Applications of bending-wave technology in human interface devices

Neil Harris

Introduction

- **NXT is well-known for its application of bending-waves to so-called "flat panel loudspeakers". This time, however, I will be looking at other applications of the technology that are both technically and commercially interesting.**
- **These applications are also part of the interface between human and machine, but focus on the sense of touch rather than of hearing.**
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- **Touch screens have been around for years, but with the arrival of a new generation of devices typified by the i-Phone, they now need to offer greater sophistication and more features.**
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- **If touch sensors are the analogue of the microphone, then haptic feedback generators are the analogue of the loudspeaker. Bending waves are beginning to find application here too.**

History

- As a company, our roots are in audio, so it comes as no surprise that our focus to date has been on sound – the flat loudspeakers.
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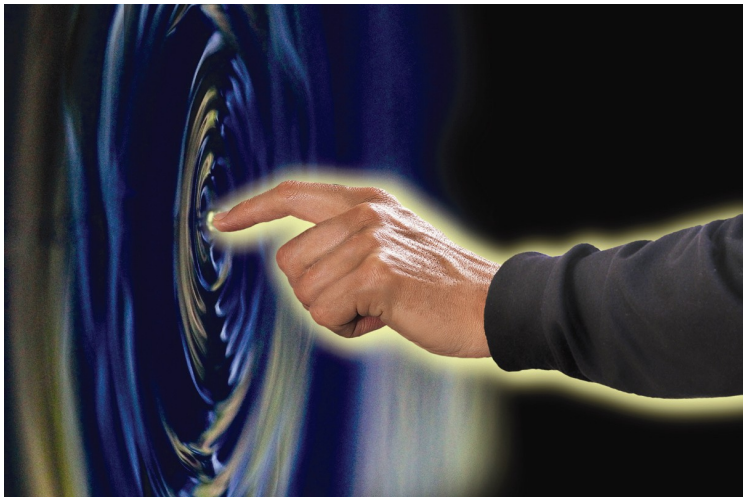
- However, sound has already been combined with vision in products – for example the NEC ValueStar series of computer monitors and laptops – consequently, it was not too a great a leap for us to consider combing touch.

Touch – a bending-wave input device

- **Bending waves have also been applied to touch sensing in a 3M product range. DST (Dispersive Signal Technology) calculates touch locations by analyzing the bending waves created by the user's touch within the glass substrate. Bending-waves are traced back to their source on the panel, taking note of the dispersive nature of bending waves.**



- **The use of bending-waves provides reliable touch performance and is unaffected by contaminants, scratches, or static objects on the screen. It also supports hand, glove and stylus input.**

Haptics

- **Haptic technology, from the Greek "haptesthai," meaning “to touch”, refers to technology that interfaces to the user via the sense of touch by applying mechanical stimulation to the user. (Hence, if touch sensors are the analogue of the microphone, then haptic feedback generators are the analogue of the loudspeaker)**
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- **Simple examples include the “rumble” feedback provided by the hand-held controllers of some games consoles. However, these are to haptics what the sub-woofer is to audio.**
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- **The application of haptics is still in its infancy, so now is an exciting time to be involved in developing the technology.**
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AVT (Audio – Video – Touch)

- **A wide range of acoustic and other sensory functions may be simultaneously integrated into the touch panel. Since it is a single component assembly which may provide an increased number of functions, it may be termed a hyper-functional surface (HFS).**
- **For example, by using a transparent, touch-sensitive panel with haptic feedback in a device, it may be used to view information, hear acoustic signals (messages, bleeps, clicks etc) and feel simulated button clicks through one's fingertips. It would, of course, also be possible to use a conventional (i.e. resistive or capacitive) touch screen to provide the sensing, and just use bending-waves to provide audio output.**
- **For high quality audio we need the reasonable bandwidth and linearity provided by bending-waves. These features may also be usefully exploited by the haptic feedback.**

