GESTURAL

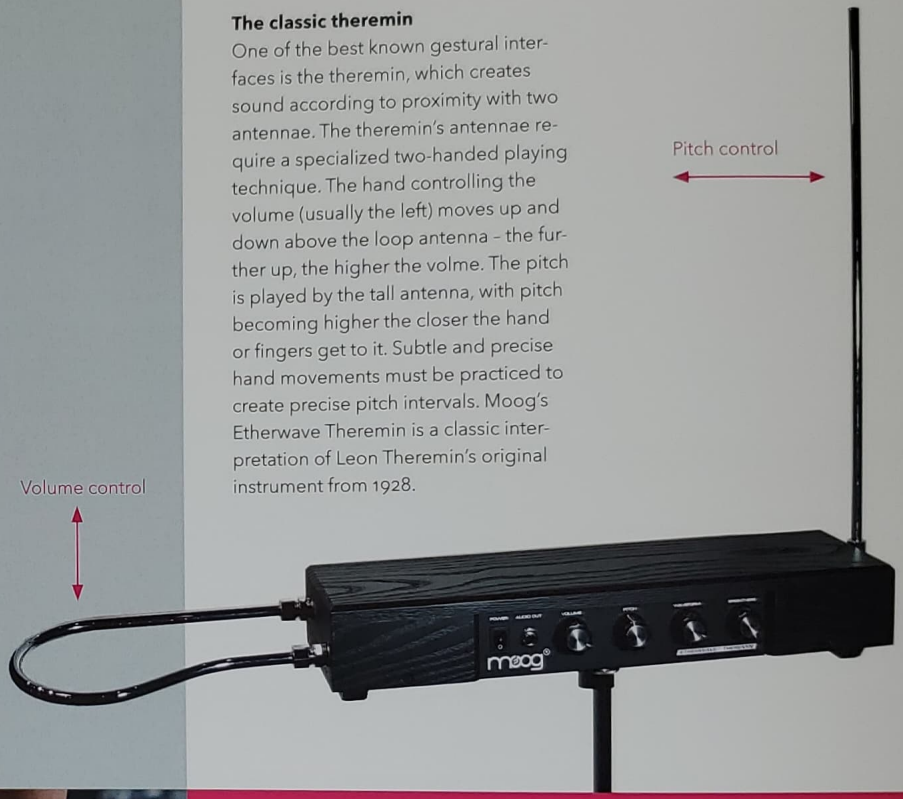
The concept of gestural interfaces is that one or more sensors are used to recognize bodily movements which form the main interaction with the instrument.

Typical technologies employed are built-in motion sensors in wearables or camera tracking. Connected software converts the signals to something understandable (like MIDI) for the audio environment.

Though gestural interfaces can captivate an audience, the instrumental feedback to the user from the interaction is primarily in terms of audio. Visual feedback happens by the user's awareness of hand and body position during performance. Control and practice of movements builds muscle memory; disciplined self-control of the performer's body is required to obtain consistent results.

The classic theremin

One of the best known gestural interfaces is the theremin, which creates sound according to proximity with two antennae. The theremin's antennae require a specialized two-handed playing technique. The hand controlling the volume (usually the left) moves up and down above the loop antenna – the further up, the higher the volme. The pitch is played by the tall antenna, with pitch becoming higher the closer the hand or fingers get to it. Subtle and precise hand movements must be practiced to create precise pitch intervals. Moog's Etherwave Theremin is a classic interpretation of Leon Theremin's original instrument from 1928.



Sensing movement

There have been several implementations of gestural control via finger rings. The Wave ring from Icelandic startup Genki Instruments is a different take on this form of gestural control, as feedback and software configuration is extensive. Wave senses three kinds of movement: horizontal, vertical, and rolling the finger/hand. Taps or hits can be registered by a 'shock-sensor' as well as by clicks on the two large buttons.

The clicks can be cycled through, so the user can, for example, have four different samples on one button.

The ring features haptic feedback in the form of a small 'buzz'. This can be employed in many ways. For example, it can indicate reaching minimum or maximum parameter values, or when the user moves a finger horizontally and crosses the invisible boundaries between 'sample sections' (when playing back audio samples in Hit or Tap modes).

