'*PegLegs* in Music' - Processing the Effort Generated by Levels of Expressive Gesturing in Music

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ABSTRACT
In this paper we discuss the possibility of augmenting existing musical performance by using a novel sensing device termed 'PegLeg'. This device interprets the movements and motions of a musician during play by allowing the musician to manipulate a sensor in three dimensions. A force sensitive surface allows us to detect, interpret and interface the subtle but integral element of physical "effort" in music playing. This device is designed to extend the musicians control over any given instrument, granting an additional means of 'playing' that would previously have been impossible – granting an additional limb to extend their playing potential – a *PegLeg*…

KEYWORDS
Gesture, weight distribution, effort, expression, intent, movement, 3D sensing pressure, force, sensor, resolution, control device, sound, music, input.

INTRODUCTION
Much of the work that has been done in gesture interpretation to date, tends to concentrate on monitoring the position and motion of persons using computer vision techniques, where data from a camera is processed to obtain tracking information [1]. While being both effective and useful, these systems do suffer from slow response times for real-time performance, as well as having limitations with multiple users. The current limitations of existing technologies can tend to dictate properties of performances, such as use of space, positioning, mobility, lighting and even costume. Another considerable flaw in existing systems is their inability to detect the imperative ingredient of weight distribution and transference in movement: the complex dynamic of "physical effort".

Two almost parallel developments were taking place on both sides of the Atlantic in 1997, both with similar objectives. Paradiso et al [2] developed the *MagicCarpet*, a floor space that detected people's footsteps in terms of location within the carpet and impact force. Almost at the same time, Fernström and Griffith [3] developed *Litefoot*, a floor slab with embedded sensors that detected people's foot movements on the floor. The objectives of both groups were similar, to create a floor space that could be used as input device in ubiquitous computing or smart environments. Each group was aiming at a gesture sensitive device that could be used for artistic expression and control by musicians and dancers as well as a device suitable for installations in public environments such as art galleries and museums.

The Z-tiles surface emerged as a direct descendant of these two developments. While it harboured some of the shared objectives of its precursors, the novel sensor design was specifically concerned with the dynamic of force in movement and gesture. By interfacing *Z-tiles*, a novel force sensor with existing sensing technologies it is possible to control up to five different musical parameters in a series of preset programs.

GESTURAL MOVEMENT IN MUSIC
Musical expression is manifested by an artist through the modification of aspects such as tempo, timing, accentuation, timbre etc.

Gestures are a learned form of movement, used as a means of communication. A gesture is a motion of the body that contains information [4]. Musicians constantly perform movements – or gestures – that are not directly related to sound production. These gestures have been called *expressive, accompanist, ancillary* or *non-obvious* [5]. Gestures increase the level of expression when used during a musical performance. Although certain gestures are learned and applied through watching other musicians, every musician adapts and develops his or her individual style of gesture making. These gestures, which have an undeniable visual impact during performances, are part and parcel of top instrumentalists' technique [6]. There is no clear consensus on the origin of these gestures, it seems obvious that they are present in skilled performer's technique, and are dependent on several factors, therefore presenting different movement levels [5].

In PegLeg the emphasis is on how we gesture and move while playing a physically unaltered musical instrument. Within 'PegLeg' gestures are interpreted as changes in weight distribution. These changes will influence the sound in a variety of ways. While the interface is designed to be intuitive as possible, playing PegLeg requires that the musician becomes sensitive to how they are physically moving while they play. These are intentional if not always voluntary movements and a sensitivity or awareness of them is learned and adapted to individual tastes and requirements. In becoming conscious of this gesturing the musician learns different aspects of the musical instrument, thereby extending it's capability.

An inspirational pioneer in the area of full body gesture for musical expression is Norwegian musician composer Øyvind Brandtsegg. Brandtsegg's main instrument is a vibraphone/computer combination that works in conjunction with a series of sensor technologies. This medium has granted the artist an expanded means of manipulating audio. The sensors he employs include IR, piezoelectric film, and EMG sensors. By using such sensing technology he has expanded the musical parameter by adding up to six additional dimensions, which he plays with both perceptible and imperceptible body movements. [4]

The type of instrument and the intended audience plays a large part in dictating the amount and type of gestures used. If the instrument requires the use of two hands, for example the flute, the musician may move the upper body in a swaying motion compared to that of a seated bodhran player who might use foot tapping. These gestures are individualised by the exaggerations and subtleties employed by the artist, which in turn can also be influenced by fellow musicians or the audience.

