Camera-Based Motion-Tracking and Performing Arts for Persons with Motor Disabilities and Autism

Alexandros Kontogeorgakopoulos
Cardiff Metropolitan University - CSAD, UK
Robert Wechsler
MotionComposer, Weimar, Germany
Wendy Keay-Bright
Cardiff Metropolitan University - CSAD, UK

Abstract

The aim of this chapter is to discuss a range of computer applications designed to enable people with disabilities to interact through music, dance and the visual arts. A review of the main motion tracking algorithms and software environments is included as well as an overview of theoretical positions regarding the mapping of real time extracted motion features to sound, interactive music and computer-generated or modified visual content. The chapter concludes with rich descriptions of how the concepts have been applied to research projects undertaken with different groups of young people with motor limitations and autism spectrum disorders.

INTRODUCTION

The World Health Organization estimates that some form of disability affects one out of every seven people. This means that as many as 110-190 million people are directly affected by disability and many others are indirectly affected because of their responsibility as carers (SCRPD, 2012). People with disabilities disproportionately face social isolation and reduced physical activity as compared to their non-disabled counterparts (SGUN, 2010): These factors are major contributors to secondary health problems such as those associated with obesity and depression[1].

This chapter focuses on two distinct groups of people, those with autism and those with motor disabilities. They are described as a group because they meet diagnostic criteria, however, they are nonetheless diverse individuals. Identifying with these populations gives this chapter a distinct context for exploring camera-based applications. Furthermore, their inclusion in implementation and evaluation has provided a helpful framework for understanding the benefits of these technologies and for speculating on future work. In the body of the chapter we will describe the characteristics of these disabilities in relation to their significance in the design of the technologies and the relevance for music, dance and arts based programmes.

For most human beings dance and music are social activities and events that involve movement. For people with disabilities they can be additionally employed as therapeutic interventions, used to promote physical and emotional well-being (Muller & Warwick, 1993; Wimpory et al., 1995). Advances in technology, and particularly in Human Computer Interaction, have led to a number projects that offer novel conditions for enabling people with a range of physical, and developmental disabilities to engage in expressive performances, and to investigate the wider impact of such interactions on social communication. Camera-based motion-tracking is one such technology example that has been extensively explored in the last decade (Dixon & Smith, 2007). The most notable benefit of camera based motion-tracking is that is can support full unencumbered body movement, offering a more inclusive, open-ended, accessible mode of interaction and performance.

Camera-based interactive dance has had a powerful resonance among experimental artists and their audiences the last three decades. In 1995, Palindrome, then based in Nürnberg, Germany, began working with the computer engineer Frieder Weiss (the inventor of the Eyecon motion tracking system, which is discussed later in this chapter) and quickly gained a reputation as a pioneering interactive dance company[2]. Other early players in this burgeoning artistic trend included Troika Ranch, Company in Space, Die Audio Gruppe, John D. Mitchell, Armando Menicacci and Alien Nation. There were sporadic dance and technology conferences (The University of Wisconsin, Madison, 1992; Simon Fraser University, British Columbia, Canada, 1993; York University, Toronto, Canada, 1995; Arizona State University in Tempe, Arizona, 1999), but it was not until The Monaco Dance Forum began sponsoring bi-annual of dance and technology conferences (2002, 2004 and 2006) that the players began to share their notes more widely and an understand grew that a larger world of interactive performance that was arising.

Similarly in music, artists such as David Rokeby in 1989, Bruno Spoerry in 1991 and Todd Winkler in 1997 began using computer vision techniques implemented in the Very Nervous System (developed by Rokeby), in their interactive compositions and installations (Chadabe, 1997; Winkler, 1997). Luciano Berio has composed music using camera-based interaction using the Eyesweb software in his opera Cronaca del Luogo in 1999 (Camurri et al., 2004). Since the Digital Dance Seminar held in Copenhagen in 1996, various artists including Wayne Siegel have used computer vision software, such as the Big Eye (developed by STEIM, in Amsterdam), in music studies and compositions (Siegel & Jacobsen, 1998; Siegel, 2009).

Much of the research into camera based motion-tracking focuses on bodily input as a means of control, rather the amplification of outputs as observable forms of gesture and communication. However, motion-sensing technologies permit a more extensive range of possibilities for personal and shared expression. Of particular significance is how natural, unconscious, rhythmic responses might lead to the sense of autonomy, self-awareness and harmony with others, which is in itself a highly personal, social experience.

The Motion Composer project has discovered that gestural movements, which are not necessarily directly linked to semantic meanings, can serve as an expressive outlet for individuals who experience challenges in conforming to cultural or societal norms of expression (Billerbeck, 2012; Acitores and Wechsler, 2010; Wechsler, 2012). For people with autism spectrum disorders, who are characterised as having poor social communication skills, these interfaces can trigger creative sensory responses, whereby people can synchronise and move in resonance with sounds, music, and even graphical outputs (Keay-Bright, 2013). When we sense that our movement is in time with the movements of others, this can lead to feelings of empathy and harmony (Godoy & Leman, 2010).

Each of the projects described in this chapter have different properties in design and implementation, from one-off installation artworks, to orchestrated community performances and simple apps, downloadable for consumer use. However, they share similarities in that they place the user at the heart of the experience, allowing them to trace, map and mirror actions either individually or as a group. This mirroring of behavior is crucial to development. It has been scientifically and empirically proven that mimetic activities that foster expression and musicality, are not only a source of pleasure, but they are known to strengthen relationships, stimulate conceptual development and imagination, as well as personal identity (Dissanayake, 2000; Gallese, 2005; Foster, 2005).

Neuroscientists have discovered that the mirror system is grounded in brain regions where the perception of action and the execution of action partly overlap. The mirror system offers a neuronal basis for understanding how people can understand each other's intentions without having to rely in building a mental representation, or needing to construct a theory of mind (Gallese and Goldman, 1998; Gallese, 2005). This is of particular significance for designing interactive performing arts experiences. As well as exploring the dynamics of interaction afforded by the technologies as personal instruments, we can extend our investigations to include co-located interaction resulting from the capacity to mirror behaviour.

The authors of this chapter have been investigating these theories, applying them in a variety of projects that explore how camera-based, motion-tracking technologies could provide access to expressive, performing arts for people with disabilities. The technologies are non-invasive and do not require a pre-determined skills. The case studies describe the importance of unencumbered body movement in providing possibilities for self-discovery, which can ultimately lead to the desire to perform with others. Though our studies we propose that technology can be a socially inclusive medium for improving well-being for people with disabilities. We will draw on examples of arts and music therapy that have evidenced particular benefits where the goal is to promote self-expression.

The idea of the physical interface is described in the next section as we focus on computer vision algorithms and methods and to make the most common camera-based motion-tracking systems used by artists and designers. We will also discuss mapping strategies, which refer to the association of gesture to visual or sound events generated by the computer, and their importance in interaction design. Finally, we draw on case studies that shift the emphasis away from the technologies towards the real world experiences of people with motor disabilities and autism spectrum disorders as they have engaged in highly individual and unforeseen ways. To conclude we explain how these studies have inspired our more recent direction.

CAMERA-BASED MOTION-TRACKING FOR ARTISTS AND DESIGNERS

Capturing information about body movement demands a data acquisition system that will measure certain physical properties, sample and digitize them, then send the information to the computer for further processing. A complete data acquisition system may include sensors for converting physical parameters into electrical signals and a signal conditioning circuitry for converting these electrical signals into an appropriate form that can be processed at the sensor interface. The sensor interface finally converts analogue signals into digital code and transmits them using a digital protocol to the final computer system (Miranda Wanderley M. 2006).

In the last decade, within the field of interactive performance, various technologies have been developed and implemented for motion tracking. Siegel gives an overview adopting a convenient taxonomy firstly suggested by Alex Muder (Siegel, 2009). He classifies these systems in three categories: (1) inside-in systems where a variety of sensors like flex sensors, accelerometers, piezoelectric sensors and wireless transmitters/receivers are used for tracking fine motor movement; (2) inside-out systems where sensors such us a compass or a camera are utilised to sense external sources such as light-emitting diodes, and (3) outside-in systems where external sensors such as infrared sensors, ultrasonic sensors, cameras, microphones and even touch sensitive dance floors are employed to measure source or markers placed on the body.

In this section we will focus on camera-based motion-tracking. A camera, one of the most common and affordable sensing devices, is used to measure the human body movement and performance gestures. A great advantage of this technology, especially in artistic and design contexts for people with disabilities, is that it does not have to be worn. Camera-based motion-tracking technologies have been used in interactive performance since the 1970s (Krueger, 1985; Siegel 2009).

