Invention ID:	D18872			
Title:	**Fused Deposition Modeled Pneumatic Devices for Delivering Co-located Tactile Stimuli to Fast and Slow Adapting Skin Mechanoreceptors**			
Technology ID:			Type:	**-JHU Invention Disclosure**
Submitted By:	**Anway Pimpalkar**		Updated Date:	**4/9/2025**
Stage:	**Draft**		Status:	**None**

Invention Disclosure

Provide a detailed description of the technology and what it does. (Required)
If necessary, upload any supporting information in the "Documents" section.

The developed technology is a soft, wearable haptic actuator system designed to deliver co-located multimodal tactile feedback through both vibration and pressure. Most commercially available haptic devices rely exclusively on high-frequency mechanical vibrations, targeting fast-adapting (FA) mechanoreceptors. However, effective tactile communication also requires stimulation of slow-adapting (SA) mechanoreceptors, which detect sustained pressure and force. Research increasingly supports the importance of co-located activation of both FA and SA afferents in achieving naturalistic and perceptually meaningful feedback. This invention directly addresses that need.

We developed pneumatactors: soft, 3D-printed pneumatic tactors that simultaneously engage FA and SA mechanoreceptors by synchronizing vibrational and pressure-based stimuli. Each pneumatactor is powered by a pneumatic air source and controlled through fast-gating, silent three-way valves that rapidly modulate airflow. This enables the actuator to oscillate at frequencies up to 147 Hz while delivering up to 3.3 kPa of localized pressure to the skin. The result is a unified, co-located haptic cue that mimics the richness of natural touch far beyond what vibration-only devices can achieve. Each device also includes integrated pressure sensing, enabling closed-loop control or bidirectional communication.

The pneumatactors are fabricated using fused deposition modeling (FDM) 3D printing, making them low-cost, rapidly customizable, and easily produced using widely available desktop printers. This opens the door to mass production and global scalability, especially as FDM becomes more accessible in research, clinical, and maker settings. Their soft and flexible design closely matches the mechanical impedance of human skin, enhancing comfort and wearability for long-term use.

The system has been implemented in both desktop-integrated and wireless battery-powered versions, including mobile app control for flexibility across experimental, therapeutic, and interactive use cases. Applications span stroke rehabilitation, prosthetic sensory feedback, immersive VR/AR interfaces, and assistive communication systems. Follow-up psychophysical studies are underway to further characterize the perceptual and functional benefits of this multimodal feedback approach.

Have you previously disclosed or do you plan to disclose this invention to a third party? (Required)

Yes

What is the date of the public disclosure?

4/7/2025

Provide the Primary JHU Inventor's name and primary department. Please list one person only. (Required)

Anway Pimpalkar

If different than above, which inventor should be the main contact person for this invention?

Was this invention or material developed within a specific JHU center or institute? If yes, provide the name.

Biological Material

Does this invention include biological material? (Required)

No

Software

Does this disclosed technology contain any software? (Required)

Yes

Was this software coded by a third party?

No

Does this disclosed technology contain open source software or a publicly available database?

Yes

Source(s):

Arduino

Is the software an improvement of an existing software?

No

Select the best descriptor for the stage of the software development.

Prototype

Sponsorship

Was any form of sponsorship or funding used in the development of this technology? (federal, commercial, university or other)
If "Yes", select the name of the funding institution and provide the grant or contract number in the Funding Section below.

Yes

Funding

Funding

Grant / Contract No	Title	Granted Date	Funding Institution	Internal ID
1207350850	Johns Hopkins - Jeremy D. Brown Discretionary Funds		Johns Hopkins University	1207350850
80038899	Johns Hopkins Mechanical Engineering Haptic Interface Design for Human-Robot Interaction Class Fund		Johns Hopkins University	80038899
90098744	NSF CAREER		National Science Foundation	90098744

Commercialization

What problem does this invention solve? What product do you envision this Invention being developed into? (Required)

This invention addresses the need for compact, wearable systems capable of delivering naturalistic tactile feedback to the skin. Existing haptic technologies are often limited to vibration-based actuation, which primarily stimulates a narrow range of mechanoreceptors and fails to convey the richness of real-world touch sensations such as pressure, stretch, or sustained force. These limitations reduce the effectiveness of haptic feedback in applications that require fine motor control, perceptual grounding, or intuitive sensory reinforcement.