Besides the physical feedback, lights beneath the two big buttons indicate which action is mapped to the button, with brightness indicating whether it is active or not. Using a small preset button, the user can switch between four presets, indicated by lights.

Sensing motion

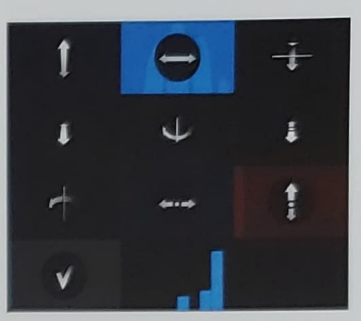
As an example of a gesture-sensing device, the Leap Motion controller is a USB-connected device that can be placed on a desktop or mounted on a virtual reality headset. It uses two infrared (IR) cameras and three IR LEDs to cover an almost hemispherical area in a distance of about one meter. With an accuracy of less than a millimeter when detecting motion, it is highly optimized for detailed gestural control.

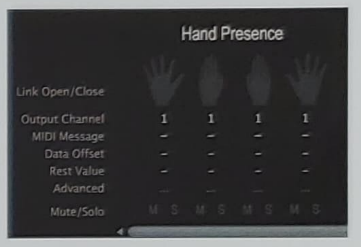
Translating gestures

Any of the control streams from the Leap Motion can be mapped to continous MIDI control messages on 16 different MIDI channels in the highly visual GECO software. The user interface is fully customizable in terms of colors and graphical elements. Data output can be adjusted in terms of range inversion, minimum and maximum boundaries, distribution curves, and attack/decay times.

The GECO software can sense whether it is a left or right hand and whether it is closed or open. This gives four main positions, and coupled with the following 10 kinds of data input, it allows for up to 40 different control messages:

- **Distance** from the Leap Motion Controller (Y-axis)
- **Up and Down Movement:** distance from when your hand was first seen (Y-axis)
- **Left and Right Position:** distance from the Leap Motion Controller (X-axis)
- **Left and Right Movement:** distance from when your hand was first seen (X-axis)
- **Back and Forth Position:** distance from the Leap Motion Controller (Z-axis)
- **Back and Forth Movement:** distance from when the hand was first seen (Z-axis)
- **Pitch Inclination** of the hand's palm
- **Roll Inclination** of the hand's palm
- **Yaw Direction** of the hand's palm
- **Presence** of the hand





Haptic feedback by air

Uniquely among gesture-based instruments, the Syntact from Ultrasonic provides contact-free tactile feedback to the musician. By utilizing airborne ultrasound, a force field is created in midair that can be sensed in a tactile way by the user's hand. The interface allows a musician to feel the actual sound with its temporal and harmonic texture. While an optical sensor system is interpreting hand gestures, users can physically engage with the medium of sound by virtually molding and shaping it – i.e. changing its acoustic appearance – directly with their hands.

The Syntact is operated via optical hand-gesture analysis. An integrated USB camera is used to analyze the hand position in the focal point region of the instrument. Image descriptors are then extracted in realtime and converted to MIDI data, which can further be used for sound synthesis or processing parameters.

The feedback section of the instrument uses audio signals (from a connected synthesizer or other sources) to compute an ultrasound signal mix that reflects the harmonic and temporal characteristics of the signal. The ultrasound signal mix is projected through a curved array of 121 ultrasonic transducers, focusing all the acoustic energy in one spot.

THE BODY AS THE INTERFACE

Interview with Dorit Chrysler, thereminist, composer and musician

"Playing a theremin combines audio and physical expression in a very direct way.

Dorit Chrysler has been dubbed a superior wizard of the theremin. An Austrian-born, New York-based composer, producer and singer, Chrysler is the co-founder of the NY Theremin Society and founder of the first school for theremin, KidCoolThereminSchool.