Computer vision

Computer vision is a complex scientific field with many practical applications, including interactive multimedia art performance. The components of a complete computer vision system include a radiation source, a camera or an optical system to collect the radiation, as well as the photosensor or an array of photosensors to convert the received radiation into an electrical signal. This signal is then sampled and digitized to form a digital image as an array of digital numbers (Szeliski, 2009). The system architecture is very similar to the generic data acquisition system previously discussed. The signal processing and the pattern recognition that occurs in the final stages allow the whole system to make useful decisions on the sensed digitized image.

In this section of the chapter we discuss how computer vision can be used to capture human gestures in a performance situation in a controlled environment such as the performance stage. Camurri presents a description of the most common methods employed computer vision systems for visual gesture recognition (Camurri & Moeslund, 2009). Levin likewise presents similar elementary computer vision techniques accompanied by their source code, widely used interactive artworks (Levin, 2006). Camurri's research explores expressive gestures with a focus on dance and music performance. The computer vision techniques employed in this chapter share similar processes. According to his investigations, gesture-based sound and graphic control employ simple motion feature extraction algorithms and pattern recognition methods. Since the goal is real-time processing, this is an essential requirement. Interestingly, he also states that "simple features and recognition methods often produce inaccurate results, but this maybe compensated by the fact that visual gesture-based sound control is often used in new interfaces where inaccurate results might actually be a quality of the system. This is especially the case in artistic context" (Camurri & Moeslund, 2009, pp. 464).

According to his publication, in a typical computer vision system used for interactive performance during the feature extraction stage, silhouette-base features, appearance-based features and motion-based features can each be calculated by basic algorithms that process the pixel values of the digital image arrays. Common silhouette extraction is accomplished by subtracting the input image from a static background image and then by comparing each pixel with a threshold value in order to derive a binary image. Small imperfections, which appear as single noise pixels disjointed from the white background or the black silhouette can be removed by two-dimensional digital filters. These filters are often simple median filters. A component analysis algorithm can be followed to group the connect pixels into binary areas called Blobs and then remove the unnecessary ones according to their position, size or other easily derived characteristics. From the calculated silhouette, it is very simple to obtain the centroid with pixel averaging or other useful features such as the containing rectangle of the silhouette. We may also apply this process in particular regions of interest within the initial image or even on regions determined by dividing the final silhouette into smaller regions.

Appearance-based features, such as the position of the moving object, can be extracted by comparing its colour with the background. In this case the requirement for a static background is not essential. Coloured markers or appropriate clothing can facilitate the extraction. Normally the *Hue-Saturation-Intensity* colour space is used instead of the *Red-Green-Blue* when the pixel colour is measured. In that case the minimum and the maximum *Hue* and *Saturation* values of the object to be tracked can define whether a pixel of the image is part of it or not. As a result, it is possible separate the information from the background and consequently we can easily compute features such as the ones described in the previous paragraph.

With motion-based features, once again the background does not necessarily have to be static. In this process, the incoming image frame is constantly subtracted from the previous one and the new image is thresholded. Hence the moving pixels appear as black pixel regions and their number give us precise quantitative information about the amount of motion. The regions indicate the exact location where the action happens. Moreover, if we compare the calculated amount of motion in predefined regions with a threshold, we can detect if any kind of motion activity is taking place.

Camera-based motion-tracking systems used by artists and designers

Here we present some of the most common computer languages, software frameworks and applications used by artists, designers and musicians for camera-based motion-tracking. We can classify these tools in three basic categories: text programming languages, visual programming languages and software applications. The programming languages presented below are feasible for introducing programming in the context of music, art and design. This is a vital requirement for artists and designers who need a simple but expressive environment for experimentation and creative coding. The design process followed in the case studies presented in this chapter would not be realistic without the help of appropriate programming languages.

Each programming language encourages a specific mode of thinking. Reas and McWilliams remind us that, "each programming language is different material to think and work with" (Reas, McWilliams & Barendse, 2010). From the variety of text programming languages and software frameworks, OpenFramworks and Processing have probably been the most popular among artists, designers and musicians for camera-based motion-tracking.

OpenFrameworks[3] is an open source C++ framework developed for creative and artistic expression. It integrates several software libraries including OpenCV[4] developed for real time computer vision. OpenFrameworks is used predominantly for the development of interactive audio-visual work. It provides a clear existing structure so the programmers can easily build stable and robust applications. A decent presentation of useful OpenFramworks programming guidelines and examples can be found in (Noble, 2009).

ofxOpenCv is an add-on library for OpenFrameworks that make use of OpenCV and provides a set of classes for contour detections and tracking. All basic algorithms presented in the previous section can be implemented and explored using methods like ofxCvGrayscaleImage::absDiff() for frame subtraction, ofxCvGrayscaleImage::threshold() for thresholding a grey scale image and convert it into a binary one, ofxCvImage::blur() to reduce the noise detail, ofxCvImage::setROI() for setting regions of interest in an image, ofxCvColorImage::convertRgbToHsv() for converting the image RGB values in the Hue, Saturation and Brightness colour space. Methods and classes variables used for contour finding and tracking are the ofxCvContourFinder::findContours() method, the ofxCvContourFinder::draw() method for drawing the detected contours, and the class variables ofxCvContourFinder::ns for returning the number of contours found, the vector ofxCvContourFinder::Blobs for returning each contour found, ofxCvBlob::area for returning the area of the contour, ofxCvBlob::nPts for returning the number of points that are contained within the contour, ofxCvBlob::boundingRect for the bounding rectangle of the contour and ofxCvBlob::centroid for returning the x and y positions of the contour centroid.

Processing[5] is an open source programming language built in Java, specifically designed for the development of interactive art and design projects. It includes an integrated development environment (IDE), which simplifies the programming of applications. It also comes with many downloadable libraries including one for computer vision, which uses the OpenCV library. Even without the library, the language has a basic video library and let you process pixel information. In (Levin, 2007) some illustrative and descriptive code is presented for detecting motion, presence and for tracking bright pixels from the frames grabbed with the camera. The given code demonstrates practically how with simple signal processing operations on pixels you can quantify the amount of movement using frame-differencing, detect presence using background-subtraction, determine whether a region is contained with the contour of a moving object, and track the brightest pixel of the incoming video image.

Processing implementation of some of the core elements of openCV library has very similar methods and class variables to the ofxOpenCv library for OpenFrameworks. The OpenCV class in Processing contain methods such as ROI() for setting the region of interest, absDiff() for evaluating the difference between two frames, , convert() for converting colour spaces, blur() for smoothing and filtering the image, threshold() for applying a threshold and getting a binary image and the Blobs() for detecting the contour. The last method returns a list of Blob objects where we can extract information about the area of the contour in pixels, the centroid and the contained rectangle.

Visual programming languages offer an alternative more graphic programming paradigm: instead of writing lines of text, you create diagrams by connecting basic objects or modules on the screen.

This networking of objects is similar to patching analogue gear in the old studio setups. Computer vision objects based again on the openCV library are available on visual programming languages like on MAX MSP[6] with the cv.jit implementation and on PD[7] with the Pd_OpenCV implementation. Simple colour tracking or other basic computer vision algorithms can be implemented on those environments even without the use of these more advanced libraries. SoftVNS software is a widely used generic toolbox for video processing in MAX initialized firstly in 1983 as an interactive sound installation. Cyclops is a convenient single MAX object, which divides the screen into a number of regions and reports the motion activity. All these systems run in the visual programming environment and therefore some basic visual programming is necessary in order to accomplish motion tracking. Among all the previous visual programming languages including the relevant computer vision libraries and externals, Eyesweb[8] probably stands as the software environment with the most advanced motion-tracking features. It is essentially an open platform, developed by the InfoMus research centre for the design and the development of real-time multimodal systems.

Eyecon[9] software is a commercial computer vision application for Windows operating systems, specifically designed and developed for interactive dance performances by the Palindrome Inter-Media Performance Group (Wechsler, R., Weiß, F., & Dowling, 2004). It offers very intuitive features that let the users to graphically define lines, zones and fields wherein the conceived interaction is taking place. For example a performer can touch one of these virtual lines, which are drawn in order to match the architecture of the performance space and send MIDI or OSC data to a host application to generate multimedia content. Other interesting motion features that Eyecon calculates from the input signal are the centroid, which supports colour specific tracking, the direction of movement, the area of the rectangle containing the silhouette and the amount of motion on predefined zones. It is interesting to mention at this point that the MotionComposer project[10], which will be presented on the next section, used Eyecon for its prototyping, and employed Eyesweb as the software kernel for the final device (InfoMus now a partner on the MotionComposer Project and is currently developing not only the motion tracking software but also the custom 2d/3d camera component for the device).

Similarly, the STEIM Institute in Amsterdam developed JunXion[11], a useful commercial data routing software application that supports basic motion-tracking functionalities. It integrates part of BigEye, software developed by the same institute, available only for old Power PC Macintosh computers. The simple Graphical User Interface of JunXion lets the user perform easily colour tracking and extract motion features such as the coordinates of the centroid or the width and height of the rectangle containing the silhouette. These features, like in the Eyecon system, can be processed and sent to the output of the system as MIDI or OSC data.

