DTU Compute
Department of Applied Mathematics and Computer Science

Computer Vision for Focus Calibration of Photopolymerization Systems

Christian K. Ingwersen & Harald L. Mortensen, B.Sc. Mathematics & Technology, DTU

Photopolymerization by mask projection allows for rapid construction of extremely detailed and intricate objects, such as hearing aids. To obtain the optimal quality for photopolymerization systems, it is paramount that the focal plane of the projector is exactly at the build plane. Currently, The Dept. of Mechanical Engineering at DTU is manually and subjectively finding the position of optimal focus. In this project we have fully automated this procedure and established measures to objectively evaluate the found focus.

Introduction

We present an autofocusing solution for mask projection based photopolymerization systems (MPPS), with ease-of-use equivalent to autofocus as known from ordinary DSLR-cameras. The autofocusing solution has been implemented and tested on the experimental MPPS (Figure 1) at DTU Dept. of Mechanical Engineering and submitted to be part of the Summer Topical Meeting with American Society of Precision Engineering (ASPE) at University of California, Berkeley.

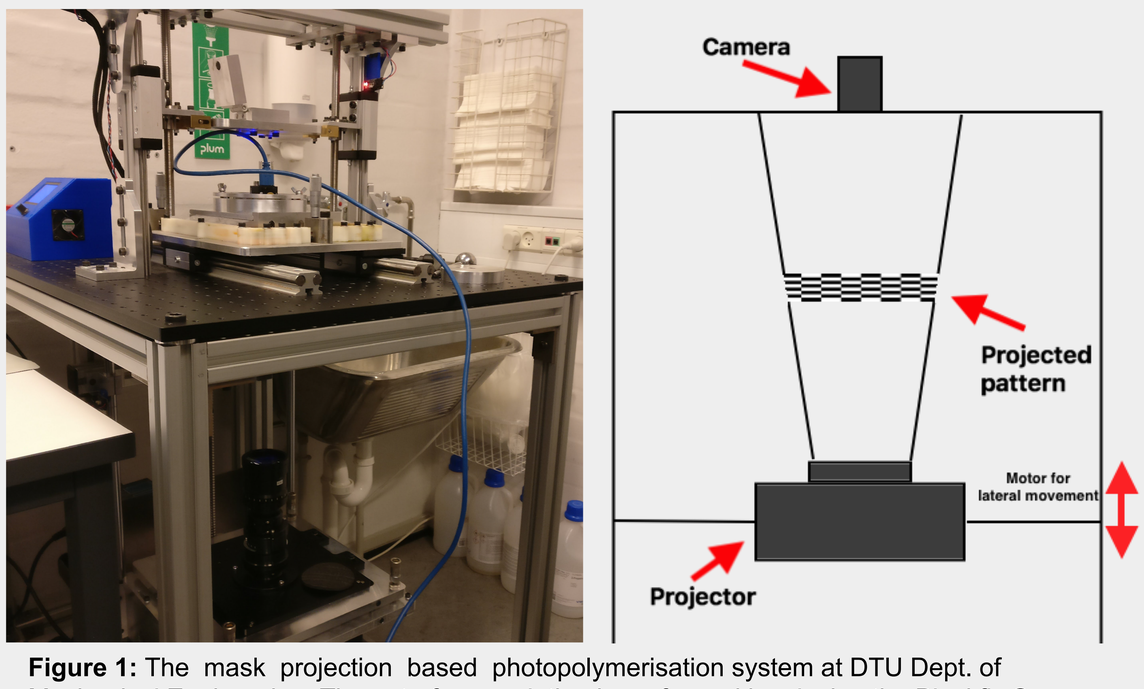

Figure 1: The mask projection based photopolymerisation system at DTU Dept. of Mechanical Engineering. The auto-focus solution is performed by placing the Blackfly S camera in a specially constructed mount atop the glass build plane.

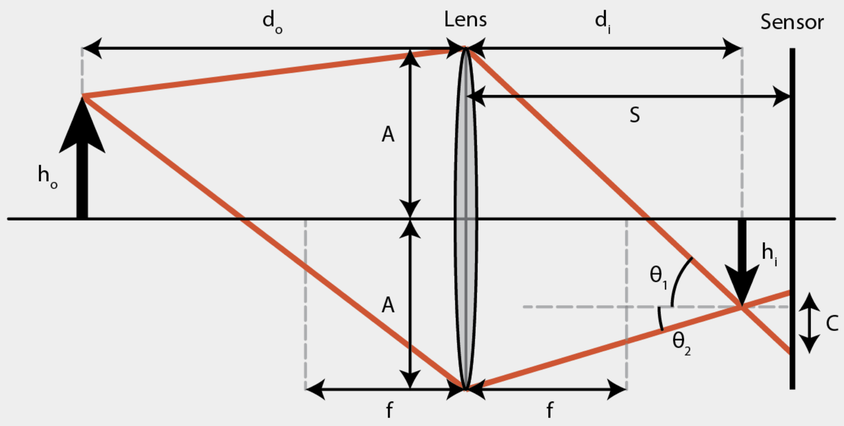

Figure 2: An illustration of the illumination from the projector. If the build plane is not exactly at the point of maximum focus, then the light from each micromirror will not be a point but a diffuse circle. This will seriously harm print quality.