As much as the theremin is a tool in Chrysler's electronic instrument arsenal, she is also one of the most visible thereminists spreading the gospel of this mysterious-sounding instrument, which is basically played by massaging thin air. Dorit Chrysler has, besides her many solo records, collaborated with artists such as Anders Trentemøller, Tocotronic, TheThe, the San Francisco Symphony Orchestra and Ohland. She has performed worldwide in a variety of places like Australia, Japan, South Korea, Europe and Brazil.

The original inspiration to start playing the theremin came when Dorit Chrysler's musical adventure was already in full swing. As she explains:

"From the age of seven I was singing at the local opera house, being exposed to the repertoire of Mozart, Bizet, Alban Berg and Prokoviev. As a teenager I played in a New Wave band and, after studying systematic comparing musicology in Vienna, I moved to New York where I started an experimental rock band, playing guitar. When I first saw the theremin at a friend's house in NY, its sonic capacity and history were fascinating to me, as was its unique interface. I was affected instantly and dived into attempting to master the instrument. It proved to be the ultimate challenge."

The body as the interface

As if starting the NY Theremin Society was not enough, Dorit also founded the KidCoolThereminSchool where she's deeply engaged in teaching young children, teenagers and adults the fundamentals of this, the ultimate 'air instrument'. With all kinds of controllers, software tools, hardware synths and iPhone apps available, what does the theremin – an instrument almost a century old – provide that these things don't?

"Unlike the other devices you mentioned, the body of the player acts as the interface of motion to sound – the player is instrument and capacitor in the magnetic field a theremin provides – this physicality makes the experience of sound production more primal in an age of automation where we use our bodies less. Playing a theremin combines audio and physical expression in a very direct way – this is especially appealing to children; their familiarity with iPads and other gadgets can also be applied with an added dose of imaginative mystery since nothing is touched."

Developing and mastering a great technique on the theremin takes a lot of time. On the other hand, the interface is very simple. There seems to be a two-sidedness to this.

"The theremin is not a simple instrument. One can produce sounds on most instruments without being able to play them – but to explore the full sonic potential takes time. As there is no visual reference and high sensitivity to slightest movement in pitch response, it takes time to master a theremin. This does not exclude exploring more abstract and instrumental voicing. The advantage is that there are no strictly-defined techniques for achieving the best results, leaving it to the player to achieve their own goals."

Physical expression

As Dorit plays other instruments and uses Ableton Live as well, one can wonder what interaction with the theremin adds that other instruments and the computer don't?

"Most intriguing for me is a theremin's dynamic range – so expressive and physical. Nothing compares to this way of producing sound. It feels like an extension of one's inner voice – computer and analog gear serving to support this primal phenomenon."

"The experience of playing an instrument where you don't even touch it, as compared to one where you do, somehow feels more personal and intuitive, maybe comparable to a voice, a very natural part within yourself," she explains.

"It can feel more abstract and scary to not physically touch something in a live situation. I do sometimes miss clutching a guitar, its physicality adds another note of gravity – whereas the theremin always taps into what I like to call 'the Houdini effect' – it's a curse and a blessing."

Future possibilities for the theremin

In recent years, different versions of the theremin have appeared, some easier to play than others.

"Different models of the theremin have different advantages and disadvantages. These always depend on what you aim to do with the instrument. The Moog Theremini really went beyond being a theremin, as it allows – through the same interface – the triggering of classic Moog sounds and permits pitch control and set scales – a short cut to playing in tune easier. That can build a bridge towards progressing with the instrument and also allows faster results for children – whose attention needs to be held."

For Dorit the more sensitive the volume antenna functions, the better the instrument – it permits more expressive performance as each note can be sculpted in detail with the volume hand. Though she is left-handed, this hasn't stopped her from playing the theremin – it is simply a matter of turning it the other way around.

Dorit Chrysler teaching kids to play Theremin at KidCoolThereminSchool, Helmhaus, Zurich.

With Virtual Reality and other gesture-based approaches, there could be possibilities for the theremin to evolve into something else in the future. As she elaborates:

"It would certainly make sense to apply its sonic interface to future devices to expand multisensual experiences. I am working with other artists to turn the live playing of theremin into live visuals picking up all the fine details; kinetic processes are helpful and the potential is manifold."