DESIGN AND EXPLORATION OF MAPPING STRATEGIES

Mapping in Interactive Computer Music and Computer Graphics

In this section, we will address the question of mapping motion features into music and visual material. The term mapping denotes the association of human body gestures to sonic or visual parameters that control the generation of the audio-visual content by the computer. Two decades ago Rowe proposed an oversimplified, but still useful, conceptual three-stage model that describes the functionality of an interactive composition system (Rowe, 1992). The data acquisition presented in the previous section is described as the sensing stage. The second stage is described as the processing stage, which is core to the system. During the processing stage the computing system analyses the received performance data (i.e. the motion features) and algorithmically evaluates the system outputs. The link of the analysed data parameters into composition procedures, or directly into sound synthesis input parameters, is called mapping (Miranda & Wanderley, 2006). The final response stage renders the music outputs. An overview regarding the modeling and classification of interactive music systems can be found in Drummond, (2009).

The model described above can be generalized and used for any type of interactive multimedia system, including the ones described in our case studies, which were designed for people with autism and motor disabilities. In those systems the response stage sonically and visually synthesizes the parameters generated by interaction. Mapping relationships link simple motion features like the centroid to the pitch of a sound oscillator or to the parameter of a computer generated geometric shape like the width of a rectangle.

Mapping can take place between the performance data and more complex musical or visual processes. For example, in interactive music composition, the compositional methods can be *generative* - algorithmic generation of musical output, *transformative* - modification of existing musical material, or *sequenced* - usage of pre-recorded musical material (Rowe, 1992). According to this classification, a motion feature, such as the amount of motion or presence in particular regions, can be mapped into a parameter. This conditions the degree of a minor scale and generates random arpeggios or control directly a digital audio effect parameter, which process a sound sample. Alternatively it processes into some specific notes of a sequenced musical pattern such as a melodic phrase. Some of these methods have been employed in the MotionComposer workshop presented as a case study in the end of the chapter. Winkler suggests numerous composition and analysis algorithms that can be employed in the context of interactive music performance (Winkler, 1998).

According to Hunt (Hunt & Wanderley 2002), in explicit mapping strategies when we have two sets of parameters there are three possible mapping strategies: one-to-one, one-to-many and many-to-one. Other researchers have proposed similar classifications in the past. Moreover, several multilayer approaches have been suggested with layers being interface specific, abstract or perceptual and system specific. These mapping strategies have been introduced mainly for digital musical instruments and not for interactive performance. Some useful considerations on mapping motion to music or to sound can be found in the work of Siegel, Winkler and the third author of the present chapter (Siegel, 1999; Winkler, 1995; Wechsler, 2006). In the following section we propose a mapping scheme considered in the MotionComposer.

Coherent Mapping From Dance to Music

There are many ways to map physical actions to music and while most may be intelligible, particularly if some explanation is given, few are palpable. In other words, although one might be able understand that a given action has a given effect; this does not mean that were one to walk into the interactive environment, without explanation, that one would recognize that anything special is taking place. Thus, in order to construct environments that a person can use intuitively, and which have a noticeable effect on the user, considerable care and analysis in the design process is needed. The following table describes 11 body movement/shape parameters, which are used by the MotionComposer project[12] (figure 1).

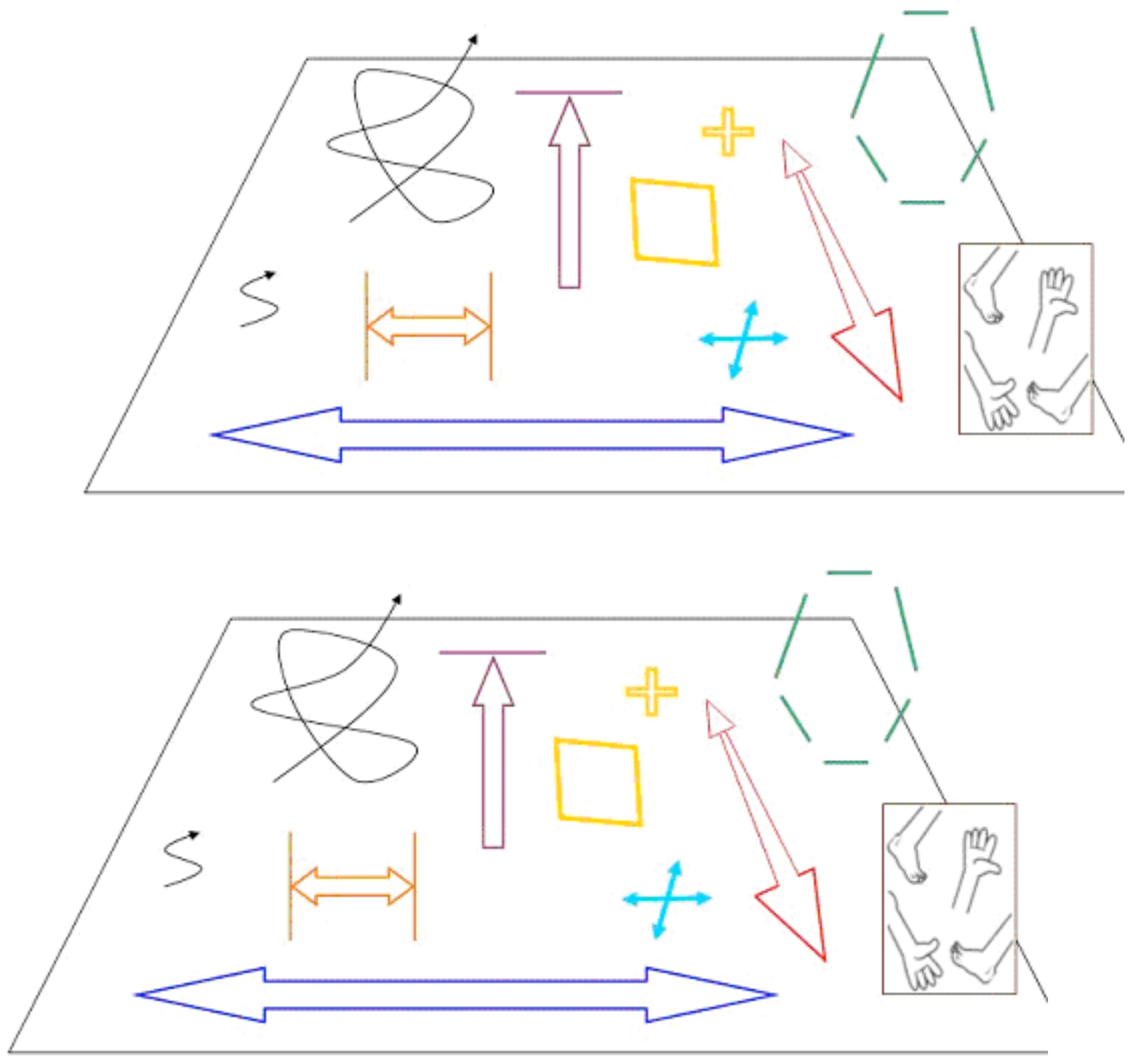
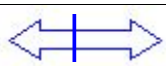
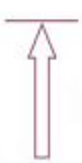


Figure 1: Body Movement Parameters

Table 1: Table of Human Movement Mapping

#	pictogram	name	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 are discrete -- with clear beginnings and endings -- they lend themselves to association with discrete sounds, for example single notes on a scale or in a melody or sound particles.
2		Gestural Movements	These are the typical movements we do with arms, hands and head (though any body part may be involved). They are fairly discrete, but in contrast to Small Movements, they are tracked by measuring their dynamic as continuous modulations, curving up and down along with our movements.

3		Large Movements	Adults generally make large movements only during sports, running for a bus or in a genuine emergency. In any case, large movements are associated with loud sounds and strongly felt modulations of all kinds. They can also be mapped as simple "bangs", or bursts of high energy. We treat such movements as a separate kind of motion, i.e. one with its own data stream. Large movements are calibrated in such a way that the mover has the feeling that there is no limit that can be reached. As with dance or any body work, we do not want people to sense limits, but rather have the feeling of limitless possibilities.
4		Direction of Motion	The activity feature of the motion tracking software we are developing delivers a value for direction of motion. The combination of these two data we call "flow". Perseveration, or back-and-forth movements, is common in general, but particularly with certain pathologies. Unconscious rocking, shaking or shifting of weight from foot to foot, repeated head or torso movements, as well as hand, foot, arm or leg may be involved. Translating such unconscious movement to music can be a useful therapeutic device.
5		Stillness (not moving)	While often overlooked, stillness is actually a special activity. It is not merely the absence of motion, since it generally requires concentration with specific intent. Nevertheless, it is something most people can do without much practice. 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 continuous sound.
6		Center-X	Assuming we have a sense of communication in our movements, we usually assume a direction in the room we call "front". Movement perpendicular to this direction we refer to as center-X. Center-X offers a one dimensional location-orientation and maps well to content-bearing sound elements.
7		Width	Width is like expansion. 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 changes that occur as the mouth is opened wider and wider while speaking or singing.
8		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, when a voice goes from low to high it is not simply the pitch that changes!

