Pneumatactor Arrays for High Frequency Vibrotactile Feedback

Anway Pimpalkar, Preshit Ameta, Ahan Dalia, Jeremy D. Brown

Johns Hopkins Whiting School of Engineering

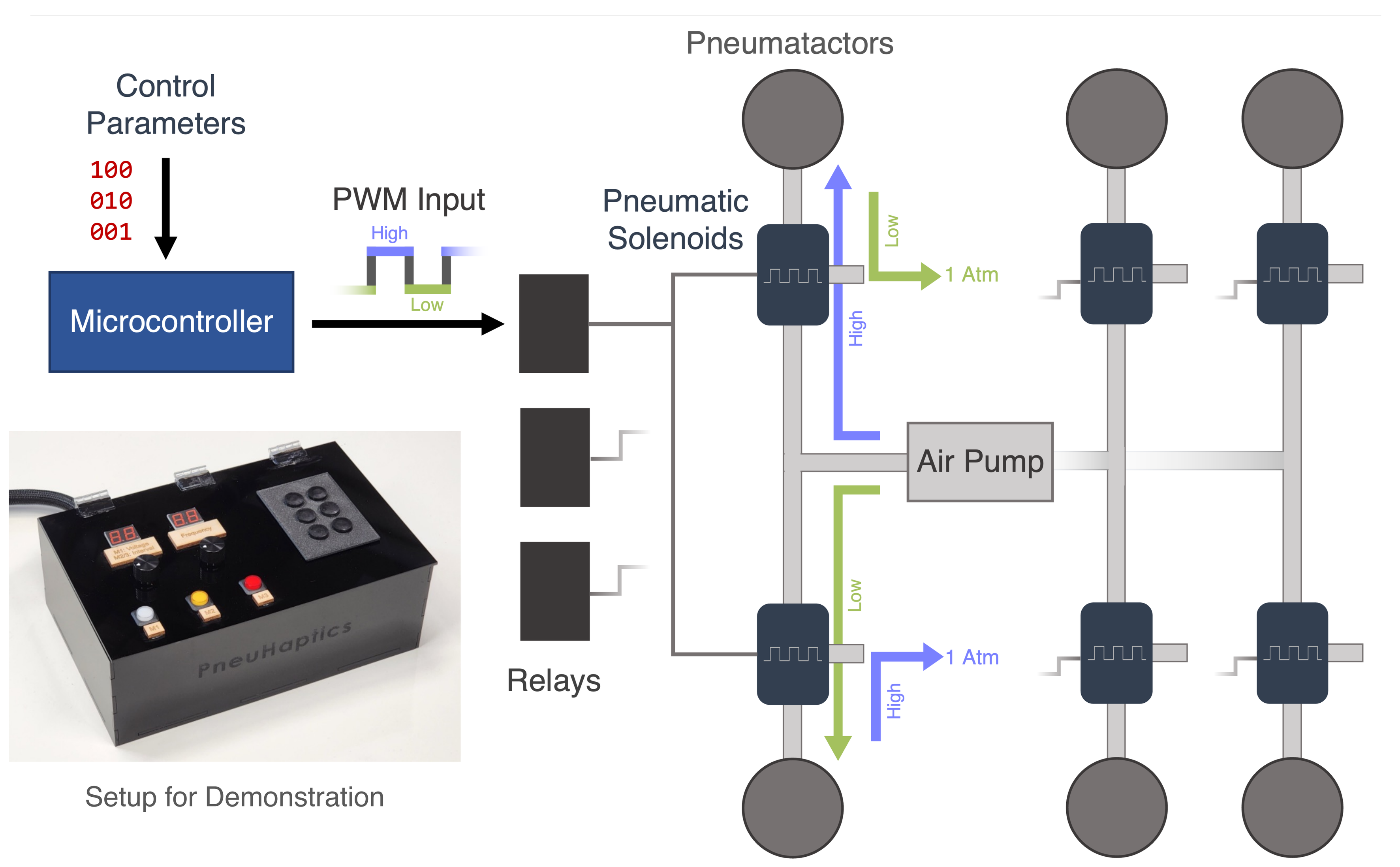
HAMR Haptics and Medical Robotics

Background

- Vibrotactile haptic displays built on rigid substrates are limited in their abilities to render realistic experiences in a variety of form factors.
- Pneumatic vibrotactors, or **pneumatactors**, can be manufactured in any shape and size, effectively mimicking natural environments.
- Their **adjustable stiffness** can be manipulated to resemble human skin to create **softer, more authentic haptic feedback**.
- Such capabilities hold promise for **applications in virtual reality, prosthetics, and beyond**.
- In this context, we present a framework designed to serve as a foundational **platform for future experiments and applications** pertaining to the **perception of tactile feedback across various stiffness levels**.