Our invention, pneumatactors, solves the limitation of current haptic systems that rely solely on vibration by introducing a wearable actuator that delivers co-located pressure and vibration stimuli, engaging a broader spectrum of tactile receptors.

This technology can be developed into a wide range of products across healthcare, consumer technology, and human-computer interaction. It has potential use in wearable rehabilitation systems for stroke and neurological injury, sensory feedback modules for upper-limb prosthetics, tactile displays for assistive communication, and haptic feedback solutions for virtual and augmented reality interfaces. Its modularity, low power consumption, and compatibility with scalable fabrication techniques such as FDM 3D printing make it suitable for both high-performance applications and affordable, widely deployable devices.

What is the size of the unmet need? (Required)

The AR/VR market is projected to exceed $450B by 2030, with growing demand for immersive, tactile experiences. Over 94M people live with stroke-related impairments, and 2M+ in the U.S. live with limb loss who could use for rehabilitation, prosthetics

Is this a marginal or ground-breaking improvement to current technology? What makes this Invention unique vs other available products? (Required)

This invention represents a ground-breaking advancement in haptic technology by introducing a soft, co-located pneumatic actuator that delivers pressure-based feedback, a tactile modality rarely addressed by conventional vibration-based systems. What makes this invention especially unique is its compatibility with fused deposition modeling (FDM) 3D printing using thermoplastic polyurethane (TPU), a flexible, biocompatible material with excellent elasticity and fatigue resistance. TPU's ability to form airtight, deformable chambers directly on consumer-grade FDM printers enables rapid, low-cost fabrication without the need for post-processing or multi-material systems. Because pneumatactors can be mass-produced using widely available desktop printers and standard TPU filaments, this technology offers a scalable, customizable, and democratized approach to delivering high-quality tactile feedback across clinical, research, and consumer applications.

What type of company might license this technology (also name any specific target companies)? (Required)
(i.e. Diagnostic, Therapeutic, Research tool, Medical device)

This technology may be licensed by companies developing wearable haptic interfaces, immersive systems for virtual and augmented reality, neurorehabilitation tools, or prosthetics. It is particularly well-suited for companies aiming to deliver rich, spatially targeted tactile feedback that goes beyond vibration-based solutions.

Potential licensees include major players in the VR/AR space such as Meta (Reality Labs), Apple (Vision Pro), Sony (PlayStation VR), Microsoft (HoloLens), Google (ARCore), and Snap Inc., as well as haptics-focused companies like HaptX, Ultraleap, bHaptics, and Teslasuit. Other targets include neurotech and rehabilitation firms such as Neofect, Ekso Bionics, Psyonic, and SRI International, etc.

Who would be the end-user of a product using this invention? (Required)

VR/AR users, gamers, robotics operators, wearable tech users, telepresence system users, human-computer interaction designers, researchers, educators, stroke survivors, prosthesis users, individuals with sensory or motor impairments

How much funding has been invested in the invention to-date? (Required)

Approximately $1000 - $1300

What is the current stage of development and what further work is required, if any, to make this technology a candidate for commercialization or corporate partnership? (Required)

The technology is currently at an advanced prototype stage, with fully functional pneumatactors demonstrated in both desktop-integrated and wireless, app-controlled formats. Initial results have been presented at the 2024 IEEE Haptics Symposium, and psychophysical studies are underway to characterize perceptual and functional benefits. To move toward commercialization, the next steps include refining durability for long-term use, integrating scalable pneumatic control hardware, and conducting user studies in applied contexts such as VR/AR interaction and rehabilitation.