Gesture-based control and expression is not necessarily the ultimate way of interacting with electronic instruments, though, as she explains:

"It is up to each artist to decide what sound they need to express their vision. As a teenager I was fascinated by the 'coldness' in the sound of synthesizers; to translate human emotion into a machine running on electricity is interesting to me."

EXPRESSIVE GESTURAL PERSONALITY

Interview with the team behind the mi.mu gloves

Imagine waving your hands in the air to control the filter cutoff, or starting a loop just by a flick of your finger. That kind of highly sensitive technology is what the performance-oriented mi.mu gloves are all about.

The project was initiated by artist Imogen Heap, who wanted a more expressive and visual way of performing her music. As she says:

"Fifty percent of a performance from me five years ago, you'd see me racing around between various instruments and bits of technology on stage. But for example, pressing a record button doesn't look or feel very expressive when actually, that moment of recording something is a real creative act; it's a musical act. These actions are traditionally hidden from the audience and can disengage me from that flow I'm focused on achieving, so I wanted to find a way to integrate these actions into the performance, expressively. It's these unsung heroes being brought out of hiding, that are alive and well in the studio environment but hard to unleash live on stage."

Tom Mitchell says that the team believes the gloves add something completely new to the current landscape of controllers: the opportunity to design your own musical actions.

"There are two perspectives to consider with new digital controllers and instruments: the user actions that provide the source of control messages, and the destination audio parameters that produce a sonic response. Previously the musician's actions were largely dictated by the instrument or controller: buttons must be pressed, strings can be plucked/bowed, and so forth. Freehand musical controllers like the gloves enable users to design their own actions as well as the sounds that they control. In our opinion, this gives an unprecedented degree of expression, and this is what motivates us."

Adam Stark is a researcher, computer scientist, and musician based in London. **Tom Mitchell** is a computer scientist, researcher and electronic musician lecturing in computer music at the University of the West of England, Bristol. **Chagall van den Berg** is a Dutch vocalist, songwriter and electronic music producer living in London. ***Imogen Heap*** *is a Grammy-award-winning recording artist. Together with Rachel Freire, Hannah Perner-Wilson, Kelly Snook and Seb Madgwick, they form the small and dedicated mi.mu team, where each specializes in a different area of glove technology, design, and performance. They are engaged in performances, conferences, design, and hacking at events all over the world to promote their innovative performance technology.*

Controlling

With 17 motion sensors (and a button) on each glove, a huge amount of control data can be sent wirelessly to the computer, as Tom explains.

"Most of these sensor readings can be directly mapped to any type of MIDI or OSC (Open Sound Control) message using our software, Glover. However, more interestingly, this data is processed in lots of different ways to give more meaningful information about the wearer's movements, like the current orientation of each hand or when different postures and gestures have been performed."

Tom emphasizes that wearers can also train the gloves to recognize their own unique gestures and then use combinations of gestures and postures made with both hands to send controller messages.

"Glover is designed so that mappings can be changed instantaneously, enabling the same gestures to easily control different aspects of your music at different times. This all means that there are practically no limits on the different ways in which gestures can be used to control music with the gloves, which is why our users have so many personalized ways of performing."

Adam Stark adds that working with Imogen Heap to 'hard code' the musical controls she wanted into the software revealed the need for customization.

"Imogen had musical ideas for the gloves much faster than we could implement them in code, so it became clear pretty quickly that we needed some way for musicians to be able to 'compose' their own relationship between gesture and sound. To solve this, we created a mapping system as part of our own custom software. It allows musicians to rapidly experiment with sound-gesture mappings."

The software allows the musician to connect complex gesture combinations to MIDI or OSC messages, which can be understood by other music software. But as he explains, this became a bigger thing than the team expected.

"Now that we have many musicians using the gloves, each one is able to build their own gestural 'language' around the music they compose and perform, so that in each instance, using the gloves has a unique expressive personality."

Gesture data and mapping

With such a vast amount of gesture data, and the possibilities of mapping, Adam Stark describes how helping new users to work with the gloves has been a large area of research during development.

