Tactile interface for augmented reality to enhance communication

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Abstract
At Somatic Labs, we develop technologies that use the sense of touch as a reliable method of communication. We have developed a platform, Zorb, that communicates real-time information as sensations felt on a user's skin. Our hardware reference design can be configured to deliver high-resolution haptic feedback into form factors that best fit the needs of the end-user. Our software suite allows any third-party developer to easily integrate sensors and deliver real-time alerts and instructions through custom haptic patterns. We propose integrating our platform with existing communication channels to provide tactile alerts and instructions that notify a firefighter of environmental risks, provide proximity updates for firefighter pairs inside a building, and assist in indoor wayfinding. We will embed our technology into the SCBA face pieces to provide firefighters high-resolution haptic feedback needed to respond quickly to real-time information. Unlike other products on the market, our tactile interface does not impede or overload already stimulated visual or auditory input channels. We provide an unobtrusive, hands-free AR solution that integrates with thermal imaging and gas sensors to allow a first responder to "feel" heat differentials and environmental conditions while staying focused on given assignments. Tactile directional cues will assist with indoor wayfinding and provide radial proximity updates to first responder teams inside a building.

Project Description

Problem
Responding to a burning building poses unique challenges for communication and navigation. Building infrastructure often disrupts wireless communication channels, such as WiFi and Bluetooth, and makes communication of real-time navigation instructions difficult between a fire chief and crew members. Personal protective equipment limits a firefighter's ability to use additional communication accessories, such as handheld sensors, radios, or smartphones, as gloves impact grasping movements. Firefighters need a new method of conveying information to ensure clear communication while on duty, but current systems for virtual and augmented reality focus on two modalities that are already overloaded: hearing and vision. We propose a communication system built on the human sense of touch as a solution to these challenges.

At Somatic Labs, we develop technologies that use the sense of touch as a reliable channel of communication. We have developed a full-stack platform (software and hardware) that enables rich tactile effects that move across a user's skin and create unique sensations that convey both spatial and symbolic information. Because our system provides haptic communication, we can enable firefighters to efficiently communicate and maintain situational awareness when their environmental surroundings demand their visual and auditory attention. Instead of merely supplementing visual and auditory reality, we want to integrate our platform with existing communication systems to include more than two senses. We propose using the human sense of touch to augment a firefighter's situational awareness and perception of information.

Proposed Solution
We have created the most versatile development and creation tools available on the market for haptic feedback, a system known as the Zorb Design Studio. Our software and hardware system enables the rapid creation of high resolution tactile patterns consisting of pulses, shapes, directions, and complex illusions of motion delivered to the surface of a user's skin. Our platform, Zorb, can improve any communication task for first responders that work in hazardous environments by relaying alerts, directions, or proximity through a non-intrusive, silent tactile interface.

Our design is modular at each level of the platform stack to allow for easy integration into existing communication channels and products. Our hardware reference design delivers haptic feedback to the user through an array of linear resonant actuators and we have embodied it in a wide variety of form factors, including a wrist-band, baseball hat, and hard hat. Our software can be adapted to fit the particular needs of first responders. The haptic feedback we provide can be easily manipulated and customized using our software, allowing commands, instructions, and real-time sensor data to be conveyed through touch. Our software is designed to allow third party developers to programmatically modify the tactile feedback provided to an end-user and provide a platform that supports future integration of new apps and platforms as IoT solutions evolve. We can easily add sensors already in use — including ones used in SCBA equipment, gas detection meters, and thermal imaging cameras — to provide firefighters with vibrotactile, real-time updates on environmental metrics, such as: temperature and oxygen levels of a room, presence of toxic gases, remaining oxygen level in a firefighter's tank, and changes in differential heat. Our platform's ability to reprogram a user's sense of touch provides an

additional modality for information, with the potential to reduce user error, improve reliability, and reduce the occurrences of communication failures. We propose integrating our platform with existing communication systems used by first responders to provide an augmented reality solution that addresses current challenges. The implementation of our embedded haptic design has three specific aims: (1) notify a firefighter of environmental risks, (2) allow a fire chief to know the location of crew members inside a building, and (3) provide proximity updates regarding firefighter pairs inside a building. We will embed our hardware into the edging of Scott SCBA's that firefighters already wear as a component of their protective equipment. Firefighters will be able to receive high-resolution haptic feedback and be able to respond quickly to real-time information.