Results

Using our autofocus algorithm, we reliably reach an extremely high degree of focus in just 4 minutes. The in-focus view of the projected pattern found by our autofocus algorithm can be seen in the bottom of Figure 4. We can clearly distinguish the smallest checkers, each corresponding to one micromirror only 1.57 µm wide.

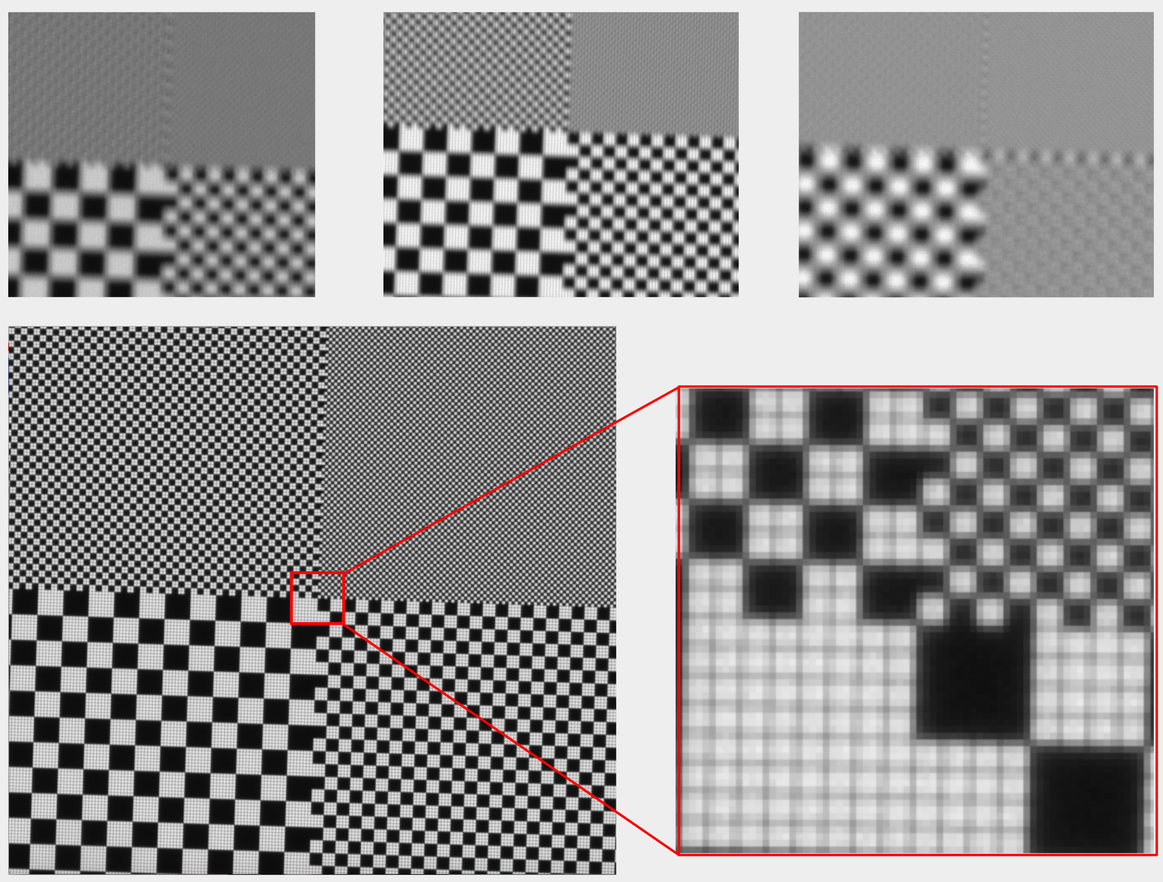

Figure 4: Top: Out of focus views of projected patterns. **Bottom:** In-focus view of the projected pattern found by our autofocus solution.

Methods

Our autofocusing solution is based on a multi-scale global search with a local curve fitting approach. A variety of focus measures were evaluated by their entropy as a measure of “peakedness”, their PCA transform and a qualitative inspection of their ability to find optimal focus.

