Ultrasound on a Chip Brings Medical Imaging to the iPhone

Ultrasound machines are crucial but arduous devices that play an important role in the medical technology space.

These large carts possess big computers along with multiple probes and transducers that get pushed around hospitals. Each transducer is built with small piezoelectric crystals that vibrate to emit sounds, receive an echo, and then form an image of a baby in development or other abnormalities located close to the surface like a clogged artery, vein, or abscess.

But there is an additional layer of complexity for these apparatuses when it comes to delivering an overview of an imaged area or identifying certain conditions, according to *Wired*.

Every crystal needs to be individually wired together and then have cables that are attached to a separate machine for processing. Next, the crystals need to be tuned in order to produce the desired type of ultrasonic wave for imaging at a certain depth. In addition, separate probes are needed for the heart, stomach, uterus and other areas.

However, a startup has created a unique device that can bypass these limitations.
Butterfly Network created a device called the iQ. It’s a compact, inexpensive ultrasound tool that hooks into the lighting jack of an iPhone.

“What we’ve done is we’ve engineered these ultrasound machines onto a chip and we’ve given it very broad acoustic bandwidth,” said Matt Dejonge, head of product development for Butterfly Network, in an interview with R&D Magazine.

The acoustic transducer is infused with thousands of little drums, each one the size of a human hair, which sits on the custom chip developed by the company. Butterfly’s team of engineers were able to integrate all of the functions of the large computers built into traditional ultrasound machines within that component.

Piezoelectric crystals are only good at a very narrow bandwidth of sound, but this specialized chip means Butterfly’s invention can span the entire range of ultrasound applications with just one transducer.

**Market applications**

Emergency medicine is one of the core markets the company is targeting with its device, said Dejonge.

“Emergency medicine has embraced what the industry has come to call point-of-care ultrasound. So it’s this idea of using ultrasound almost as part of the physical examination.”

Imagine a scenario where an individual gets in a serious car accident.

Typical ultrasound machines would be used to peek inside the body when the patient arrives in the emergency room to determine if there is internal bleeding. Next, physicians could send the patient off to receive a CT scan, which could require the patient to wait a long time and involves a very high dose of radiation. It would also take additional time to interpret the results from a CT scan.

Furthermore, a doctor may have to perform something called a guided procedure, where they need to make sure they are putting the large needle in the correct area to drain that fluid. This procedure has very high complication rates associated with it because the needles that are placed in the internal jugular vein could accidentally get placed in the carotid artery.

“It’s a lot like a battle field in the sense that these physicians are short-staffed, they’re caring for a lot of different patients at once and are lucky if the emergency department even owned an ultrasound sound machine,” continued Dejonge.

Essentially, having Butterfly’s ultrasound device of its size and breadth would give doctors the ability to get the answers for diagnosis right at the point-of-care, therefore optimizing their decisions for treatment of their patient population.

They could either put the probe down on the patient, look inside the body, and see if there’s internal bleeding or place the transducer on the individual’s body to gain more specific insight into where the needle needs to be placed to remove an obstruction.

**Better education**

An artificial intelligence application will be built into iQ to enhance the device’s hardware capabilities, which Dejonge noted will be split into two steps: acquisition assistance and automated interpretation.

“You’ve got to really be able to position that probe in just the right way to get the anatomy of interest on screen in a high quality way with the added step of being able to interpret what you are looking at.”

To achieve the acquisition assistance step, the team’s software is being infused with deep learning neural networks which tell the user in real-time how to position the probe on the body. In this setup arrows will be drawn on the screen, providing a path to the designated target through the cameras that are part of the iPhone. A checkmark will appear on screen to alert the user that they have arrived at the right spot.

Automated interpretation would be a process where the software measures the anatomy and delivers feedback regarding what the user is looking at.

**FDA approval and updates**
The company recently received clearance from the Food and Drug Administration for 13 different clinical use cases, including fetal, abdominal, cardiac, gynecological, urological, and pediatric use cases.

The A.I. update is expected to arrive via an upgrade issued in 2018. Dejonge feels this device has a couple of advantages that could make it popular among the healthcare practitioner community.