Haptics – a short primer

- Just as in audio the ear is not equally sensitive to all frequencies, neither is the sense of touch. While the ear's sensitivity peak is in the low kilohertz range, the finger's peak is at around 300 – 400 Hz
- At its most sensitive, the finger can detect displacements of the order of 1 micron. At lower frequencies, this sensitivity reduces to around 200 microns.
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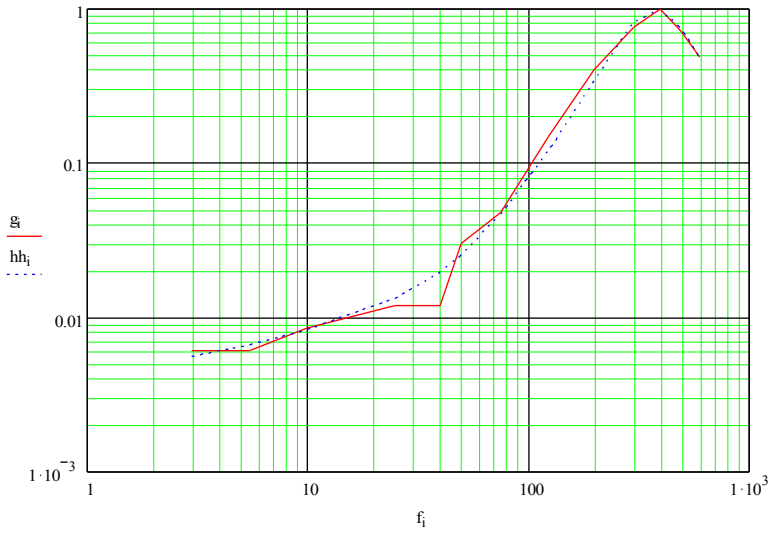

- Haptics hardware has typically used mono-phase motion and operated at low frequencies – 20 Hz to 50 Hz.
- A bending-wave device would typically work in the region above 100 Hz, right through the most sensitive range for touch.

So what can you do with bending-waves?

- **The wide bandwidth available with bending-waves allows the tactile feedback to be tuned or altered in both amplitude and frequency, allowing very wide variation in haptic signals and subjective feel.**
- **Because this bandwidth extends into the audio range, and because of the linearity of the system, it is possible to combine haptic and audio feedback into the one device.**
- **One example of its use is to simulate the feel of writing or drawing on a textured surface, such as paper with a pencil, instead of a stylus on a touch-screen. It can also simultaneously reproduce the characteristic sound, should that be desired.**
- **Additionally, because bending-waves are waves, it is possible to use superposition techniques to produce different haptic feedback signals in different areas of the panel. This aspect, which is a subject of on-going research, generates substantial commercial interest.**

Simultaneous multi-region haptics

- **Simultaneous multi-region (SMR) haptics refers to the ability, unique to bending-wave haptics, whereby separate haptics signals are applied simultaneously at two or more separate points on the surface.**
- **The fundamental starting point is the ability to create a non-active zone anywhere on the panel.**
- **Starting with a simple 1D analogue, this presentation leads through the principles at work in SMR.**
- **We look at the real-world reasons why this process is not as trivially simple as the 1D example would suggest.**

1-Dimensional analogue

- If we consider a stretched string with a perfectly terminating generator at each end. The generations can each produce a pulse that travels from its own end to the other without reflection.
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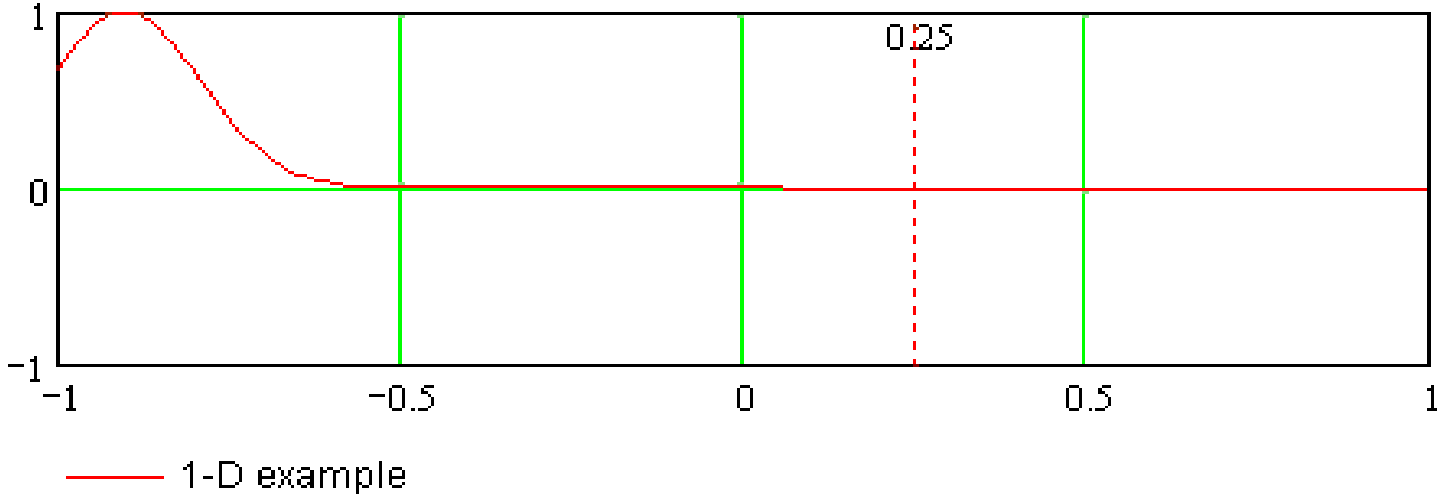