Once the hardware is embedded, we will use our software to integrate with the sensor used to alert a firefighter of how much oxygen remains in the tank and create a custom tactile notification for low oxygen levels. Similarly, we will create unique vibrotactile patterns that inform a firefighter when the temperature of a room has gone above a certain threshold, when the oxygen level of a room has become dangerously low, and when toxic gases such as carbon monoxide and hydrogen sulfide are present. Our embedded design will also enhance indoor navigational and wayfinding techniques needed to ensure firefighter safety. Our hardware has a built-in inertial measurement unit (IMU) — composed of an accelerometer, gyroscope, and magnometer — that can be used for inertial navigation tracking. Inertial navigation tracking allows a fire chief coordinating logistics on the outside of a building to know the location of the crew inside and also supports indoor wayfinding and navigation. Lastly, to improve communication between firefighter teams inside a building, we can program the SCBA hardware to recognize another respirator mask and create proximity alerts that occur if two team members are separated by more than a given radius. The vibrotactile proximity alerts ensure that crew members remain in pairs while inside a building and can alert a firefighter if a partner needs help.

Unlike any other products on the market, we provide enhanced communication and situational awareness without requiring a user's hearing or vision. Our tactile interface does not impede or overload already stimulated visual or auditory input channels. By embedding our technology into a firefighter's face mask, we deliver critical, real-time information to firefighters and allow firefighters to maintain high work performance. Our solution permits full-range visibility in the face mask and provides hands-free situational awareness. Additionally, the embedded design uses a form factor that firefighters are already familiar with and does not add extra equipment that would impact the one minute firefighters have to don protective gear.

Current Technologies

Current state-of-the-art VR technologies used for first responders are typically designed for training simulations only. VR products such as Flaim Trainer and Ludus can create scenarios for firefighters to practice response techniques and protocols at a lower safety risk. VR offers an invaluable opportunity for firefighters to prepare for a variety of situations, but current platforms are limited by headset bulkiness, high-costs, and low durability that decrease real-life operation efficacy. The VR headsets are not easily integrated with required protective gear, (i.e. SCBA masks) and VR controllers do not easily transfer to real-life situations where firefighters need hands-free technologies. The haptic feedback used in Flaim's VR simulations demonstrates the

effectiveness of using tactile feedback to communicate information, but has not been developed as an augmented reality tool for feedback in real-life operations. AR technologies with direct applicability to firefighters are thermal imaging devices. Several companies, including Scott Sight and Halo Thermal Imaging, have created a thermal imaging camera that fits into the SCBA mask worn by firefighters or is a handheld device. While thermal imaging is a powerful tool for helping firefighters assess a given situation, these AR displays and handsets still limit a first responder's abilities. Because thermal imaging actively requires vision to navigate, this AR implementation burdens an already overloaded sensory input as firefighters rely heavily on sight and hearing to complete tasks. Additionally, protective gloves and the need to move debris makes using handheld thermal cameras a less effective AR technology for firefighters.

Our solution is equipped to address the limitations of integration readiness, real-time operation effectiveness, and overloaded sensory input. The modular design of our system allows for easy adaptation and integration of existing systems, and provides a tighter feedback loop to make any desired user interface modifications. Embedding our hardware into the SCBA mask already worn by firefighters lowers implementation cost and increases adoption rate as the face mask is a familiar form factor. Our solution is also unobtrusive and hands-free. Once turned on, our software notifies a firefighter of real-time information without the use of external buttons or toggles, and allows the primary focus of a firefighter to remain on environmental hazards. Lastly, we recognize the value of thermal imaging cameras to help firefighters see through smoky rooms. In order to make thermal imaging less intrusive, we will also integrate thermal imaging cameras as part of our solution. Our system will process thermal imaging data as an input and use haptic feedback to allow firefighters to "feel" the heat gradient of a room.

Performance Metrics

With our solution, we envision a system that can work in any building for a team of firefighters that will (1) enable efficient navigation of indoor spaces based on intuitive tactile directions, (2) allow fire chiefs to know where crew members are inside of a building, (3) provide real-time data of environmental hazards based on integrated sensor data.

Our platform's baseline capability includes the following functions: (1) the platform is able to deliver haptic feedback to a device using Bluetooth connection for a range of 300 feet, (2) the software is able to integrate with external sensors (gas and temperature) to provide haptic alerts via embedded hardware for changing environmental conditions, (3) the hardware can provide position information about a person's location based upon a known entry point using the built-in inertial measurement unit, and (4) the embedded design is sweat-proof.