Implementation

- The constructed device serves two goals:
  1. To **frequencies and amplitudes**.
  2. To generate **independent tactile patterns**.
- At any given instance, airflow within the two valves is directed towards one of the two paired pneumatactors, resulting in **180° out-of-phase actuation**.



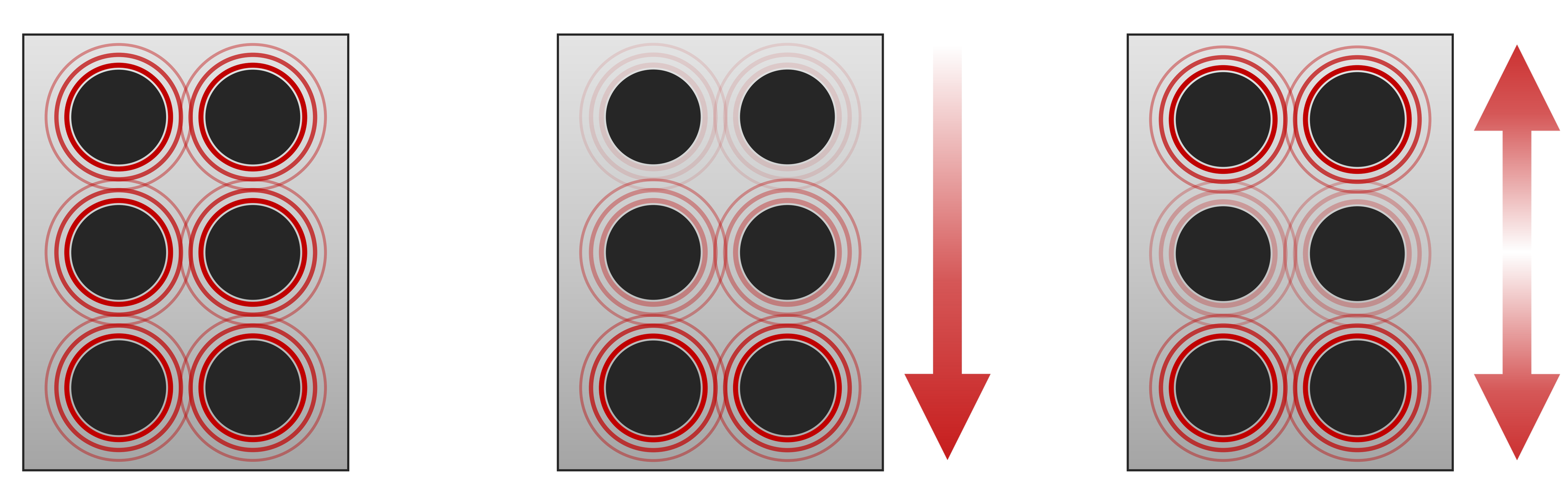
Setup for Demonstration

Potential of Pneumatactors

- The pneumatactors can achieve **different stiffnesses** through various manufacturing methods such as **FDM or SLA printing**.
- They can also be printed in **different patterns, shapes, and sizes** to generate various tactile experiences.

FDM • Shore 75A | FDM • Shore 70A | SLA • Shore 55A

Demonstration Modes

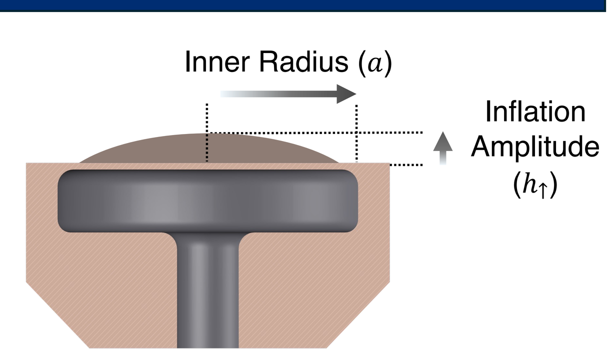


Mode 1 Synchronized Operation | **Mode 2** Propagating Wave | **Mode 3** Diverging Wave