"We have complex gesture inputs from the musician and a world of multi-parameter synthesis and effects on the other side. We have been developing our software into a tool where this complexity can become fun and playful, a space for exploration and creativity. For new users, this can take a little bit of getting used to, but once people understand the compositional potential they tend to go off on their own journeys. We try to help new users along with tutorials, videos, and example projects. "

Adam adds that the greatest benefit of the gloves is their ability to bring people closer to electronic music than ever before.

"For musicians, this means having hugely intimate control over sound, being able to make subtle changes to sound with the bend of the fingers or orientation of the hands."

For audiences, this means that electronic music performance is visual, and not lost somewhere inside a computer. Adam believes this is highly important.

"In acoustic instruments, the physical mechanism – strumming a guitar, hitting a drum, striking a piano key – is inherently connected to the production of sound. So when you watch a great drummer, pianist, or cellist, you see someone interacting in an incredibly physical way with their instrument. The production of sound is a whole-body effort."

"This has big implications for performance. Recorded music is ethereal and intangible. While it is beautiful, it exists behind glass. When you see a person perform that music, you see it humanized and made real. Through physical and visual performance we can connect raw sound with human identity and everything that goes with it - culture, attitude, community, fashion, politics... and also a sense of fragility."

In Adam's view, with digital musical instruments, we have separated the physical action from the production of sound.

"Complex music can be created in a laptop using synthesizers and effects, but no one can see how it is done. With computer music, we have lost the need for physical performance, and so we have also lost part of the connection to human identity and agency. With the mi.mu gloves, we are putting the visual and physical relationship between musician and sound back at the center of computer music performance."

With the majority of instruments played by the artist touching a kind of surface, the gloves are fundamentally different, but according to Adam, this has another advantage.

"By not needing to interact with a physical object, the gloves allow performers to really focus on their body as an expressive medium for musical performance. There is nothing in the way for the musician; they can render themselves physically into sound. Audiences can often experience this as a form of communication, with the gestures embodying some hidden meaning behind the music. However, the tactile advantages of surfaces are clear too - particularly in the way they provide something to resist the hand or fingers, providing a frame of reference."

To Imogen Heap, the advantages of the mi.mu gloves are many and obvious:

"What this glove enables me to do is access mappings inside my computer and the awesome music software inside it, along with all the virtual instruments and production tools, so that I don't have to go to a keyboard or a fader or a button."

"There are so many types of sounds or effects that don't have a physical presence. They are software, they are hidden inside the computer. A bassline might

sound sculpted; it might have this blobby, stretchy sound. For me, it doesn't feel natural to play a sound like that on a keyboard because a keyboard is designed primarily for melody and harmony and one only has two hands. I can play a melody but if I wanted to manipulate any kind of parameter of that sound, my other hand is completely used up. We have these incredibly expressive bodies, yet making and playing music can often find us hunched over at a desk. Humanizing the music tech we know and love is at mi.mu's core; where it doesn't exist, we develop and build it and/or collaborate with others who are."

The development process

The development of the technology and gloves has been a group effort, and most members of the team have been practicing musicians at one time or another. Tom Mitchell emphasizes that this experience has been crucial and has impacted on every design choice along the way.