'PegLeg is a direct offshoot of the University of Limerick and Media Lab Europe *Z-Tiles* project which was initiated in January 2001. The Z-tiles project was focused on the design, development and implementation of a device that would facilitate the exploration weight distribution, particularly the "effort" of executing certain gestures. Essentially, the Z-Tiles sensor could be used in any control surface where force or pressure might be exploited as a control parameter.

SENSOR DESIGN & DEVELOPMENT

Z-Tiles is a new design for a fully scaleable, self-organising, force sensitive surface. This unique interface - with its extensible resolution - allows us to detect a range of objects by employing blob detection algorithms based on perception principles. The Z-tiles detect x/y location as well as the force applied, our z-axis. Based on our experiences with the MagicCarpet and Litefoot, we aimed for a fully pixellated surface area that could detect location and force in real-time. Some simple calculations revealed that to create a massively parallel sensor device connected to a single computer would probably be quite impractical, hence we decided to try a modular design where each module would have its own inbuilt computational power and a communication protocol that allowed modules to use high-level descriptions of their sensor data. PegLeg uses an array of the modular Z-tile sensors to distinguish shifts in weight distribution. The PegLeg/Z-Tiles surface is designed to measure an extensive dynamic pressure range that will indicate not only where the user is standing, but also how heavily he or she is standing and where the majority of the weight is placed.

In early 2001 we found a possible mixture of silicon rubber and carbon granules that showed interesting properties for inexpensive force sensors. This kind of force sensitive and conductive polymer can be screen-printed on a surface to be made force sensitive. See Figure 1. The sensor works on a simple premise: the electrical resistance of the mixture changes with applied pressure, and this change can be monitored by a micro-controller.

Project developments to date have covered the creation of the sensor material, physical and mechanical design,

Figure 1. Making the Z-tiles force sensor

exploration of its chemical, physical and electrical properties, and integration of the sensor material into a control surface for use in different scenarios. These include direct mapping to audio-visual representations, a volume control for an installation piece, and an input device for *PegLeg* - Processing the Effort Generated by Levels of Expressive Gesturing

In our first scenario we used an array of Prexels as an input device for controlling a MIDI module, i.e. as a musical controller. We used direct mappings between location-pitch and force-loudness. A PC was employed to illustrate the voltages as colour changes on a computer screen. The pressure values were displayed as degrees between black and red, as shown in Figure 2. This was felt as a natural mapping that demonstrated the sensors basic capability in a simple but effective manner.

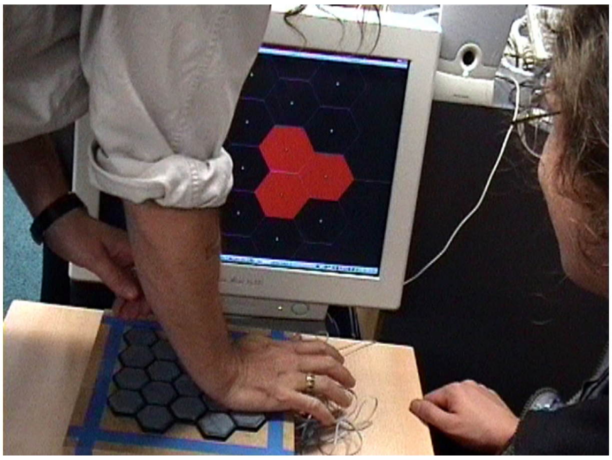

Figure 2. The Z- tile as a audio visual control device

The Z-Tile sensor has also been used as volume control for "The Cardboard Box Garden"; a sound based installation created by a student of interactive media in the University of Limerick [7].

PEGLEG SENSOR IMPLEMENTATION

The initial musical controller application of the Z-tiles sensor has been elaborated in the PegLeg application. While the physical form of the instrument remains intact, the environment in which it is played becomes sensitive to how the musician is gesturing, moving and physically engaging with both the instrument and his physical surrounds.

In the development of this demo we interfaced the Z-tiles sensors with pre-existing sensing technology. The AirFX is an Alesis product that incorporates A xyz patent pending technology that consists of an infrared beam that can be manipulated in three dimensions, along the X, Y, and Z-axis. Alesis claims that by using triangulation, up to five different parameters can be controlled in each of the 49 presets programs. [8] Both the AirFX and the Z-tiles sensors work on a similar principal of x, y and Z sensing. However, during testing the AirFx demonstrated some limiting features. Due to the nature of IR sensing the device requires a certain type of lighting, which cause problems in stage lit environments. Also the AirFX has a limited range of 15cm, any action outside this range is ineffectual, while the Z-tiles sensor is unaffected by lighting conditions and allows for increased interaction to take place within a comparable large dynamic range. Integration of the two sensor types enhances the overall performance capabilities of the device.