2-Dimensional analogue

- **Let us now consider a similarly perfect transmission line in 2D where we have signals radiating from point sources. To get a null point, it is no longer just the delay between the two pulses that must be adjusted. We must also compensate for the different pulse amplitudes at the target location.**
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- **The cancellation no longer occurs at a point. The delays difference is constant along a line (a hyperbola). The amplitude ratio is constant along another line (a circle). In general, both match at two points.**
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- **This is just like triangulation working in reverse. The ambiguity is resolved by adding a third source – now there is only one point at which the delays all match, and at the same point the amplitudes also match.**

The real world

- **With bending-wave haptics, we have a 2-D surface, but with added complications.**
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  - We have boundaries which cause reflections and modes.
  - We have bending waves, which are dispersive (velocity varies with frequency)

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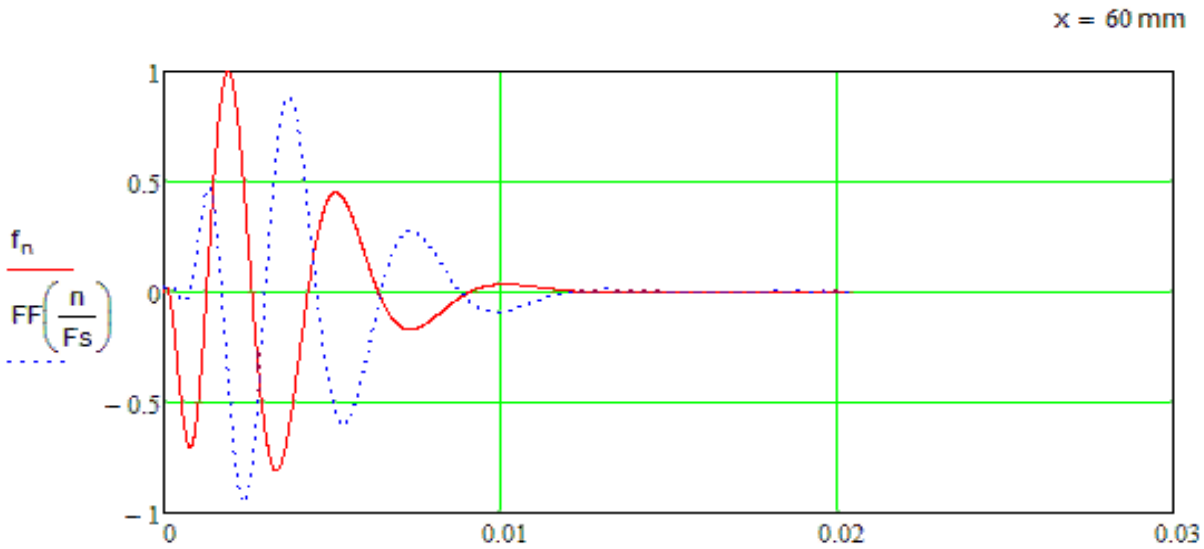

Summary

- **Bending-wave technology is well adapted for use in haptic interfaces. A wide variation in haptic signals and subjective feel are possible. Because the bandwidth extends into the audio range, it is possible to combine haptic and audio feedback into the one device.**
- **Because bending-waves are waves, it is possible to localise the haptic feedback signals to different areas of the panel. Given that localisation is possible, it is also possible to have different feedbacks at different locations at the same time. This ability is unique to bending-wave haptics.**
- **Finally, the touch panel gets its revenge! – Now it can touch back with precision and subtlety.**
- **Thank you all for listening.**