Project performance metrics focus on decreasing response latency to real-time data and enabling faster navigation through a building. At the end of the project, we expect the following metrics to be accomplished: (1) a series of vibrotactile patterns that correspond to sensor and proximity alerts and are easily understood by the wearer, (2) comfortable, fire-proof embedded design, (3) reliable connection between fire chief and firefighters inside a building using inertial navigation, (4) faster response time for reacting to environmental conditions and team needs. For the duration of the NIST challenge and simulation, we will conduct verification interim metrics using Bluetooth, but we recognize Bluetooth is not optimal for wireless communication. Once we have demonstrated the efficacy of our solution, we will work on the integration into

firefighters' existing communication systems (i.e. radio) over a longer timeframe. Additionally, we will also work to ensure our embedded design meets compliance standards outlined by the National Fire Protection Association and National Institute for Occupational Safety and Health for SCBA systems.

Our technology is ready for pilot testing. We have already developed the hardware and software needed to implement our proposed solution. We have already produced and sold 200 units of our hardware reference design, and de-risked our supply chain in the process. We will configure our hardware reference design to fit the inside of a Scott SCBA face-piece. After embedding the hardware, we will assign vibrotactile patterns to correspond to specific sensor data and the alerts and instructions commonly utilized by firefighter crew members. Our library of over 100 haptic patterns was created using our proprietary software engine. The haptic patterns were designed based on extensive user feedback and research into an individual's ability to perceive tactile cues.

We will conduct pilot tests with firefighters affiliated with the NIST challenge and within local Phoenix fire department stations to meet our end performance metrics between Stage 1 and Stage 2. The specific interim metrics our pilot test will measure are pattern recognition rates, increased situational awareness, wayfinding speed, and response latency. To measure wayfinding speed and response latency to alerts, we will conduct pre and post tests to quantify how much time our solution saves, in comparison to traditional equipment, for evacuating a room and exiting a building. We will also measure pattern recognition rate accuracy by tracking if a firefighter had an appropriate response to a vibrotactile alert. Participating firefighters will be asked to complete a survey before and after using our solution to measure an individual's perceived situational awareness. Survey results combined with response latency and pattern recognition will be used to demonstrate the efficacy of our solution.

Team Resume Information

As a startup company, we are poised for rapid growth and can execute projects quickly. Within 11 months, we were able to progress from a breadboard prototype to a manufacturable at scale product to create and sell our wrist-band reference device. All of our hardware, firmware, and software used to create Zorb and the Zorb Design Studio was developed during this time span. Our team of four has over 20 years of combined experience starting companies, conducting cutting-edge research, developing new technologies, and validating products with customers.

Shantanu Bala

Shantanu Bala, CEO and co-founder of Somatic Labs, spent eight years conducting haptics research at the Center for Cognitive Ubiquitous Computing at Arizona State University (ASU) and as a Thiel Fellow. He built devices that transformed video into touch, allowing a blind person to see through vibrations on their hand, which resulted in over nine peer-reviewed publications. Shantanu leveraged his domain expertise in haptics to come up with the concept Zorb after graduating and working on a previous startup company. Shantanu holds bachelor's degrees in both computer science and psychology from ASU.

Experience

2014 - Present	Co-Founder and CEO, Somatic Technologies, Inc.
2009 - 2014	Undergraduate Researcher, Center for Cognitive Ubiquitous Computing
2012 - 2014	Founder, Ebook Glue

Products

Bala, S. (2017). Wearable Device That Indicates the Passage of Time as a Tactile Sensation Moving across the Surface of a Person's Skin, *U.S. Patent No. 9,552,707 B1,* Washington, D.C.: U.S. Patent and Trademark Office.

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Bala, S., Ramesh V., Krishna, S., & Panchanathan, S. (2010). Dyadic Interaction Assistant for Tracking Head Gestures and Facial Expressions. *Center for Cognitive Ubiquitous Computing (CUbiC).* Retrieved from ieeexplore.ieee.org/document/5623964/.

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Krishna, S., Bala, S., & Panchanathan, S. (2010). Exploring the Dorsal Surface of the Fingers for Visuo-Haptic Sensory Substitution. *Center for Cognitive Ubiquitous Computing (CUbiC).* Retrieved from ieeexplore.ieee.org/document/5623974/.

McDaniel, T., Goldberg, M., Bala, S., Fakhri, B., & Panchanathan, S. (2012). Vibrotactile Feedback of Motor Performance Errors for Enhancing Motor Learning. *MM'12 Proceedings of*

the 20th ACM Internaytional Conference on Mulitmedia, (pp. 419-428). ISBN: 978-1-4503-1089-5, doi>10.1145/2393347.2393408

McDaniel T., Bala S., Rosenthal J., Tadayon R., Tadayon A., & Panchanathan S. (2014). Affective Haptics for Enhancing Access to Social Interactions for Individuals Who are Blind. *International Conference on Universal Access in Human-Computer Interaction.* DOI: 10.1007/978-3-319-07437-5_40

Jake Rockland

Jacob Rockland, CPO and co-founder of Somatic Labs, previously founded KorkBoard, a digital event bulletin for college campuses. KorkBoard connected students to events on three college campuses—The University of Arizona, Clemson University, and Sciences Po. Jacob previously developed calibration/testing software and firmware for Spectral Instruments, and brings expertise to the team in user experience design. He will receive a bachelor's degree in computer science from the University of Arizona.

