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Applications of Motion Tracking for Persons with Disabilities

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Summary

The idea of the MotionComposer[1] is to build a device for persons with disabilities that allows musical expression through movement. Under a grant from the German Ministry of Economy and Technology, we been working to develop this idea into a practical easy-to-use and therapeutic tool. Together with therapists[2] and composers[3], we are designing musical environments with the intention that they generate intuitive and synaesthetic responses in the user. In on-going workshops with persons with disabilities in Germany and Spain[4] we are gathering valuable experience and while perhaps not yet "easy to use", we are making significant progress particularly in the area of mapping.

1 Introduction

Everyone knows the sensation of having music "inside us" when we dance, but to parse this experience, to break it down into parameters which we can then be controlled by data collected from sensors, represents an interesting and complex challenge. There are many ways available today to extract data from human motion and to use it to modulate sound. The challenge lies in the mapping; this is where psychology comes into play. The relationship of sound to movement (music to dance) is not a particularly logical one. The cognition of causality, while important, is only part of the story. There is an intuitive aspect as well. As with expressionist painting, the environment (in this case aural) can seem to reflect our

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1 http://www.motioncomposer.com. (accessed 28.7.2012)

2 Principle among these is Dr. Alicia Peñalba Acitores, University of Valladolid.

3 Marc Sauter, Pablo Palacio, Dr. Andrea Cera, Adrien Garcia, Dr. Dan Hosken, Dr. Alexandros Kontogeorgakopoulos and Dr. Andreas Bergsland.

4 Schule am Burkersdorfer Weg, Dresden; WfbM Apolda and Fundación Música Abierta in Valladolid, Spain.

impulses and intentions on an unconscious level leading to a much richer experience. Instead of "I *make* the music", we can have something akin to "I *am* the music". If this is where we want to go, then we must approach the problem from the perspective of synaesthesia, the world in which our senses overlap.

2 Synaesthesia

When dancers synchronize their movements to music, the experience can be one of *hearing the movement*, *seeing the music* or *I am the music,* the latter of which refers to the kinesthetic sense -- the feeling we derive from our muscles. These are not just figures of speech, a real confusion can occur. The term for this is synaesthesia.

There are many ways to turn human movement into sound. Hand clapping is perhaps the simplest. Tools and technology amplify this process and transform our movements into vastly more complex sounds and while there may be other paradigms for music making (other definitions of music) this basic model is at the center of our work. We contract muscles in an organized, perhaps rhythmic way and this causes movement. The movement in turn acts on a device to generate music. As a part of this process, many movements occur which do not, strictly speaking, have anything to do with the generation or control of sound. African drumming, for example, typically involves large coincident movement. But even in the case of finger-played instruments, musicians generally sway or move their arms, legs, head and feet as they play. All of these movements belong to the things that unite dancers and musicians and grow out of a basic human instinct, one for which there is, remarkably, no word in English[5].

Why do musicians make these extra movements? Indeed, why do people make music and dance at all? Though it may not be well-understood, one thing is certain: it has a long legacy. Human beings have been doing *it* -- this thing that has no word -- for 10,000 years[6]. The urge to do it must surely be deeply-rooted. Music and dance can be thought of as two manifestations of a single urge. While their physical forms are different, in our psychology they overlap and often represent a single experience built out of multiple sensory factors.

Many people think that we are trying to build a new musical instrument, one that is played invisibly in the air. This is partly true, but the differences are important to understand.

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5 There are words for the combination of dance and music in other languages. The Awa of the Dogon tribes (Guinea Coast) offers one example (H. Michel, "Afrikanishce Tänze", DuMont Buchverlag, Cologne, 1979). Capoeira, a Brazilian dance-martial art-music tradition, is another. "Capoeira" describes neither a movement form, nor a music tradition, but a particular combination of both.

6 Almost certainly, much longer. There are images showing dance in the Bhimbetka rock shelters in Devanagari, India dating from 12,000 years. The Paleolithic cave drawings at Lascaux and Niaux in France also contain examples of dancing and making music (3-8,000 BC). (http://www.wikipedia.org, accessed 27.7.12)

With some exceptions, musical instruments are played with the extremities: fingers, hands, feet and mouth. Dance is said to come from the middle of the body, the torso. It is often

more concerned with weight and flow than the exact position of body parts. Although some dance forms are, of course, concerned with rhythms and stylized gestures, at a more fundamental level, dance concerns reaching out and stretching one's physical limits, extending oneself into the largest and the smallest, the highest and the lowest, the fastest and the slowest. Musical instruments are often designed for control, efficiency and ergonomics. While control over movement is sometimes important, so is the opposite: the wild and the irrational. To function intuitively and synaesthetically, the MotionComposer should be able to associate a wide range of expressive movement with sound.