Inventors

Inventors

First Name	MI	Last Name	Email	Significance	Contribution	Working For Company	Working For Department
Anway	Sudhir	Pimpalkar	apimpal1@jh.edu	1	60.00 %	Johns Hopkins University	Biomedical Engineering WSE
Jeremy		Brown	jdelainebrown@jhu.edu	2	20.00 %	Johns Hopkins University	Mechanical Engineering WSE
Preshit		Ameta	pameta229@gmail.com	3	10.00 %	Johns Hopkins University	Mechanical Engineering WSE
Ahan	Kamal	Dalia	daliaahan@gmail.com	4	7.00 %	Johns Hopkins University	Mechanical Engineering WSE
Jiaxi		Zhang	denniszg331@gmail.com	5	3.00 %	Johns Hopkins University	Mechanical Engineering WSE

Documents

Documents

File Name	Created By	Date Created
Figure_PneumatactorsOverall.png	Anway Pimpalkar	4/9/2025
Pimpalkar2024_HS2024_WIP.pdf	Anway Pimpalkar	4/9/2025

Remarks

Remarks

By	Comment	Date Added
Anway Pimpalkar	The work presented at the IEEE Haptics Symposium 2024 included a short Work-in-Progress paper (attached) and a live demonstration of the pneumatactors at the venue.	4/9/2025
Anway Pimpalkar	This project began as a class assignment in Dr. Jeremy Brown's Haptic Interface Design course and evolved into a peer-reviewed publication at the IEEE Haptics Symposium 2024. It was further developed by Anway Pimpalkar as part of his master's research in Dr. Brown's lab and is now advancing toward experimental studies building on the initial design.	4/9/2025

Patents

Agreements

Inventor Details

Prefix	First Name	MI	Last Name	Suffix	Address	City	State	Zipcode	Country	Citizenship
Mr.	Anway	Sudhir	Pimpalkar		3501 Saint Paul St Apt 1112	Baltimore	MD	21218	United States	United States
Dr.	Jeremy		Brown	PhD	210 Spencers Way	Lutherville Timonium	MD	21093	United States	United States
	Preshit		Ameta		3400 N. Charles Street	Baltimore	MD	21218	United States	
	Ahan	Kamal	Dalia		3400 N. Charles Street	Baltimore	MD	21218	United States	
	Jiaxi		Zhang		3400 N. Charles St.	Baltimore	MD	21218	United States	

JHU INVENTOR CERTIFICATION and ASSIGNMENT

If you have questions about this email, please contact Tina Preston at tpreston26@jhu.edu

This section is completed by those JHU personnel subject to The Johns Hopkins University Intellectual Property Policy. Students may or may not be subject.

● I/we, the Inventors, hereby certify that the information set forth in this Report of Invention is true and complete to the best of my/our knowledge.
● I/we, the Inventors, hereby certify that I/we will promptly advise JHTV of any commercial interest regarding the Invention described herein.
● I/we, the Inventor(s), subject to The Johns Hopkins University Intellectual Property Policy and not under an obligation to assign intellectual property rights to another party, hereby affirm that in consideration for The Johns Hopkins University's evaluation of commercial potential and a share of income which I/we may receive upon commercialization of my/our Invention, on the date of my/our signature(s) as indicated below do hereby assign and transfer my/our entire right, title and interest in and to the Invention described herein unto The Johns Hopkins University, its successors, legal representatives and assigns.

I hereby agree and affix my typewritten signature with the intent to sign this Report of Invention form and to convey title to the described intellectual property.

Not signed yet

Anway Sudhir Pimpalkar (Lead Inventor 60.00 %) Date

Not signed yet

Jeremy Brown (Co-Inventor 20.00 %) Date

Not signed yet

Preshit Ameta (Co-Inventor 10.00 %) Date

Not signed yet

Ahan Kamal Dalia (Co-Inventor 7.00 %) Date

Not signed yet

Jiaxi Zhang (Co-Inventor 3.00 %) Date