variables that we looked at were the flux of the light projected onto the resin and the dose that was given each sample. After the build finished, the parts were cleaned and dried, and the method for this depended on the material that we were testing. Then the parts were put under a Zeiss microscope to be examined and measured. Axiovision software was used for the measurements. These actual measurements were then compared to the desired measurements. These were taken by measuring the bitmap file of the image that was projected into the resin. Using Gimp software, the desired measurement was found in terms of a number of pixels and then converted to micrometers using the magnification of the LAPμSL machine.

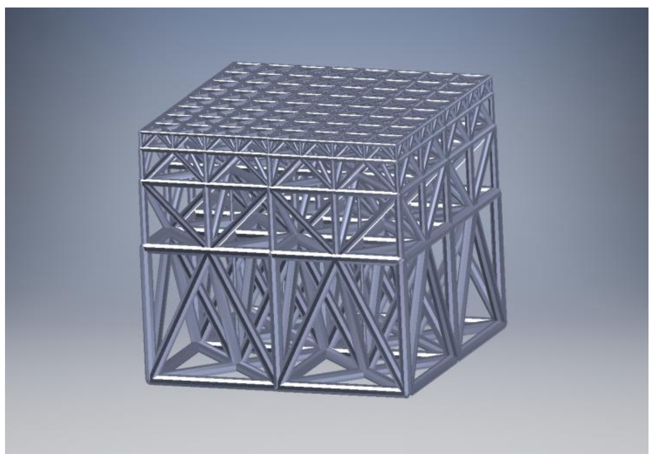

Figure 2: A model of the gradient lattice structure used as a test piece.

My project explored the use of two different types of resins in this system, Autodesk Standard Clear Prototyping Resin (PR48) [1] and Hexanediol Diacrylate (HDDA). PR48 is a newer resin that was created by Autodesk for open source use and development. HDDA is an older resin whose properties are better known and more widely used.

After numerous builds and hundreds of measurements, we successfully found printing parameters that allowed us to print high quality PR48 pieces (Figure 3) while using the full capacity of our system. The build time was nearly eighteen times faster than that of our older LAPμSL system. Testing with our HDDA resin yielded unsatisfactory builds despite testing parameters from across the range of our system. However, testing this resin resulted in its thorough characterization, which has led to some interesting insights. The most important is the relationship between the flux and dose that the build recieves while it is being printed. One of our initial assumptions was that the quality of the builds is consistent as long as the dose of light that it received is constant. We now know that the flux of the light, which is directly affected by the power outputted by the systems LED light source and the exposure time of the image, can drastically affect the quality of the build (Figure 3). This has helped prompt the group to begin exploring the use of other resins for our system, resins that will be able to print well from a light source of higher flux. Smaller results of my project include being able to use an encoder to get a more accurate height measurement, preventing rust and particulates from forming in the resin by using aluminum washers rather than copper clips, and the realization that the bitmap images that are projected are not the same size as the 3D model they were taken from.