“We can manufacture these life-saving ultrasound devices in the same way that you would manufacture all the chips in your iPhone in many cases, at the same factories, using the same technique. We run these chips through hundreds of processes as well and at the end we get a life-saving high-performance ultrasound,” he noted.

Essentially, this keeps costs low because the transducer gets built at an incredibly low price of under 2,000 dollars. It can see in inside the entire body and can be carried around inside the physician’s pocket.

These tools are expected to start shipping in 2018.
How Spider Silk Could Help Enhance Hearing Aids

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An unconventional material could be the key to improving an important piece of assistive technology.

Researchers from Binghamton University found that fine fibers like spider silk could boost the quality of microphones built into hearing aids.

Hearing aids are built with three basic parts: a microphone, amplifier, and speaker. The device receives sound through a microphone transforms the sound waves to electrical signals and sends them to an amplifier. The amplifier boosts the power of the signals and then sends them to the ear through a speaker, according to the National Institute on Deafness and Other Communication Disorders.

Almost all of these devices have two microphones built into them, but users can encounter difficulties when they are in a crowded area since competing conversations can drown out the conversation they are trying to hear due to difficulties of processing different sounds.
However, this experiment could provide a way to solve that conundrum.

Ron Miles, a co-author of this study and mechanical engineering professor at the university specializing in vibrations, acoustics, and other areas, answered a few questions in an interview with R&D Magazine regarding the inspiration for this research and how it could lead to enhancements for these important medical devices.

**R&D Magazine: Where did the idea for this experiment come from?**

**Miles:** "The idea came from previous work studying hearing in small animals. Many animals have ear drums like we do where they process sound based on pressure, but most animals, including lots of insects, can sense the motion of air in a sound field via very fine hairs. Using a fiber to sense sound is something I've been interested in for a very long time especially seeing how the fiber moves within a sound field."

**R&D Magazine: Why did you explore how this silk could improve the microphones built into hearing aids?**

**Miles:** A significant issue with hearing aids is when the user is in a noisy place so competing conversations can drown out the conversation you are trying to hear.

Virtually all hearing aids are built with two microphones. Both mics detect the difference between the pressures and the hearing aid processes that sound to get rid of unwanted noises. However, the wavelength of sound depends on its frequency so at low frequencies (long wavelengths), the difference signal picked up by the two mics is much smaller than it is at higher frequencies. As a result, the signal being processed sounds bad, making the hearing aid less effective at eliminating unwanted noises.

Basically, you need a directional microphone that can process these signals with really good fidelity to eliminate that background noise.

**R&D Magazine: Walk me through how the experiment was performed.**

**Miles:** We used natural spider silk that came from a common spider that occurs in the northeast. It was the easiest material we could get. Originally, we tried thicker materials like wire as well as a PMMA material like plastic that was spun into a very fine fiber. It agreed with our analytical models and everything, but it was very easy to break.

The spider silk was coated in gold that was about 80 nanometers thick. We placed the fiber in an anechoic chamber, which is a very quiet room with no reflection from the walls.

We had the fiber positioned three feet away or so from a loudspeaker placed in the chamber to create a sound field. The fiber was oriented perpendicular to the sound the speaker was creating.

A magnet was placed next to the fiber and we used an amplifier to measure voltage across the two ends of the wire.

We also used a laser vibrometer to measure the small vibrations of the fiber which helped us verify our mathematical model.

**R&D Magazine: What was the significance of these findings?**

**Miles:** The silk was able to deliver an extremely broadband uniform response. We showed it was directional even when picking up really low frequencies all the way down to 3 Hertz.

**R&D Magazine: What is the next step in this research?**

**Miles:** The basic idea of this was to show that it is effective, but there's a lot of work that needs to be done. Engineering this application into future products would mean the fiber would need to be made out of a man-made fiber such as carbon nanotubes similar to graphene. The most important thing would be to have a fiber that is very thin. Less than a micron in diameter could be a really excellent sensor for sound.
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Imagine waking up to excruciating pain in either your face or neck. The discomfort can vary in intensity, but symptoms like nausea and sensitivity to light and sound can impair mobility and basic functioning.