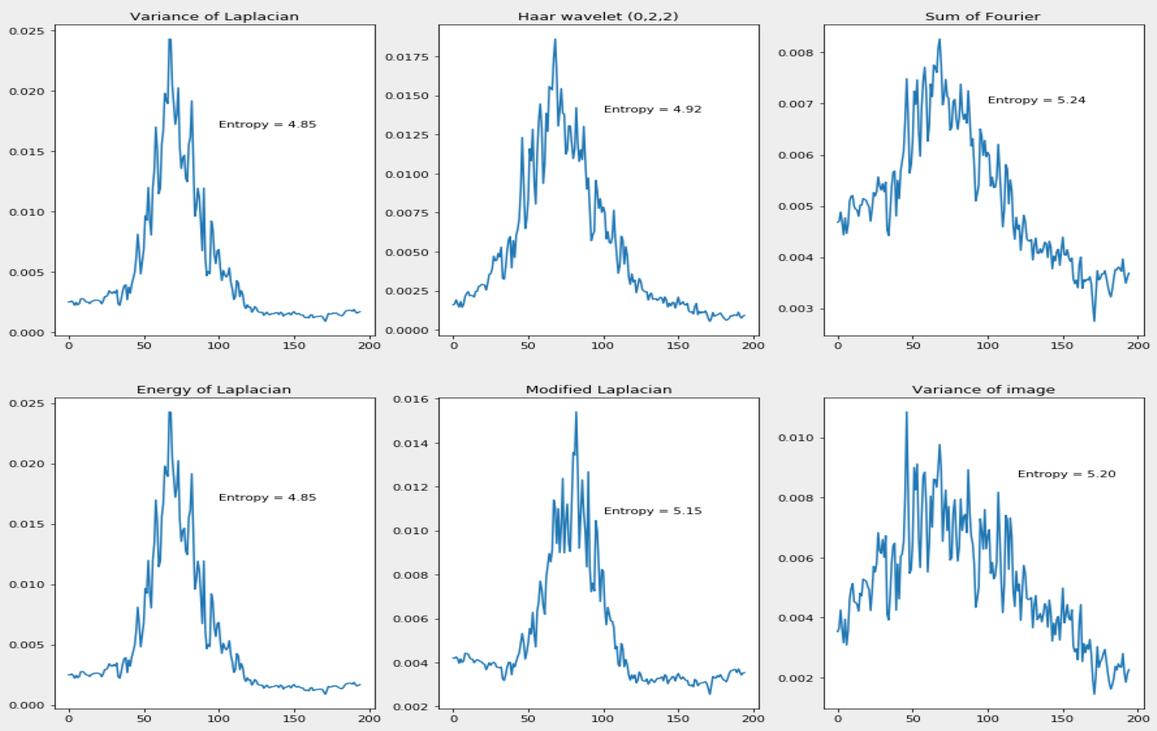

Figure 3: Normalized focus measures evaluated on a stack of 200 images captured with 10 µm vertical displacement between each image. Low entropy corresponds to high “peakedness”, thus we want low entropy.

Future Work

The projector is not only able to move vertically, but can also pivot. Finding the optimal focus along the vertical axis is thus not necessarily enough in ensuring print quality - we also need to ensure parallelity between the projected plane and the build plane. To do this, we wish to implement a local focus evaluation to construct a depth map of the projected pattern. We have successfully implemented a proof of concept on the UM2+ 3D-printer, which accurately constructs a depth map of our chosen tilted object.

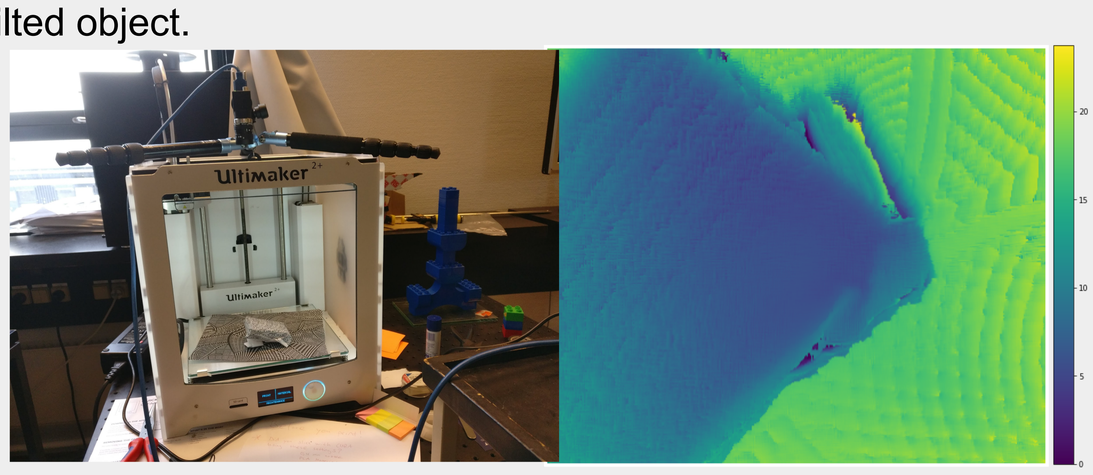

Figure 5: Proof of concept solution of depth from defocus depth map construction on the Ultimaker 2+ 3D printer in DTU Compute Imagelab, using a BlackFly S camera.

Acknowledgements

Thanks to our supervisors Allan Aasbjerg Nielsen[1], David Bue Pedersen[2] , Eyþór Rúnar Eiríksson[1] and to Macarena Mendez Ribo[2] for practical assistance.
[1]Dept. of Applied Mathematics and Computer Science, [2]Dept. of Mechanical Engineering

DTU Mechanical Engineering
Department of Mechanical Engineering

For further interest contact:
Christian Keilstrup Ingwersen: s154264@student.dtu.dk
Harald Løvenskjold Mortensen: s154436@student.dtu.dk