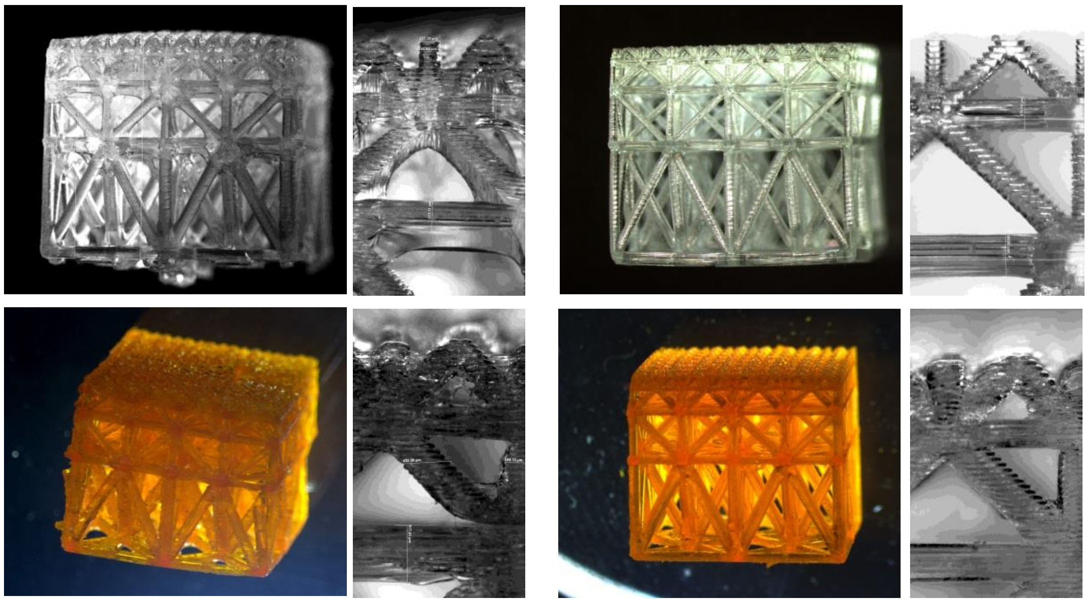

Figure 3: From right to left, top to bottom – PR48 lattice printed with a flux 211 mW/cm^2 and dose 349 mJ/cm^2, PR48 lattice printed with flux 211mw/cm^2 and dose 53.9 mJ/cm^2, HDDA lattice printed with flux 211 mW/cm^2 and dose 159 mJ/cm^2, HDDA lattice printed with flux 10.6 mW/cm^2 and dose 106 mJ/cm^2. Note the parameters for the HDDA builds yield very different results even though the doses are similar.

Future Work:

My project has helped direct the development of the newest LAPμSL system. We have optimized the system for Autodesk PR48 resin and are able to make HDDA prints of decent quality, but still need to complete the data set for the characterization of both. This could easily take a few weeks to complete, provided the system does not run into major problems. Future work could also address decreasing the build time and improving the quality of HDDA parts, improving the software for the LAPμSL systems, and further exploring the relationship between flux and the quality of the builds. It would also be enormously useful to be able to analyze the degree of polymerization of the resin, in other words how much of the build is fully polymerized and solid. We began to study this factor using Raman Spectroscopy, but have yet to see any data due to the age and highly unstable nature of the spectroscopy machine. This direction of research, assuming both the LAPμSL and Raman Spectroscopy system are functioning, would probably take several weeks to analyze a single resin but would yield invaluable data. This project consisted of just these two types of resins, but there are plans to explore the use of others for this system. Each resin would probably be characterized like the HDDA and PR48 were, and analyzed with Raman Spectroscopy. This continual testing of new resin, new structures, and in the far future new LAPμSL systems, could go on indefinitely.

Impact on Laboratory or National Missions:

As part of the additive manufacturing group at Lawrence Livermore National Laboratory, our systems often service other projects in the lab. The LAPμSL systems, in particular, have been used to facilitate research into coating the polymeric lattices with metal and burning out the polymer to have a structure that is both lightweight and strong. My project has helped this overall mission by further characterizing the new system and exploring the use of PR48 as a substitute for the more common HDDA resin. This primary research project was funded by a Laboratory Directed Research and Development.

Conclusions:

This summer I furthered the characterization and optimization of the newest LAPμSL system that my additive manufacturing group has built. This was done through the careful scrutiny of the gradient lattice structures that were printed. Examining these structures printed in PR48 and HDDA resin led to increased knowledge about the nature of the system, including the use of PR48 as a replacement for HDDA resin and the way the flux of the light affects the builds. My project evidences the need to complete the characterization of different resins and improve the quality and speed of builds made by this system.

Appendix

Participants:

1. Melissa R. Ng[1,2,3]: Author, operated above mentioned LAPμSL system, created samples, took measurements, and analyzed data.

2. Bryan Moran[2]: Technical Mentor, invented the LAPμSL systems, provided training and guidance for operation of the LAPμL systems and direction of research.

3. Logan Bekker[2]: Built the above mentioned LAPμSL system, provided training and guidance for operation of the LAPμSL systems and direction of research.

4. Nikola Dudukovic[2]: Operated the first LAPμSL system, provided training and guidance for operation of the LAPμSL systems and direction of research.

Affiliations: 1 – Ohlone College, 2 – Lawrence Livermore National Laboratory (LLNL), 3 – Community College Internships (CCI)

Scientific Facilities:

Lawrence Livermore National Laboratory, Materials Engineering Division, Additive Manufacturing Laboratory