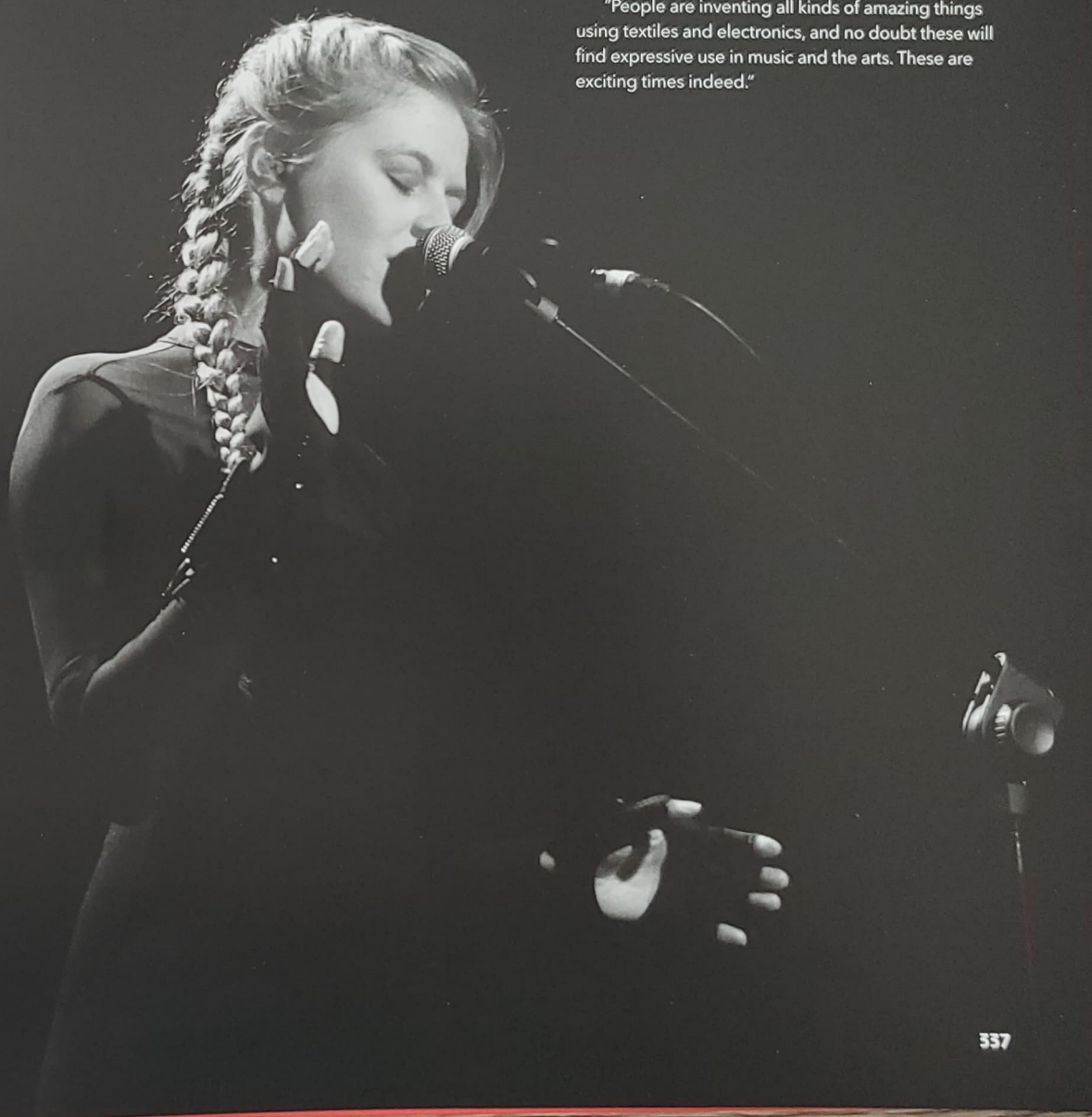
"The entire development process has been punctuated by numerous high-stakes performances, which have either been an amazing success or a big learning process. Either way, this agile approach has always kept the realities of musicianship in the foreground of the development process."

Adam Stark elaborates on the learning experience as they've been through many different versions of the gloves.

"At every stage, we improved the textiles, positioning, and type of sensors, wireless communications, feedback and many other things. It has a been a huge learning experience and there was a lot of trial and error. Even though we have now hit upon something that works really well, we are still improving the design to make it more durable and easier to produce."

Support for MPE (Multi-Dimensional Polyphonic Expression) is on the to-do list, and the team hopes to start experimenting with VR in the near future. Stark believes the world of e-textiles holds huge promise for futuristic controllers.

"People are inventing all kinds of amazing things using textiles and electronics, and no doubt these will find expressive use in music and the arts. These are exciting times indeed."



> "The mi.mu software makes using the gloves very flexible and allows users to create their own personal sound-gesture relationships. Each Glover has the freedom to imagine a new gestural way of controlling sounds and effects, and it is always a surprise to see how different people use them. There is no such thing as 'glove music' because the gloves can accommodate any genre of music or type of performance, supporting each individual's preferred creative process.
>
> Chagall van den Berg