Open source system for controlling mirror galvanometers to reflect laser beam

The RepRap project that started in the University of Bath in 2005 kickstarted the development of consumer level fused deposition manufacturing (FDM) 3D printer. FDM 3D printers work by depositing molten filament, usually PLA or ABS plastic, in layers, until the object is fully built. The aim of the project was to create schematics and software for FDM 3D printers that could be built cheaply from widely available materials. Since 2005 the price of FDM 3D printers has come down drastically, while the availability increased to the point where they can be found at general consumer electronics store. This can be attributed to the open-source nature of the RepRap project and the countless amounts of hobbyists that improved upon the existing designs and software. However the same is not true about stereolithography (SLA) 3D printers, which offer far superior finish of the final model compared to FDM printers. SLA printers work by curing photosensitive resin layer by layer by shining a laser beam at it. The laser beam in such printers is usually controller by a closed-loop mirror galvanometer - a device that rotates a mirror proportional to the current flowing through it. Two such devices can be used to reflect the laser beam anywhere in the XY plane. Currently the prosumer market is dominated by printers made by Formlabs, which retail for around $3000, while the professional market is dominated by Stratasys printers, which can go for tens or even hundreds of thousands of dollars. There currently exists no resources a hobbyist could use to build an SLA 3D printer from the grounds up. The aim of our capstone project is to modify one of the existing open source 3D printer firmwares written with FDM printers in mind to add support for controlling off-the-shelf mirror galvanometers, as well as design and build the hardware necessary for the firmware to interact with galvanometers.

We chose the Smoothieware project as the starting point. The Smoothieware project aims to create open source hardware (Smoothieboard) and open source software (Smoothieware) for controlling FDM 3D printers and CNC machines. The board is based on a 32-bit Cortex-M3 CPU, which is significantly more powerful than other popular controller boards that are usually based on Arduino Mega running 8 bit Atmel Atmega2560 CPU. This allows Smoothieware to have cleaner code base because there is no need to hyper optimize the code to run on hardware where each clock cycle of the CPU and each kilobyte of memory matters. Additionally, the permissive license of the project lead to many manufacturers making their own versions of the Smoothie board, which means a board capable of running Smoothieware can be purchased for under 20 dollars on amazon.

Mirror galvanometers can be purchased fairly cheaply from Chinese website such as Ali-express or JD online shopping for under 100 dollars. The position of the mirror is determined by the input voltage fed into the galvanometer. Generally the accepted input can be between -15V and 15V where each voltage value corresponds to a distinct orientation of the mirror. We would need to build a DAC capable of receiving an input via SPI from the Smoothie board, and outputting the correct voltage to the galvanometer. (Also, we will invite professors or instructors to help us monitor the range of our voltage and make sure it is in the reasonable range.)
On the reprocessing side, we aim for 100% compatibility with the existing slicers. Slicers are software that take an input 3D object, usually in STL or OBJ format, and turn it into a g-code file, which contains the sequence of steps (in G-CODE format), the 3D printer needs to take to print the model. We plan to modify the movement planning part of Smoothieware to seamlessly translate the g-code to movement of the laser beam, with minimum changes necessary to the slicer configure.

Being able to control the laser beam has plenty of applications beyond just SLA 3D printing. It is also in the heart of selective laser sintering (SLS), another 3D printing technology, as well as laser etching, laser cutting and more.

Creating a working SLA printer is not the end goal of this project. We aim to create the tools that would enable other people to do so. Additionally we don’t want to work with high power lasers and run into all the health risks associated with it. We plan to use a class 2 laser (< 1mW) that pose minimal health risks, just verify that our system produces the correct image. (Like the Laser Pointer, the laser is in a class 2 laser, we will make sure the laser is same with the class 2, or lower than that value. Not only it can show the achievable consequence, but also we can protect our safety from the reflect of laser. When we obtain our equipment, we hope the professional instructors can direct us some important safety rules. Although the range is in class 2, safety knowledge should also be known or learned from the instructors since safety is the first rule for everything. This is our basic proposal about our design.)