REBUILDING THE DEVICE

On opening the case of the AirFX unit, the secret of its operation was discovered. A dark near-opaque, but IR transparent plastic dome on top of the unit conceals a bright infrared source, whose light is directed upwards out of the unit. Surrounding this light are four photodiodes (Figure 3), which separated from the light by an opaque barrier, but exposed to the outside world through a plastic filter, which while almost completely opaque to light at human-visible wavelengths, is transparent to infrared light. Under general lighting conditions indoors, very little light falls on the photodiodes. However, if a user should position their hand a few inches above the unit, their skin will reflect the infrared light emitted from the center of the dome down and outwards to the sensors. This system works very well when the only ambient light comes from ordinary fluorescent office lights.

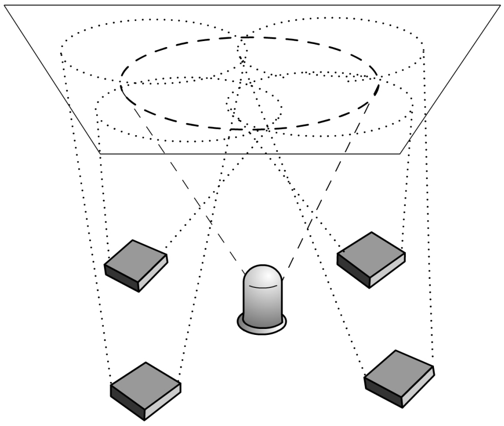

Figure 3: AirFX IR interface

Our intention was to modify the unit to accept input from our Prexels in place of that offered by the IR photodiodes. So, as a first step the photodiodes were removed from the PCB on which they had been mounted, and leads for a single Prexel were soldered to the board in place of each – in hopes that the resistance changes in the Prexels would mimic the behaviour of the photodiodes. Having realized that this procedure would not give the desired result various resistors were connected from either side of a given Prexel connection to either ground or +5V. After testing resistors with values ranging from 10 kilo Ohms to 10 mega Ohms in each of four possible configurations, the desired effect had still not been achieved, and it became apparent that a new approach was called for.

The alternative approach was a simple but elegant solution: to couple *optically* our Prexels with the photodiodes. In theory, a very straightforward approach, requiring only that each Prexel be used to vary the brightness of an IR light placed close to one of the four photodiodes. Having removed the Prexels from the AirFX board and soldered the old sensors back in place, some IR LEDs were powered up and placed right next to the AirFX unit. The Prexels control the brightness of incandescent bulbs, which emit over quite a broad swathe of the spectrum. These have the additional advantage that their brightness is more readily adjusted than that of an LED. These can, of course, be replaced by IR-LEDs with the exact matching wavelength to the photodiodes. Figure 4 illustrates the working sensor hybrid.

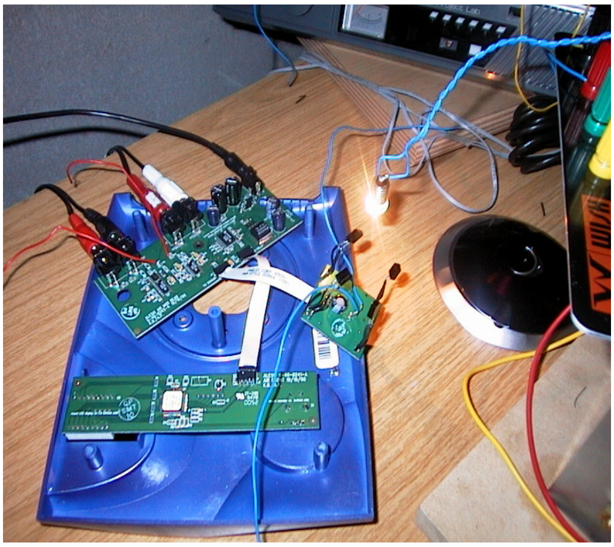

Figure 4. The sensor hybrid in action

ITERATIVE DESIGN OF *PEGLEG* SCENARIO

While continuing technological development is taking place at the time of writing, so too is the enquiry into suitable mappings. Mapping inevitably depends on the nature of the particular instrument we are attempting to augment and the playing style of its owner. As previously discussed the types of gestures made depends not only on the music being played but also on the social dynamic and the learned style. The device naturally lends itself to the interpretation of an infinite dynamic range of weight shifts, and it is as adaptive as individual playing styles might require. Not only will the device guarantee a unique performance for each user but each user can also chose between a range of 49 audio effects.