This is what it could feel like to have migraines, a debilitating condition that, currently, has no cure.
However, there are some promising treatments in the pipeline. Pharmaceutical companies like Eli Lilly, Amgen and Allergan are racing to develop monoclonal antibody treatments targeting a protein called the calcitonin gene-related peptide (CGRP). This small protein can widen blood vessels and helps transmit pain signals throughout the body, according to The Verge. These experimental drugs are being designed to essentially block the function of CGRP.

Right now, preventative measures are the most effective way for patients to manage migraines. One company is offering a piece of technology that does just that, by alerting patients as to when they are most likely to experience a migraine episode.

The mobile application is called Migraine Alert, and was released by Second Opinion Health, a company based in Mountain View, California.

The company’s chief executive officer is Simon Bloch, who previously worked at Samsung Electronics on mobile technologies and wearables. It was there he conceived the idea of using these tools to assist people with migraines in conjunction with current chief technology officer Jitendra Kulkarni.

“Basically, what we do as a company is use artificial intelligence and machine learning technologies to help people manage their chronic diseases,” said Bloch in an interview with R&D Magazine.

The app is intended for patients diagnosed with intermittent migraines, which is defined as those who experience four to 14 episodes a month.

Migraine Alert works by using machine learning to collect and analyze triggers that correlate with the onset of an episode like weather, stress, activity, and sleep.

“Migraine is a neurological disease and there are no biomarkers you can spot,” continued Bloch.

He elaborated that when his team thought about identifying triggers for the condition, they classified them into two groups, controllable and uncontrollable, since a combination of these triggers affect every individual in a different way.

Weather, stress, activity, and sleep are the four major triggers that cover about 75 percent of the likely reasons involved with causing these attacks, according to Bloch.

**Clinical development**

A clinical trial performed by the Mayo Clinic generated positive feedback for the initial program.

“We gave participants a Fitbit, had them pair it up with a smartphone, and then continue to live their life as they had before enrolling in the trial,” elaborated Bloch.

Participants were asked to submit information through the app when they experienced a migraine. The things they would need to add include a start time, end time, severity levels, and other factors they may have been exposed to either before or during the migraine.

An additional step involved the machine learning algorithm working in the background to “label” this incoming information to add more context to the analysis, like tracking the time frame of before, during, and after they had a migraine. Weather data gets obtained through the closest weather station in proximity to the user. Data about activity, sleep, and heart rate were collected through the Fitbit.

“We grade all that information, we store it in a database, and then we continuously monitor the machine learning algorithms to see when the triggers begin to correlate,” elaborated Bloch.

The measurement used in this scenario was called the Area Under Curves (AUC) to help build a strong predictive model.

“When the ...[correlation of triggers]...start happening, we created an individual prediction model. Next, we start showing the individual their prediction number of a probability of having a migraine attack which is presented in terms of forecast,” said Bloch.

“It’s very similar to a weather forecast. We say, ‘The forecast for you getting a migraine attack for 11 a.m. today is so and so percent.’” Higher than 66 percent indicates the person would need to follow his physician’s instructions and take possible actions to prevent an attack.
Potential for partnerships

Second Health released the first commercial iteration of its platform in early August 2017 for the iPhone, but there’s still more work that needs to be done to keep refining the program.

Currently, the company is in the middle of a second clinical trial being conducted at the University of Southern California. The trial will last for about five months. The investigation will be used as a way to learn more about the migraines of an individual and validate the accuracy of the predictive model in a blind study.

Bloch ultimately envisions this program as being a companion to managing this chronic condition, especially with pharmaceutical companies and health insurers.

Teva Pharmaceutical and Amgen have filed biologics applications for their respective migraine drugs, but there’s still no infrastructure in place for how health insurers will reimburse different parties for these drugs.

“We can help the drug companies increase the perceived efficacy of the drug and work with insurers to better identify certain people that they will be willing to reimburse for the cost of using the drug,” Bloch continued.

Finally, Bloch considers this program to be a form of proactive technology that provides consumers with a higher level of self-care compared to what was used in the past.