9		Points in Space	The EyeCon software is perhaps best known for its ability to place sounds at fixed points in space which you then trigger by touching them. While extremely convincing, there are major problems with this approach. It does not tend to give a feeling of hearing movement (synaesthesia). Reaching out and touching these points in space leads to a feeling of controlling a system, pressing buttons, etc.. This is something we do with our extremities, fingers, hands and feet and leads to more deliberate and less intuitive involvement.
10		Depth (center-Y with overhead camera or distance from sensor with 3-d camera)	Closer to the camera might imply brighter, sharper, louder vs. farther away which implies muffled, muted and vaguer Combined with center-X, it offers the possibility of a 2-dimensional array (around the room). While plotting positions in the room may be a favorite of installation artists, to us it is one of the least important. Not only is it technically challenging requiring a very high overhead camera (it is a myth that wide-angle lenses solve this problem), but it is not a particularly intuitive mapping.
11		Body-part Tracking	A favorite of video games is the tracking of individual body parts in space. As with positioning in the 2d space, it may sound logical, and it is certainly an interesting exercise, it is not really a particularly intuitive approach.

While a physical action may cause a sound, it may also stop a sound, which is already playing. Also, it may alter it in some way. These represent Boolean variables, but there are also continuous variables to consider as well. Thus, even after one has identified the parameters of the body and of the music which one wants to use, the task is not complete.

The complex psychological interdependence between the elements in a given mapping make it useful and necessary to look at body movement and music control separately, and yet finally, and most importantly it is their combined effect *in vivo* that is important.

For example, if I were to reach out my hand it could play a sound, say an "ooooh" sound, when I remove my hand the sound stops. Now imagine instead of the "ooooh" sound, we hear "dooooo-eet"; that is, now we have an accent at both ends of the sound ("d" when my hand is first extended, and "eet" when it is removed). The person extending the hand is now, through this simple change, much more likely to feel "part of" the sound, and have a sound-movement experience.

Thus, by using a synthesis approach, as opposed to analytic, one can reverse engineer these observations back to their constituent parts. Instead of merely assigning movement parameters to musical ones, one can instead think in terms of the qualities of a human experience. For example, beginning with descriptors such as *fling, shuffle, bob, twist, shudder, slink, slouch, prickle* or *suspend*. These words describe sounds as well as movements and while perhaps difficult to define precisely, it is intuitively clear what meant. By searching for such qualities, which overlap music and movement, and giving the user a role in them, responsive and intuitive systems are far more likely to arise.

CASE STUDY: MOTION COMPOSER

The second author on this paper is choreographer of the Palindrome Dance Company, a pioneering group in the area of motion tracking technology with live dance. The idea to apply the same basic technology to the needs of persons with disabilities is at the centre of the MotionComposer project, which began in 2010. In 2011, then based at Bauhaus University, MotionComposer received a 100,000 Euro grant from the German Ministry of Technology and Finance to develop an easy-to-use device that turns human movement into music. With additional partners[1], the project is scheduled to produce its first prototype late in 2012 and serial production starting in 2013.

The work has progressed with the help of the first author on the chapter, as well as other engineers, music and dance therapists and the composers Marc Sauter, Pablo Palacio, Dr. Andrea Cera, Adrien Garcia, Dr. Dan Hosken, Pablo Palacio, Goran Vejvoda and Dr. Andreas Bergsland.

Description of the MotionComposer Device

The MotionComposer (figure 2) will contain a dedicated microprocessor (mini-computer), and hand-held tablet controller (with video monitor and control panel). It will be equipped with a custom 3d sensor, providing depth information as well as low-latency, high-resolution video.

[1] InfoMus, directed by Dr. Antonio Camurri, Dipartimento di Informatica, Sistemistica e Telematica, Università degli Studi di Genova, are developers of the custom 3d motion tracking hardware and software. IMM-Holding, based in Mittweida, Germany will be the manufacturer.

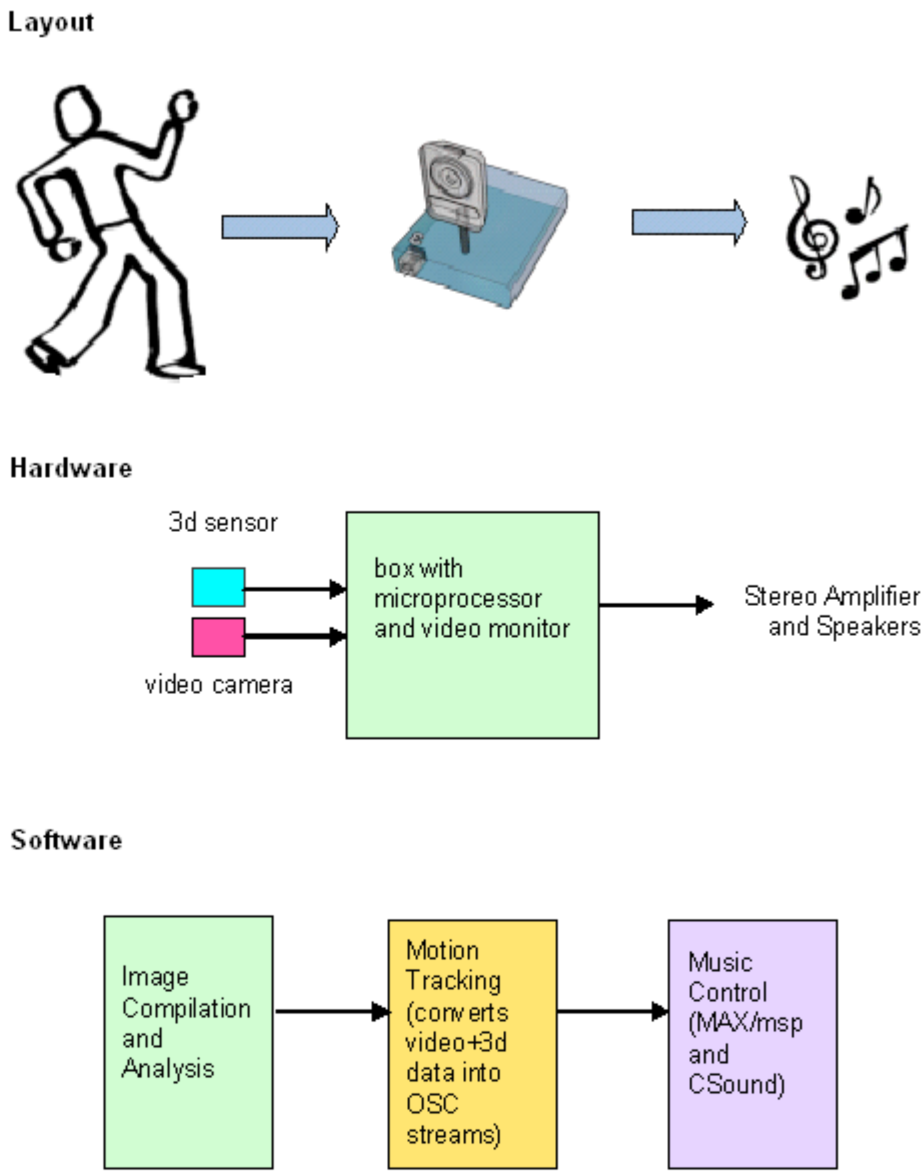


Figure 2: MotionComposer System Layout

The mappings and musical transformations form the heart of the innovation. Four separate DSP environments control music. This means that the user will be able to choose between these four as each gives a unique body-music experience. Each environment can operate with a variety of sound libraries, thus, for example, the environment called "Melodies", can be used to control a piano, sitar, oboe, etc. With its unusually sensitive sensor, even eye movements and small finger movements are sufficient to play music.

People tend to think of the MotionComposer as a new kind of musical instrument, one that is played in the air like a Theremin. This is only partly true and the difference is important to understand. For one thing, musical instruments are generally played with the extremities, the hands, feet and mouth. However, dance, it is said, comes from the centre of the body, the solar plexus. The MotionComposer should respond to, and encourage, many different kinds of movement. Also, musical instruments are generally built for convenience of playing, for reasons of movement efficiency and ergonomics. If our goal is to animate movement, then one might have an opposite motivation and want to sometimes require large movements.

But the larger point is that the sense that music is coming from us is not quite the same thing as causality. Generating an engaging dance-music experience for the user involves more than this. For example, while there is a role for *dance generating music*, there is also one for *music generating dance*. In other words, the actual degree of control that the user has over the music is only one of a number of factors that determine how engaging a given interactive system will be.