3 Coherent Mapping

The word "mapping" is used to describe the ways physical action and sound are related. There are many ways to "map" and while many are intelligible (particularly if an explanation is given), few are palpable. In other words, though we might understand that a certain action is causing a certain sound, this does not mean that were we to walk into the room knowing nothing about it, that we would sense that we are doing anything at all!

It is much debated in the world of interactive art whether palpability is a good thing. The argument goes, " interactivity should never be one-to-one"; meaning that clear, linear causality is boring. To this I say, "long live one to one!". What makes art boring is boring art, not the clarity of causal relationships. Theirs is a simplistic answer to a complex problem. As Abraham Maslow said, "If you only have a hammer you tend to see every problem as a nail".

3.1 Sensors

Our technology is based on video cameras. Depending on which data bus we are using, Ethernet or an industrial frame grabber, the cameras we use have a 1/4" or 1/2" CCD chip. This gives our system high resolution and low latency, both of which are very important to a strong synaesthetic reaction.

Many of the features that are most important to us when we gesture and dance, such as a feeling of weight, suspension and effort, are actually quite difficult to measure with video-based systems. Meanwhile, the computers and software systems available are not really very intelligent. Concerning human expression, they cannot distinguish the salient characteristics from the irrelevant ones. In spite of this, it is possible to find intuitive and palpable mappings. We have had children and adults, with and without disabilities, laughing with joy at the sensation of hearing their bodies turned into music. We have also given to people the ability to "play" a musical instrument even when they could not hold one in their hands.

3.2 Measuring Body Movement

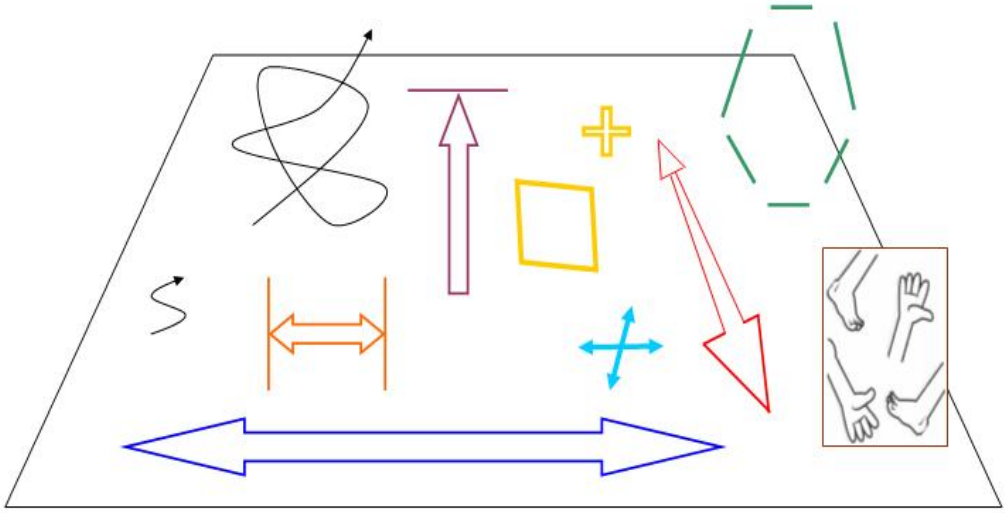
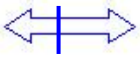
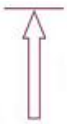