Preliminary Analysis

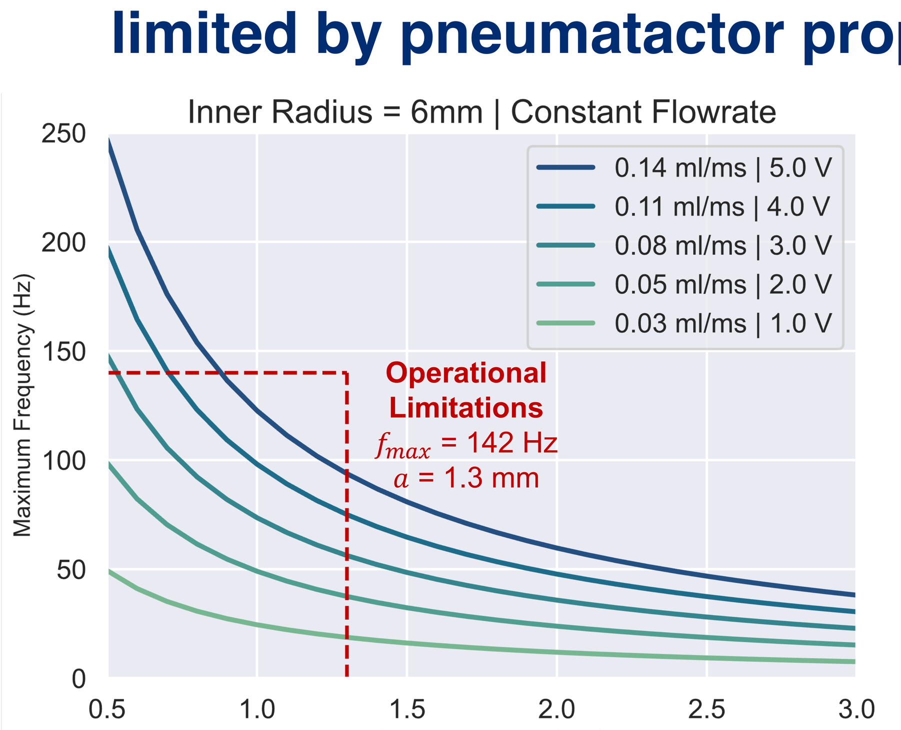
- At a given flowrate $\dot{V}$ and inner radius a, the relation between inflation amplitude $h_{\uparrow}$ and maximum frequency f_{max} is,

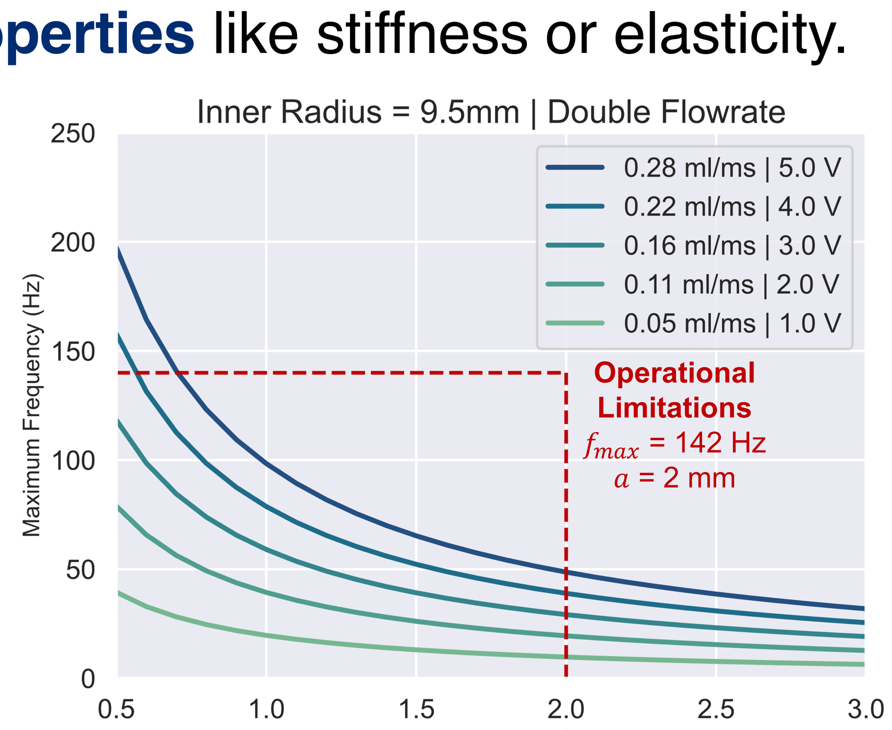
$$f_{max} = \frac{3\,\dot{V}}{\pi h_{\uparrow} \times (3a^2 + {h_{\uparrow}}^2)}$$



Pneumatactor Cross Section

- The **frequency response is higher at lower radii but is limited by pneumatactor properties** like stiffness or elasticity.





Ongoing and Future Work

- The platform can be used for **comparison of soft versus rigid vibrotactile displays for perceptual tasks**.
- Further experimental evaluation allows understanding of how different pneumatactor **stiffnesses affect perception** due to mechanical impedance differences between human skin and tactile displays.
- Adding **closed-loop pressure control** will enable combined specific pressure inflation and frequency-based activation.
- Assessment of **array scalability** and **resolution**.
- Reduction of hardware requirements, cost, and sound.

Acknowledgements

We thank Shaopeng "Jaspor" Jiang and Dr. Axel Krieger from the IMERSE Lab at Johns Hopkins University for their pivotal role in the SLA manufacturing process of the pneumatactors.