The musical environments are designed to give varying degrees of *musical help* to the user. For example, by using Markov Chains, notes are pre-selected according to which tend to sound better together. Key changes, changes in degree and even entire scale changes are predicted according to the user's activity. The result is (or can be, if it is so desired) that the instrument will sound musical no matter how it is played.

Rhythm is also supported. Rhythms, and particularly drums are powerful motivators for human movement. They lead us to move more, and keep moving longer than we otherwise would. This is valuable for everyone, but particularly for those who suffer from a deficit of movement.

It was long believed that interactive music environments could not be rhythmic - not for technical reasons, but for artistic ones. Since it is easy to synchronize one's movement to a beat, then there is essentially no way to tell whether the player is following the music or creating it. Indeed, the more accurately a performer plays, the *less* interactive he or she will appear since moving to a beat is what one expects from a traditional movement-following-music setting. For the player's interactivity to be convincing, he or she would need to play off the beat, which generally sounds terrible. Hence, there is a catch22: as soon as you succeed you fail. MotionComposer approaches interactive rhythm with a three-layer strategy:

Layer 1. The pulse, or groove of the music is not completely controlled by the user. The user initiates it, adds accents to it and alters it by degree, but their control over the pulse itself is illusory.
Layer 2. The music adapts to the user's activity, both by their dynamic and according to the density of notes or hits they play per unit time. As they play more, they are "helped" as additional instruments join in with their playing.
Layer 3. Every hit they make is audible, this is important. The trick is that they are quantized, or fit into a rhythmical matrix. If for example, a hit is made 180° out of phase with the downbeat, then it is heard as an upbeat. There are also drumming techniques such as flames and ghost beats that allow one to play at any time, and still be rhythmic.

Workshops

In order to gather essential experience for the development process, MotionComposer conducts frequent workshops. Working with primary care givers, therapists and persons with a variety of disabilities, a number of one to two-week workshops have taken place:

1. Workshop with children with disabilities, organized by Dr. Alicia Acitores, sponsored by Fundación Música Abierta, Valladolid, Spain, March 25-30, 2010.
2. Workshop at Schule am Burkersdorfer Weg, Dresden, Germany Oct 31 - Nov 5, 2011.
3. Workshop in Valladolid, Spain with persons with disabilities, students and therapists, 2-5.5.2012.
4. Workshop in San Fernando, Spain with persons with disabilities and therapists, 6-12.5.2012.
5. Workshop with four composers in residence, at SEAM, Franz Liszt College of Music, Bauhaus University, May 23-29, 2012.

6. On-going workshop at Palucca Schule, Dresden, Germany, Sept 19, 2012 until Spring 2013.

The types and severity of disabilities among participants at workshops varied and included Cerebral Palsy, blindness, autism as well as other mental and physical disabilities with severities ranging from mild to severe. In general, groups include twelve people with disabilities, plus therapists, teachers and other care-givers. The work begins with a group warm-up session. This is followed by smaller group work in the interactive environments. With one or two motion tracking environments in separate rooms, this individual session included 2-4 persons with disabilities and lasted 15-45 minutes. At the end of all the individual sessions, a final group session occurs in which users sometimes performed what they had done earlier. Finally, there is a de-briefing at the end of each day for the professionals.

While no scientific studies have been conducted, reports on the results have consistently offered strong support (Acitores, 2010; Dietz, 2011; Wechsler, 2012; Bilderbeck, 2012). The following three stories are anecdotal:

D., a 35 year-old mentally disabled man, shifted his weight almost constantly from one foot to the other. When we made these movements audible in the form of interesting sounds, he stopped and smiled as he became aware that he had been moving. He then began experimenting with his until then unconscious habit of movement.

S. is a 45 year-old man who has spent his life in a wheel chair. He loved the piano, but could never play one since he lacked the use of his fingers and had restricted arm movement. He was given the chance to play a piano solo using head, arm, mouth and eye movements.

A. Spanish therapist made an environment of different animal sounds, which were triggered according to where one went in the room. Since playing the sounds depended on continued movement, and the children tended to stop moving once they discovered a hidden animal. The therapist explained to the children that they needed to "pet the animals" in order to hear them. The children understood at once what he meant and began making petting motions whenever they found an animal. Videos and other information are available online (Dietz, 2012).

Melodic Walk: A Simple Interactive Composition for the Motion Composer Project

Melodic Walk an interactive composition or an interactive musical environment created at Bauhaus University in Weimar in 2012 (Kontogeorgakopoulos & Kotsifa, 2013). As every other composition created during the MotionComposer workshop, the overall design was informed by observations on a daily basis and by aural feedback given by the participants or the specialist accompanying them. Hence, various groups of people with disabilities who tested the prototypes through the workshop participated on the evolution and influenced the final presented form of the interactive system. During the last day of the workshop, one participant who demonstrated a clear enthusiasm for the composition was asked to perform it freely and spontaneously without any rehearsals. The entire group of participants had the choice to perform one of the pieces composed by the four invited composers.

The open-form musical piece was initiated by one or several improvised motifs played and recorded by the participants on a small common keyboard linked to the interactive software via MIDI. These motifs where then triggered and performed by their bodily movements and hand gestures. A set of few virtual lines created on the motion-tracking software defined the timeline of the music. The participants were able to move back and forth in space, touch the lines in different points and perform their pre-composed melodies on the input device according to their own pace and rhythm. The melodies and the small music phrases became the basic cell of the interactive composition. Therefore these basic cells served as the initial material for the harmonic formation, the texture and the motivic treatment and evolution of the performance.

The line segments containing the melodies could be spatially arranged, organised and composed in many ways, which defined the musical architecture of the work. Musical compositional devices like, retrograde, inversion, sequencing, the canon, and phasing, may naturally be expressed by designing and carefully positioning line segments. In one of the versions of the compositions performed in the last day of the workshop, simple harmonic content was generated by superimposing and transposing a line that controls a different musical instrument or sound synthesis algorithm on top of itself. Moreover, sustained pitch centres where obtained by using dense delay-based digital audio effects. Echo and artificial reverberation algorithms gave a modal character to the composition by offering drone type effects. The participants were free to discover interesting zones on their initial phrase and undulate or locally explore their pitch properties accompanied by sustained notes coming from the same music material.

Basic electroacoustic music techniques helped to craft further the in performance and engage more the participants. The presented version of the composition was based on a simple narrative. An eastern folkloric "magical" atmosphere influenced the sound design and the pitch-class set of the music. An invented scale with clear traditional references has been used as the basis for the construction of the motifs. Motion features like the centroid velocity altered the timbre by controlling various parameters of the synthesis algorithm. It also slightly detuned the notes of phrases in order to intensify the illusionary aspects of the narrative. The amount of motion of the performer was mapped to the cut-off frequency of a lowpass filter processing a white noise signal in order to simulate the sound of the wind. The performers, by slightly swinging the lower parts of their bodies could control this environmental sound effect. This functionality was essential for certain participants who preferred to perform gentle movements than exploring performance space and constantly move from location to location. Further electroacoustic explorations have been devised too but their presentation is not necessary on this part of the chapter.

The interactive composition was initially tested with a set of familiar German melodies chosen by the participants or by their therapist and recorded by the first author of the paper. During the first rehearsals the participants were very curiously exploring the responsive space but soon seemed to lose interest, especially when they discovered and learned how to perform the given melodies correctly. Surprisingly, it was observed that it was far more stimulating to recall and interact with their own melodic material played and recorded by themselves. However, since they were not trained musicians, their melodic choices where not always very effective for a live performance. The specialist accompanying them had formal musical training and helped them to articulate melodic phrases with appropriate length and clearer musical gesture based on a simple tonal idiom. A scale mapping or other simple interactive composition transformation algorithms would facilitate significantly the motivic construction. Rowe and Winkler present a range of small compositional algorithms that automatically ornament, locally transpose, add tremolo or add other type of events on the melodic input (Rowe, 1992; Winkler, 1998). This type of development consists a priority for future improvement.

The possibility of aesthetic success should be high on this type of interactive performances. All the motion composers developed interactive compositions that met this necessity. Since the target audience included people with impaired muscle coordination and a range of disabilities, such as autism and cerebral palsy, the complexity of the developed systems design was kept to a minimum. Consequently, the audience members were not afraid to explore it creatively by producing and performing small musical pieces. Notably, they engaged with original creative musical exploration where they felt they had ownership over the artistic outcome.

