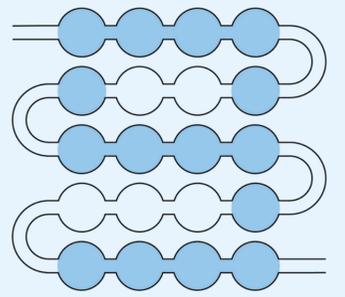


Design of a Microfluidic Display for Underwater Usage

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Background

Not many technologies for displays and screens that can work underwater exist in the market. This project aims to develop a new method of displaying text and images using a microfluidic display which can work while fully submerged underwater. A working fluid display can potentially be a sustainable replacement by greatly reducing our reliance on electronic displays.

These displays could potentially be used to guide swimmers and divers underwater or used in aquariums as signs for visitors. Additionally, the displays could have use in military operations, which value a low electronic footprint for security purposes.

Objective

The project aims to create a display which utilises nodes which act as pixels, connected by microfluidic channels. The display is made of a grid of nodes and with the right combination of air and dyed liquid pumped through the system, patterns and visuals can be produced on the display.

The project aims to achieve the following:

1. Determination of the ideal node shape to facilitate fluid flow
2. Determination of input speed of water and air into display
3. Make recurring patterns and alphanumeric characters in display
4. Automated system to generate patterns
5. Vary colours in display to generate colourful images

Approach

Modelling

Modelling system using computational fluid dynamics with Ansys to determine ideal node shape as well as speed of fluid flow into microchannels.

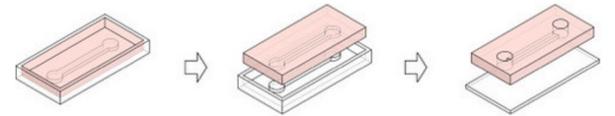
System Design

The system is made of 4 main components:

1. Pump system which is channeled into a air reservoir and a fluid reservoir.
2. Motorised valve system to control which reservoir is being pumped into the microfluidic display
3. Y-channel which connects the 2 reservoirs and is the path where the sequence of fluid or air flows through before entering the display
4. Microfluidic display made out of Polydimethylsiloxane (PDMS)

Materials and Methods

To create the microfluidic display, replica moulding of Polydimethylsiloxane (PDMS) was used. A master mould was 3D modelled and printed using



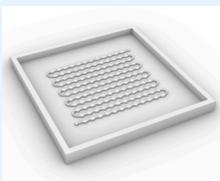
SLA and polyjet 3D printing. The moulds were cleaned and coated after printing to ensure proper curing of the PDMS. The PDMS was poured in and left to cure for at least 6h, after which, they were removed and bonded to another piece of PDMS, thus creating the finished PDMS display.

Results and Discussion

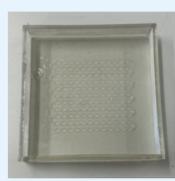
PDMS making

Making of PDMS casted channels was an integral part of the research process and various types of channel models, mould coating and PDMS bonding were experimented with. It is observed that coating of the moulds was the most important step to ensuring the PDMS cures properly and useable microchannels are formed. Otherwise, polymerisation of PDMS may occur at the walls of the 3D print, preventing the PDMS from curing fully.

- 1 SLA mould**
IPA bath, cured under uv
- 2 Coating**
Acrylic spray coating
- 3 PDMS cast**
Let cure for at least 6h
- 4 Bonding**
PDMS to PDMS with oxidation



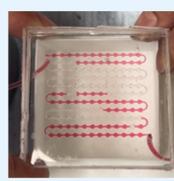
3D modelling of moulds



Printed and coated SLA Mould

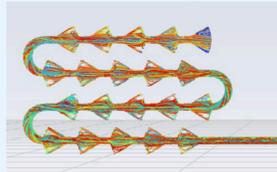
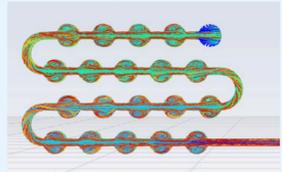


PDMS cast after curing

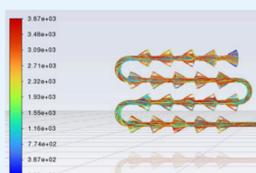
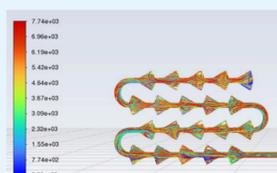
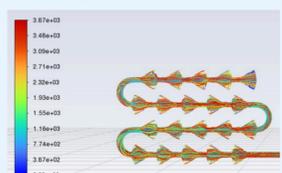


Bonding of PDMS and testing of channels

Computational Fluid Dynamics

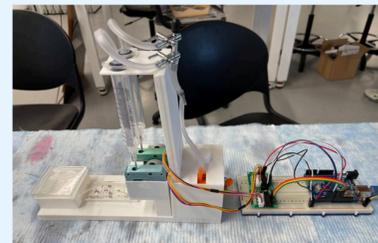


Modelling shape of the nodes shows that a teardrop shape (right) is better to facilitate fluid flow than circular (left) due to less backflow when fluid passes through the channels.

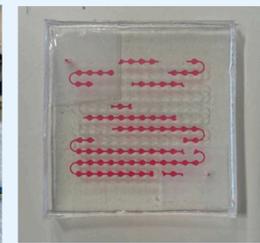


Modelling shows that an input velocity of 0.1m/s to 1m/s is optimal to ensure a manageable pressure so that PDMS bonding does not break. Higher velocity allows for rapid changing of displays but might cause lower channels to be partially filled; whereas lower speeds allows easier control but will have significant backflow in the empty nodes.

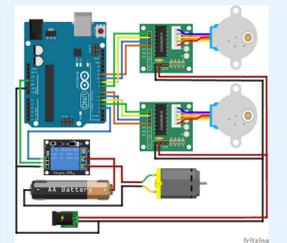
Final Prototype



Final Display



Electronic Components



Results

Through careful adjustment of the valves of the system, the speed of flow is able to be controlled by increasing head loss, giving the valves more time to open and close and alternate between air and fluid for the display.

Also through testing, we discovered that the Y-channel is not 100% precise at controlling the sequencing of air and fluid, as backflow into closed tubes can be observed while the other is open. Currently, the system can sequence a minimum of 3 nodes length of either fluid or air but is not precise to generate a repeating pattern.

Furthermore, it is discovered that the hydrostatic pressure created by the fluid column in the syringe affected its speed through the valve, thus later iterations of the valves and programming will have to account for the additional speed and in turn volume flow rate in the fluid column.

Conclusion

A microfluidics display on an 11 by 12 grid was created over the course of the project. However, as many parts of the system were original fabrications, the level of control to display repeating patterns or characters was not achieved. An automated system to control the sequence of air and fluid was still achieved with an Arduino. Lastly, due to the difficulty in precisely controlling the flow, colour variation was not explored.

Future Improvements

- PDMS displays could be overlapped with different coloured fluids inside to create a range of colours and eventually an image.
- Usage of electric solenoid valves which are more precise to control pressure such that precise sequences and in turn images can be formed.