Figure 1: Measuring Body Movement

#	pictogram	description
1		**Small Movements -** When the body is still, our focus naturally goes to the small and precise movements of our fingers, hands, eyes, mouth, etc. Because these gestures tend to be discrete -- short and with clear beginnings and endings -- they strongly lend themselves to associations with discrete sounds.
2		**Gestural Movements -** These are the movements we usually think of as gestures and they are usually done with the hand, arm or head. We track them by measuring their dynamic. The data is modulatory in nature and gives a curve following the trajectory of the gesture.
3		**Large Movements -** Adults generally make large movements only during sports, when running for a bus or in a genuine emergency. In any case, large movements associate well with loud sounds and strong modulations. They can also be mapped as single impulses, or bursts of energy. We treat them as a separate kind of motion, with their own data stream. This allows us to calibrate the sensor so that the mover has the sense that there is no limit, e.g. the larger you move, the louder the sound, forever.
4		**Direction of Motion -** The activity feature of the motion tracking software we are developing delivers highly accurate direction-of-motion information. The combination of these two data, activity and direction, we call "flow". Flow differs from activity in interesting ways. It is possible, for example, to have high activity with low flow and vise versa. Perseveration, or back-and-forth movements, is common particularly with certain pathologies. Unconscious rocking or shaking, weight shifting from foot to foot, repeated head or hand movements may be

		involved. When tracked as motion, they reads as A,0,B,0,A,0... (movement in one direction followed by a momentary stillness, followed by movement in the opposing direction) and can be represented in music in a variety of ways.
5		**Stillness** - while often overlooked, is actually a special activity. It is not merely the absence of motion, since it generally requires special concentration on the part of the user. Nevertheless, it is something most people can do with little or no training. At first glance, it may seem to imply silence, but remember stillness is not necessarily passive and may in fact be better represented by a high, continuous sound, for example.
6		**First Movement Following Stillness -** When we wish to give our gestures emphasis, we often hold still for a moment just before or after gesturing. The first movement following a stillness is thus among the most convincing of mappings.
7		**Center-X -** Assuming we have a sense of expression or communication in our movement, then there a direction in the room dancers call "front". The location of the body in a line perpendicular to this direction is called center-X. It offers a one dimensional location-orientation and maps well to content, that is, to the assignment of sounds or transformations with a direction (like words in a sentence). You may assume, as we did, that 2-d or even 3-d arrays of content must surely be more intuitive since, after all, we live in a 3-d world. Many projects involving motion tracking begin with this assumption, and indeed, the motion *capture* industry is entirely based on it. It turns out, however, not to be as intuitive than you might think. While it can be useful, our absolute position in space or, for that matter, the absolute position of our body parts (see "Body-part Tracking" below) is simply not something we have a strong intuitive sense of in relation to sound control.
8		**Width -** is like expansion (which is not listed here). When we stretch out our arms or legs we grow in size. Increasing loudness is a simple option, but there are other sound transformations that may more closely resemble this action. For example, think of the formant transformations that occur as the mouth is opened wider and wider .
9		**Top** - height maps intuitively to pitch (up = higher pitch), but as with width, there are other implications as well. E.g. low = rumbling, tumbling, grumbling, growling vs. high = thin, flighty, suspended, stretched. Indeed, the transformations that occur in the voice as it goes from low to high involve more than just pitch!
10		**Points in Space -** Sounds may be placed in fixed points in space which you trigger by touching them. While extremely convincing, there are major problems with this approach. Reaching out and touching these points in space leads to a feeling of controlling a system -pressing buttons, etc. - something concerning our extremities. Also, the absence of a haptic response leads to understandable mistakes in playing (e.g. one often does not withdraw the hand sufficiently to re-trigger a sound event).
11		**Depth -** Motion towards the audience (closer to the camera) might imply brighter, sharper, louder vs. farther away which might imply muffled and muted. It is technically a bit difficult since it requires a very high overhead camera, a second camera or a depth-sensing camera and it

		is anyway not particularly effective.
12		**Body-part Tracking -** Another favorite of installation artists, and probably *the* favorite of musicians, is the idea to give different body parts different controllers, à la Theremin. Not only is this technically challenging - think of a twisting and turning body or the body of a person in a wheel chair - but it is not really very intuitive. This is partly due to the lack of haptic response and partly due to other factors.

Table 1: Measuring Body Movement

4 Conclusion

The trick in effective mapping is to engage the basic human instincts I mentioned at the beginning of this essay. This means looking at the things that music and dance have in common. Words such as *shudder, stumble, flinch, poke, fall, shove, wobble, sustain, undulate, crystallize, melt, vibrate, jolt, twitch, trudge, float* and *flutter* describe movements as well as sounds. This metaphorical approach is a good place to start.

Some composers we work with want to sit in front of their laptops (or other instruments) the entire time. Bad idea! The ones that keep jumping up and physically trying out their patches are the ones that produce the more intuitive musical environments. Take it from a dancer: physical, full-body movement changes the way we experience music and vise versa.

Acknowledgements

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