CASE STUDY IN PARTICIPATORY DESIGN: SOMANTICS

Somantics uses touch and gesture inputs to promote exploration with sensations such as squash, stretch, push, pull, press, reach, tap, tickle and so on, where input action and system reaction are closely matched in a visceral, bi-directional feedback loop. Camera and projector set-ups enable users to capture, observe and create images with their bodies. Observations of the software in action have shown an increased interest in using dynamic gross motor movements and rhythm, creating possibilities for empathic, co-located interaction. Somantics requires no previous experience of technology. The abstract design and unencumbered bodily interaction make it possible for children and adults to discover meaning through moving together or observing one another's actions. Essentially, the goal has been to trigger imaginative responses and expressive communication rather than to teach skills. The following section describes how the users, who would not normally be included as stakeholders in the design process, have generated ideas and informed refinements to the system on the basis of their engagement with prototypes. In order to provide the reader with a perspective on the unique context for the design and appropriation of Somantics, we provide a brief overview of autism spectrum disorders.

Autism Spectrum Disorders

Autism is defined as a neurodevelopmental disorder in which a person demonstrates persistent deficits in (A) social communication and interaction across contexts, which impact on social-emotional reciprocity, non-verbal communicative behaviours, developing and maintaining relationships (B) repetitive patterns of behaviour and interests, which impact on speech, motor movements and object use.

These repetitive activities, the need for sameness and literalness enable autistic children to manage levels of over- or under- stimulation encountered every day from changing environments, providing them with a sense of control. However, when unpredicted and novel routines arise, heightened anxiety and social withdrawal often emerge, which affect the ability to engage in personal, meaningful and pleasurable interactions (Keay-Bright, 2012; Quill, 1995). Furthermore, the nuances of social interaction have a dynamic and unpredictable quality that can lead to confusion and distress (Quill, 2000).

Recent updates to the diagnostic criteria for autism now include hyper- or hypo- reactivity to sensory input or unusual interest in sensory aspects of the environment. This sensory dysfunction can manifest in adverse responses to sounds or textures, excessive touching and smelling, indifference to pain and a fascination with lights and violent movement (DSM 5, APA 2011). Sensory differences in the tactile, vestibular and proprioceptive sensory areas, which affect touch, sound and movement, can cause pain or discomfort resulting in higher levels of anxiety, hyperactivity or challenging behaviours (Bodgashina, 2003). The latter challenges contribute to an unusual perception of the environment information, which often determines the character of their responses (Grandin, 1995).

The behaviours that manifest as a consequence of sensory dysfunction are complex and difficult to diagnose.In some cases they are a way of creating sensory stimulation, but they may equally be a way of managing sensory overload (Leekham et al, 2011). Finding ways to manage these behaviours effectively is essential, as they can severely impact on a person's ability to turn their attention to new information, to concentrate over a sustained period of time and to interact creatively (Leekham et al, 2011). When considering the relevance of movement in relation to engagement, it is important to note that the complexities associated with autistic sensory dysfunction can also mean that physical activity is a challenge. In addition to poor motor functioning, difficulties in planning and self-regulation can all lead to low motivation for taking part in movement related activity (Koegel et al, 2001; Ozonoff et al 1994).

There is a wide range of literature that discusses how rhythm-based strategies can promote the management of stereotypical behaviour, effective emotional regulation and social interaction in a variety of populations (Kern et al, 1884; Quill et al., 1989;Huettig & O'Connor, 1999;Berkeley & Zittel, 1998; Rosenthal-Malek & Mitchell, 1997). Music therapy programmes and the playing of instruments have also been reported as decreasing stereotypical, self-stimulatory behaviours (Muller & Warwick, 1993; Wimpory et al., 1995). However, little work has been evaluated to date that maximises on the benefits of rhythmic strategies in the context of technology interfaces, and yet the benefits of computers to the autistic population has been well researched.

Why Technology?

Successful computer interaction usually requires a user to direct their attention towards selected information in a confined space, and to filter out distractions from other stimuli. The concept of selective attention, which refers to the tendency to focus on information that is meaningful and of interest, is of particular relevance as it is both a defining feature of autism, and a contributing factor for authentic involvement with interactive technologies (Murray & Aspinal, 2006; Murray, Powell and Jordan, 1997). Murray, Lesser and Lawson have used the monotropism theory to explain why being able to focus deeply and tightly on a narrow range of interests is one of the most defining differences between autistic and non-autistic people. For monotropic, autistic individuals, interests are highly aroused, meaning that all the available attention is attributed to one interest and they are unable to focus on other information. Non-autistic people, on the other hand, will have a polytropic tendency to focus more broadly on many things at one time. A highly aroused focus of attention that excludes anything that is not being specifically attended to can be a source of skill or excellence. Computer interfaces tend to compliment the monotropic interest system, providing clear focus on task, filtering out extraneous detail and limiting interaction to one input attributed to one output.

As stated in the previous sections, camera-based motion-tracking systems can incorporate physically direct and emotionally expressive interaction. Having access to a richer sensory world has been cited as affording a more embodied, immersive experience. The case study in the following section describes how children with autism spectrum disorders were able to experience a sense of control, a self-absorbed flow of activity and a harmony of bodily input and output.

Background

"*Man moves to satisfy a need. He aims by his movement at something of value to him. It is easy to perceive the aim of a person's movement if it is directed to some tangible object. Yet there also exist intangible values that inspire movement*" (Laban, 1960, p1).

Laban believed that the most fundamental and effective art is that of movement. His work explored the transformative quality of movement and he encouraged teachers to become skilled observers of human beauty as expressed through the body. Inspirational dance therapists have championed his methodologies, as way to heal, build relationships, and explore authentic personal expression. One such advocate of Laban's theories is Dilys Price, herself a trained dancer who studied with Laban, and the founder of the Touch Trust dance and movement charity. In 2010 the Touch Trust provided the setting for a design workshop, which included four designers, therapists, professional dancers and six boys aged 14, non-verbal, with a diagnosis of autism. The overarching goal was to respond to the interests and experiences of the children as they took part in the Touch Trust session and to generate ideas for using technology interfaces to externalise this engagement. A key component of the workshop was for all participants, including the designers, to take part in a Touch Trust session, using breathing techniques, massage, expressive movement, percussion and dance. Following each activity, simple prototypes were created that amplified the presence of each individual child through large-scale visual projections. Microphone and camera inputs captured the sounds and movements created by the children, which were output as flowing artworks on the wall of the studio. The high visibility of the projections enabled every participant to observe and join in. These celebrations of individual creativity expressed through bodily interaction informed the development of the interactive software, Somantics.

The name Somantics is derived from the Greek word for the body, *soma,* with *antics* representing the added dimension of playfulness. Our work with the Touch Trust inspired us to think of how movement rhythms could be graphically represented. For example, as the body changes while inhaling and exhaling, responding to external stimuli, including the movement of others. Movement rhythms are the earliest unconscious patterns we employ to make use of the resonance of the movements of other people in our own bodies (Kestenberg, 1975). By recreating these rhythms as responsive, environmental artworks we were interested to find out whether children would be more dynamic in their range of movements and whether this could lead to greater engagement and collaboration.

Koch and Fuchs, (2011), examining the role embodied arts therapies in enabling people to investigate cognition, emotion, perception, and action, state that a key principle of embodiment is the "unity of body and mind, bi-directionality of cognitive and motor systems, enaction, extension, types of embodiment, relation to empathy." Findings from their studies suggest that the reciprocal bi-directionality of movement can influence cognition and affect. This has particular resonance for people with complex communication disorders, such as autism, as body movement can impact on how others understand nonverbal expressions and provide a means for regulating and specifying certain emotions (Koch, 2011). In traditional arts therapies, the artwork provides an embodied representation of emotion and experience, such as trauma. In interaction design, where there is an inherent interest in the mapping of physical input with graphical output there is an opportunity to examine how the perception of bodily states of others as visual media can cause bodily imitation in one's own body (Koch and Fuchs, 2011; Bavelas, Black, Lemery, & Mullett, 1986).

Many artists have been interested in the interpretation and representation of movement. Animators particularly create the illusion of exaggerated body movement to elicit empathy from the audience towards characters. Avante-garde animators from the 1930s and 1950s, Oskar Fischinger, Len Lye and Norman McClaren, used the frame-by-frame animation techniques to create moving artworks that synchronized shape, rhythm and music. These films did not impose meaning through narrative or character, audience appreciation of the films was facilitated through engagement with light, colour, line, rhythm and beat. The films have no tools with which to physically interact, but simply watching them creates a bodily response that is similar to that of watching a dance performance.

The design team responsible for Somantics had a background in animation, theatre, interaction and product design. These influences resulted in an implicit understanding of how humans use their physical, sensory and imaginary interests to discover possibilities for action, however it was the inclusivity of the design process, located at in the Touch Trust, and a Special Education School, that gave form to many of the ideas. The Touch Trust provided the motivation to explore the therapeutic potential of movement as a highly observable form of self-expression. From our observations of the Touch Trust sessions we were prompted to take the ideas into other environments via ordinary consumer devices, widening the applications to other users and using our findings to undertake more in depth analysis of gestural interaction. As a result, Somantics became a suite of applications that could be installed on desktop computers and mobile devices, using camera and microphone inputs to amplify the movement and sound of user interest.