Experience

2016 - Present	Co-Founder and CPO, Somatic Technologies, Inc.
2015 - 2016	Co-Founder, KorkBoard
2014 - 2015	Software Developer, Ebook Glue
2014 - 2015	Engineering Intern, Spectral Instruments

Products

Bala, S., Karpur, J., & Rockland, J. (2017). Spatio-Temporally Organized Haptic Communication System and Method. *U.S. Patent Applied for,* Washington, D.C.: U.S. Patent and Trademark Office.

Ajay Karpur

Ajay Karpur, CTO and co-founder of Somatic Labs, has over five years of experience conducting research in signal processing, electrophysiology, and computational neuroscience. He also developed a haptic interface for a sports training and rehabilitation system while at the Center for Cognitive Ubiquitous Computing, and previously worked at a startup. He holds a bachelor's degree in electrical engineering from ASU.

Experience

2016 - Present	Co-Founder and CTO, Somatic Technologies, Inc.
2015 - 2016	Research Assistant, Arizona State University
2013 - 2014	Software Developer, Ebook Glue
2013 - 2014	Research Assistant, Neural Microsystems Laboratory

Products

Bala, S., Karpur, A., & Rockland, J. (2017). Spatio-Temporally Organized Haptic Communication System and Method. *U.S. Patent Applied for* Washington, D.C.: U.S. Patent and Trademark Office.

Monaghan, D., Honohan, F., Ahmadi, A., McDaniel, T., Tadayon, R., Karpur, A., Panchanathan, S. (2016). A Multimodal Gamified Platform for Real-Time User Feedback in Sports Performance. *MM ' 16 Proceedings of the 2016 ACM on Multimedia Conference, (*pp. 708-710). ISBN: 978-1-4503-3603-1, doi>10.1145/2964284.2973815
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Meilin Ossanna

Meilin Ossanna, the business development lead for Somatic Labs, has two years of experience conducting neuroscience research while attending ASU. She brings expertise in product development and validation from working at Pinnacle Transplant Technologies and EndoVantage. She has a Bachelor's degree in biomedical engineering from ASU.

Experience

5/2017 - Present	Business Development, Somatic Technologies, Inc.
2015 - 2017	Researcher, Human Mobility Lab at Arizona State University
1/2017 - 5/2017	Biomedical Intern at EndoVantage, LLC
5/2016 - 8/2016	Product and Process Development, Pinnacle Transplant Technologies

Products

Ossanna, M., Schaefer, S.Y., Honeycutt, C.F. (2017). Startle evokes nearly identical movements in two-dimensional, multi-jointed reaching tasks. *Poster session presented at Society for Neuroscience November 11-15, 2017.*

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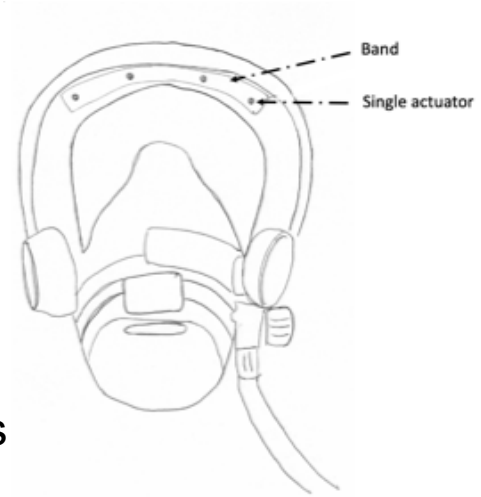
Somatic Labs

Project Summary

We have developed a platform that communicates real-time information as sensations felt on a user's skin. The integration of our platform with existing communication channels will provide tactile alerts and instructions that notify a firefighter of environmental risks, provide proximity updates for firefighter pairs inside a building, and assist in indoor wayfinding. We will embed our technology into the SCBA face pieces to provide firefighters high-resolution haptic feedback needed to respond quickly to real-time information.