We are currently involved in workshops that investigate the nature of musical gesture in Flute, bodhran, triangle and guitar playing in both solo and group environments, as pictured in Figures 5, 6 &7. Initial concerns are centered on increasing the level of awareness of musical gesture in the player - making the gesture a conscious control as opposed to a secondary communication mechanism. During this process the musicians become aware of the implications of movement on this new platform i.e. they become familiar with its early characteristics and mappings, its demonstrable controllability and repeatability. Such ongoing investigations will reveal more appropriate mapping solutions for each of the musical scenarios mentioned. When these key issues are established musicians will be encouraged to manipulate their unique gestures in order to play their extended instrument. Our main concerns are centered on allowing experimental composition to develop alongside effective musical expression.

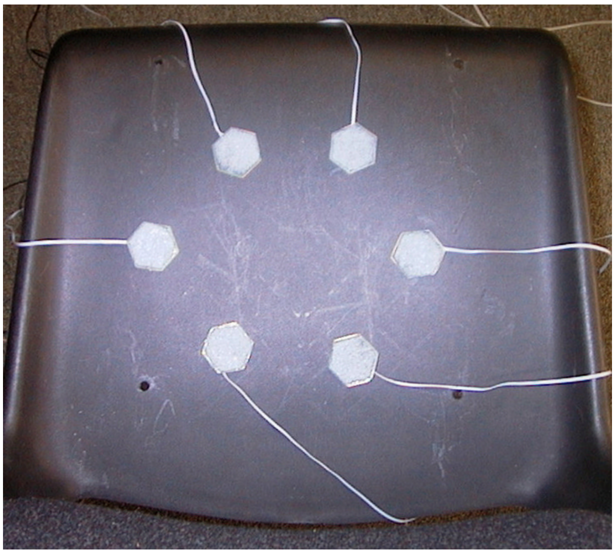

Figure 5. A sensing chair used to investigate weight distribution and gesture of seated musicians

Figure 6. A seated player testing the early PegLeg concept

POTENTIAL APPLICATIONS AND FUTURE DEVELOPMENTS

Immediate application design is focused on developing the surface for use as an interactive music controller. However, it is foreseen that future developments of the Z-tile/PegLeg application will be concerned with the areas of multi-use and mapping. Blob detection will potentially allow for the identification of multiple users, each controlling their own chosen musical parameters by movement and gesture. As discussed continuing research into the complex area of mapping will be an extremely important aspect of the application design, this becomes increasingly complicated when the locus of control becomes distributed among players.

Further enquiry into gesture and musical expression will continue. We intend to investigate the use of Formant filter principals and techniques, looking initially to the resonance and manipulation of the vocal tract in the creation of vowel sounds, from here we anticipate expanding and developing this model toward an intuitive, circular model of natural full body gesture, which could potentially be used to further articulate effort, emphasis and control.

Figure 7. Bodhran with force sensors underfoot

CONCLUSION

'PegLegs in music' has adapted and redeveloped the attitude of the 'One Man Band' scenario, potentially allowing the musician to control numerous aspects of a musical instrument concurrently in real-time. The correlation between performer gestures and musical parameters such as tempo, articulation, etc… opens up new possibilities regarding the control of digital audio effects, for which ancillary movements may provide coherent relationships between this control and the musical interpretation [5]. The musician can now control their audio processing by manipulating a sensor arrangement using the dynamics of their full body posture without 'invading' their direct control of their original instrument. The learned gestures will give new dimensions to musical performances and allow the musician to evolve and extend their playing expression in a previously unrealised fashion.

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REFERENCES

[1] Maes, P., Darrell, T., Blumberg, B., Pentland, S. The ALIVE System: Full-Body Interaction with Autonomous Agents. *Proceedings of the Computer Animation '95 Conference*, Geneva, Switzerland, IEEE Press.

[2] Paradiso, J., Abler, C., Hsiao, K., Reynolds, M. The Magic Carpet: Physical Sensing for Immersive Environments. *Proceedings of CHI'97*, Atlanta, GA, USA, 1997.

[3] Fernström, M., Griffith, N. LiteFoot – Auditory Display of Footwork. *Proceedings of ICAD98,* Glasgow, Scotland, 1998.

[4] Kurtenbach, G., Hulteen, E.A., "Gestures in Human – Computer Interaction", In B. Laurel (ed): The Art of Human – Computer Interaction, Reading, Mass: Addison – Wesley, page 310

[5] Wanderley, M., Depalle, P., Gesturally – Controlled Digital Audio Effects. *Proceedings of DAFX-01,* Ireland, 2001.

[6] http://home.online.no/~obrandts/

[7] Bannon, L., Ferris, K., The Cardboard Box Garden – Technical Report, University of Limerick, December 2001

[8] http://www.alesis.com/products/airfx/index.html