Making Concepts into Prototypes

The process of creating Somantics began as design workshops in two special education settings, providing context and giving form to ideas. From our work at the Touch Trust we were confident that certain design features could provide initial specifications for the project, these were:

1. The overall look should remain abstract, providing iconic reference points for drawing attention to action and emotion.
2. The system had to be easy to set up with minimum demand on staff time, using ordinary spaces in extraordinary ways.
3. Opportunities for repetition and rhythm should be discoverable as part of a full body interaction to assist children in extending their range of expressive movements.

Including the Perspective of Users in Design

The design team had previously relied on experience prototyping (Buchenau & Fulton Suri, 2000) as a method of including the perspective of young, non-verbal children with autism in the design of software that aimed to trigger creative encounters with technology (Keay-Bright, 2006 - 2011). Our ideas for Somantics posed a very different challenge. The target group were aged 14 and over, and we needed to spend time with them in natural conditions rather than impose new technologies too early in the development cycle.

Van Rijn, (2012) is one of the few researchers to publish extensively on methods for including children with autism in the design process. She has created guidelines for including children with autism in technology design. Our work with Somantics led to similar findings, which were that in the early stages: (a) it is essential for both children and designers to familiarize themselves with the new context before entering into any joint activities, (b) in order to discover the natural interests of children, without bias, designers must observe the and record children undertaking other creative activities (which do not involve technologies) and (c) the designer needs to work with supervising adults to identify moments in which the children give a different meaning to objects and/or interactions than they do themselves.

The design workshops took place at the special school where the boys who took part in the therapeutic Touch Trust session were in full time education. We also ran similar activities at a specialist residential college, where the students had a diagnosis of autism. During the workshops the designers, worked with young people with Asperger syndrome and art teachers. Whilst Asperger syndrome is a less severe form of autism, it is equally characterised by highly aroused, restrictive interests and poor social imagination. These young people were all known to have difficulty with emotional regulation; they were prone to anxiety, which was usually the result of frustration and feeling misunderstood. However, they had no problems in articulating their thoughts and were generally sociable.

There were four pupils in our school group, aged 10-11 years: three boys and one girl who had problems accepting that she was in a special school and was anti-social with the other children. The boys were good friends and enjoyed the art classes.

The corresponding group at the residential college comprised of six students aged between 19 - 22 years, four boys and two girls. They were verbally articulate, but had poor concentration and certain behaviours that could be challenging. The art teacher was interested in animation and wanted to find ways to use this as a tool for engaging his students. We were particularly conscious that we should not set tasks that could lead to feelings of failure and overwhelming the students with too many instructions.

We began the workshops by showing the participants three short abstract films. The purpose was to engage the children in conversation and to prompt ideas without intense questioning, which could be stressful. The films, *Colour Box* by Len Lye (1953), Allegretto by Oskar Fischinger (1936), and *La Merle* by Norman McClaren (1959) use shape and colour to create a visual harmony with music. Another film, *Free Radicals,* also by Len Lye (1958), was played without the visuals so that the pupils could only hear the soundtrack, which was based on a traditional African drumbeat. We provided a variety of drawing materials, and asked the pupils to draw anything that came to mind while we played the sound in the background. As soon as the music finished we asked them in turn to talk about their drawings, we then projected the film again, this time with the visuals and they compared their own responses to those in the film. This was a relatively short activity; the films were no more than a few minutes in length. The children concentrated well and showed no signs of distraction, they seemed to enjoy the drawing activity and talked happily about what their drawings. As we had consent to film all the activities, from parents and the children themselves, we captured the whole session on video and kept all their drawings for future reference.

Each drawing was very different. Whilst one child created a seemingly random series of yellow lines, another created an ordered pattern of different coloured circles with lines flowing around the edges of the paper. The girl designed a regular pattern of purple circles with lines flowing from each of them, joining the circles together. One of the boys created an abstract character and told a story of how the character was responding to objects in the scene.

We undertook the same activity with students at the college. Whilst they did not show any signs of stress at being asked to take part, they found concentration difficult. Two of the students in the group showed little interest in watching the films. However, when they were invited to draw whilst listening to *Free Radicals* each student worked well and we encouraged the two who were struggling with concentration to draw anything they were interested in. We did not have consent to film the session, so we documented the process by making comprehensive field notes. We asked the students to interview each other about their thoughts on the films and what their interpretations meant to them. We also asked them to imagine each of their drawings as something that other people could interact with. This line of enquiry produced the most imaginative responses and they all appeared to enjoy talking about how the artworks could respond to touch and movement.

The students' drawings were highly individual; the ideas for interaction were plausible and clearly articulated in terms of cause and effect. For example, one student created a triangle composed of multiple coloured lines and talked about how it might feel to be inside the triangle, to be able to stretch his body and have the triangle behave as if it were made from elastic, stretching around the extremes of his body movement. Another student created a flow of pastel lines; she described how the colours could reflect mood and the lines could be an extension of the arms. She was a very musical student and performed the action as if conducting an orchestra. Another student made an intricate pattern of shapes that resembled a broken glass frame, she talked about being able to push the shapes out of the way and a new image appear. Another student talked about being able to see his own image inside a painting, and that as his reflection moved, so the paint would move fluidly around him.

At the school we were sensitive to the fact that the children may become upset when questioned about their ideas and so took a different approach to exploring how artworks may come to life when they have interactive properties. We set up an activity in a large studio in which we projected Oskar Fischinger's silent black and white film, *Spirals,* (1926), and the colour film *Motion Painting No. 1,* (1947). Both films include patterns of spiralling circles, the latter introducing further flowing lines that appear to be hand drawn. Without instruction, the children put their hands on the wall as if directly drawing the lines and colours. They also interacted with each other in a synchronised manner using the both arms and feet, visibly changing the rhythm of their movement in response to the kinetics of the film.

In interpreting the ideas from the both the children and students we cross-referenced both sets of drawings. Although the drawings were different, the ideas for interaction that emerged from the students' interviews and children's performances could be applied to both sets of artwork. A key criterion for interpreting the ideas as interactive technology applications was to ensure that the flow of movement could be controlled through body movement. This meant stripping out unnecessary detail and drawing attention to simple shapes.

In dance theory Laban refers to the fact that "form is produced by the limbs of the body and is governed by their anatomical structure which permits only certain movements to be made arising from the functions of stretching, twisting, and combinations of these" (Watts, E. 1977). In terms of our interpretation, this suggested that the range of bodily interaction could be restricted to particular gestures rather than trying to translate every nuance into a matching graphical form.

Using sketches as prompts we conducted interviews with the art teachers and from these we developed three prototypes, each prototype was designed to trigger a different type of movement. The illustrations below show these prototypes: (1) *Corridor* - the vertical lines follow the user's movement, more people can create lines, but they are confined to vertical movement, such as swaying from side to side; (2) *Tunnels* - an outline line is formed by the body shape, which can morph in response the body action, this prompts the user to stretch, and (figure 4) (3) *Windmills* - an orderly pattern of short lines can be disturbed by the body, as movement is detected, a spinning trail forms, this encourages circling movements (figure 3). Over the following weeks we created seven more prototypes, five of these used mirroring to enable the user to see their own body interacting with shapes. The prototypes used the iPad for touch and Kinect camera for bodily input.

Figure 3: Somantics Windmills © Cardiff School of Art and Design

Figure 4: Somantics Tunnels © Cardiff School of Art and Design

Observations of Prototypes in Use

The workshops generated ideas for prototypes that prompted different kinds of movement. When we observed the prototypes in use in the different settings it became clear that children enjoyed simply being able to move around without being constrained by task or instruction. Furthermore, the novelty and open-endedness of the interaction provided carers with an opportunity to observe and participate in an imaginary way. As a result, ideas were freely exchanged on how the interfaces could be incorporated into the curriculum.

We decided to try out the prototypes with the boys who had taken part in the Touch Trust session. This group were considered the hardest to exchange in the school, and their teacher was open to trying out new ways to engage her pupils. We arranged to visit the school weekly, and to set up the Somantics prototypes in a large empty space where they could be projected without too many competing sensory triggers.

The boys attended each session for approximately 20 minutes at a time, occasionally in pairs but usually individually. Even though the projections were large, taking up one wall in the room, the boys were not naturally inclined to explore them. Other features of the room, such as a light switch or chair grabbed their attention and distracted them. When they did show an interest in the interfaces they needed a lot of time to process new information. They did not automatically understand the relationship between their movements and the projected effects, and each one had different sensory preoccupations. However, the staff who were with the children were keen to persevere, and over a period of six weeks, with weekly sessions, each child was able to detect that movement was causing the interface to change. The levels of engagement varied greatly, much of this was dependent on the mood of the child on the day, whether something had disturbed them or made them happy.