Concept Sketch

- Array of four actuators encapsulated in band
- Band embedded into the top lining of SCBA face piece
- Implementation will configure band on the inside of the SCBA face piece for actuators to make contact with the skin



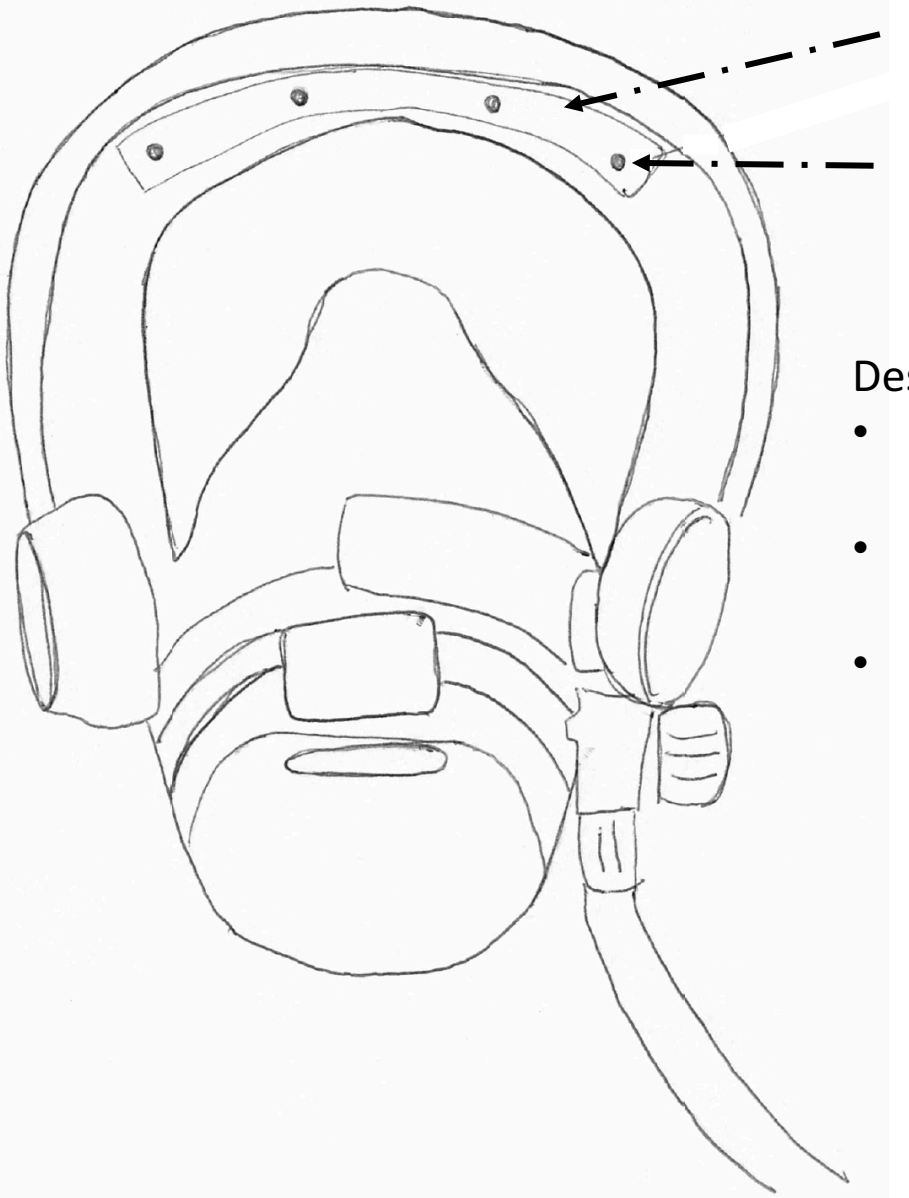
Participant Summary

Shantanu Bala, CEO and co-founder, has spent eight years conducting haptics research at Arizona State Univ. and as a Thiel Fellow. His expertise in haptics led to the development of our platform. Ajay Karpur, CTO and co-founder, has research experience in signal processing and haptic interfaces. Jacob Rockland, CPO and co-founder, has expertise in software development and user experience design. Meilin Ossanna, business development, has experience in product development and validation.

Technical Outcome

Our tactile interface does not impede or overload already stimulated visual or auditory input channels. We provide an unobtrusive, hands-free AR solution that integrates with thermal imaging and gas sensors to allow a first responder to "feel" heat differentials and environmental conditions while staying focused on given assignments. Tactile directional cues assist with indoor wayfinding and known proximity to fellow crew members inside a building.

SCBA Face Piece with Embedded Design



Design Concept

- Array of four actuators encapsulated in band
- Band embedded into the top lining of SCBA face piece
- Implementation will configure band on the inside of the SCBA face piece for actuators to make contact with the skin