Refining the Prototypes

Our weekly observations provided sufficient feedback to develop Somantics into a fully functioning system, with 10 applications, each affording a different type of movement. One of the benefits of the Kinect-projector set up was that it permitted the exploration of space and proximity, and we refined the applications to support spatial and temporal awareness, for example as the child moves closer to the projected image it becomes smaller, and disappears if they are too close. Similarly, if the child moves around too quickly the image reaction is very fast and difficult to process.

We gradually started to explore a range of observation methods in an attempt to capture each child's progress whilst at the same time valuing experiences that arose in each session that didn't necessarily match an obvious developmental trajectory. Mostly we relied on field notes, general observer feedback and inter-observer analysis of video taken from two or three angles simultaneously. We invited a range of experts - teaching staff, therapists and parents - to review and comment on the video footage. We avoided quantitative classifications of behaviour in favour of observing instances of flow and presence. We also published updates on the project blog and ran workshops through a number of professional networks.

General Findings

Although each of the pupils in our studies had very different behavioural characteristics, when they were engaged in Somantics their sequence of actions followed a pattern: (1) their attention was captured by seeing some form of graphical or video body schema moving in harmony with their movement; (2) their interest was maintained as they sensed their control though cause and effect (3) their movements became increasingly imaginative and experimental; (4) they became immersed in the flow of movement and response and showed higher than expected levels of engagement. Without exception, teachers expressed surprise at how motivated the pupils and students could be, and they were able to make suggestions on how Somantics could be introduced to pupils across the age and ability range. The occupational therapist pointed out that while pupils were watching themselves projected, their body movements were far more self-regulated than she usually experienced and she was intrigued at how unwanted stereotypical behaviours disappeared. Further to this, it was noted that pupils who would not usually pause and reflect on their actions were observed to be doing this, concentrating on the effect they appeared to be making on the environment. Staff suggested that the relaxation facilitated during the sessions carried over for up to two hours afterwards. This lowering of anxiety was considered to be beneficial to the pupil's willingness to participate in other activities.

FUTURE RESEARCH DIRECTIONS AND CONCLUSION

This chapter discussed how people with a range of disabilities, developmental and motor, have engaged in bodily interaction with rhythmic, musical and visually abstract interfaces. Experts have guided our understanding of these experiences as creative and expressive. Furthermore, users have been reported to gain self-awareness and confidence during their explorations. Our design methods have included these people, and those who support them, in ideation and prototyping activities, which have not only informed the technology development, but which have also demonstrated the abilities of the target population. These abilities emerged during the process of co-designing and became amplified through having access to prototypes in authentic settings.

As researchers, designers and artists develop an ever-better understanding of how humans respond to technology-enhanced physical relationships with music and other interactive media, we are confident that devices such as the MotionComposer or the Somantics will play an increasingly significant role in the therapeutic arena. As prototypes become robust and the new versions are developed, more clinical trails should be conducted to obtain empirical data on the therapeutic efficacy.

Work on the MotionComposer project - the first case study presented in this chapter - continues with additional workshops symposia and publications planned. Future work on the Somantics project aims to introduce sonic interaction as an extension of the visual experience and working with older adults, including those with dementia.

Computer-based technologies related to interaction design and to interactive multimedia has potential to be life-changing for individual and communities. This chapter presented how camera-based motion-tracking technologies and contemporary creative programming environments gave the opportunity to design, rapidly prototype, and develop responsive environments. Because of the affordability of hardware and software and the desire for open sharing we foresee the emergence of more interest and applications for research and development, which stand to benefit the technology industry, commercial developers, researchers, designers and end user.

REFERENCES

Acitores, A.P. & Wechsler, R. (2010). Danza Interactiva Con Niños Parálisis Cerebral. XXVII Congreso de la Asociación Española de Logopedia, Foniatría y Audiología.

Berkeley, S., & Zittel, L. (1998). Teaching the child with autism in physical education. Achieving a Balance: Proceedings of the 6th National Conference on Adapted Physical Activity. Western Illinois University: Macomb, IL.

Bracken, C; Lombard, M (2004). "Social presence and children: Praise, intrinsic motivation, and learning with computers". Journal of Communication 54: 22–3t

Billerbeck, Uwe (2012). Bewegung und Klang - Eine Woche mit dem MotionComposer. Unterstützte Kommunikation, 2/2012, ISAAC (International Society for Augmentative and Alternative Communication), Loeper Literaturverlag, Karlsruhe 2/2012, 27-29.

Bodgashina, O. (2003) *Sensory Perceptual Issues in Autism and Asperger Syndrome.* London: Jessica Kingsley Publishers

Buchenau and Fulton Suri (2000) Experience prototyping, Proceedings of the conference on Designing interactive systems, pp. 424-433, New York

Camurri, A., Mazzarino, B., & Volpe, G. (2004). Expressive gestural control of sound and visual output in multimodal interactive systems. In *Proceedings of the International Conference Sound and Music Computing*.

Camurri, A., Moeslund T.B. (2009). Visual Gesture Recognition: from motion tracking to expressive gesture. In M.Leman and R.I.Godoy (Eds), *Musical gestures: Sound, movement, and meaning*. Routledge.

Chadabe, J. (1997). *Electric sound*. Prentice Hall.

Dietz, J. (2011). Der MotionComposer: Bewegung in Musik verwandeln, Checkpoint E-learning.de. Interview. Retrieved 16.12.2012 from http://www.checkpoint-elearning.de/article/10614.html. s

Dietz, J. (2012). The MotionComposer home website. Retrieved 16.12.2012 from http://www.motioncomposer.com#events.

Dixon, S., & Smith, B. (2007). *Digital performance: a history of new media in theater, dance, performance art, and installation* (p. 154). Cambridge, Massachusetts: MIT press.

DSM 5, APA, 2011 http://www.dsm5.org/Pages/Default.aspx (accessed March 2012)

Dissanayake, E. (2000) Art and Intimacy: How the Arts Began. Seattle and London: University of Washington Press.

Foster, S. L. (2005). Choreographing empathy. Topoi 24 (1):81-91.

Grandin, T. (1995) "The learning style of people with autism: an autobiography," In: K. A. Quill (Ed.) *Teaching Children with Autism: Strategies to Enhance Communication, Socialisation.* London: Delmar Publishers Inc

Gallese, V (2005) Embodied simulation: From neurons to phenomenal experience. Phenomenology and the Cognitive Sciences 4: 23–48 Springer

Gallese, V. and Goldman, A. 1998. Mirror neurons and the simulation theory of mind-reading. Trends in Cognitive Sciences 12: 493–501.

Godøy, R. I. (2009). *Musical gestures: Sound, movement, and meaning*. Routledge.

Hunt, A., & Wanderley, M. M. (2002). Mapping performer parameters to synthesis engines. *Organised Sound*, *7*(2), 97-108.

Keay-Bright, W. (2006) Reactivities: Autism and Play. Digital Creativity, 17, (3) pp149-156

Keay-Bright, W. (2007a) 'Can computers create relaxation? Designing Reactickles software with children on the autistic spectrum', CoDesign, 3, (2) 97 – 110.

Keay-Bright, W. (2007b) The Reactive Colours project: demonstrating participatory and collaborative design methods for the creation of software for autistic children. Design Principles and Practices: An International Journal, Volume 1, Issue 2, pp.7-16

Keay-Bright, W. (2007c) Designing playful sensory experiences with interactive whiteboard technology: the implications for children on the autistic spectrum. Dancing with Disorder: Design, Discourse and Disaster: 7th European Academy of Design Conference: Published conference proceedings

Keay-Bright, W. (2008) 'Tangible technologies as interactive play spaces for children with learning difficulties: the Reactive Colours project', The International Journal of Technology, Knowledge and Society, Volume 4, Issue 1, pp.111-120

Keay-Bright, W. (2009) ReacTickles: Playful interaction with Information Communication Technologies, The International Journal of Art & Technology, 2, 1/2, pp.133-151

Keay-Bright, W. Howarth I.C. (2011): Is Simplicity the Key to Engagement for Children on the Autism Spectrum, Journal of Personal and Ubiquitous Computing, Theme Issue on Technology for Autism, Springer May

Keay-Bright, W. (2013). *Young People on the Autism Spectrum Make Interaction Magical* Special: Autism Spectrum Disorders. Nasen, 38-40

Kern, L., Koegel, R. L., & Dunlap, G. (1984). The influence of vigorous versus mild exercise on autistic stereotyped behaviors. Journal of Autism and Developmental Disorders, 14, 57–67

Kestenberg, J. S. (1975). Parents and children. Northvale: Jason Aronson.

Koch, S. C. (2011). Basic body rhythms and embodied intercorporality: From individual to interpersonal movement feedback. In W. Tschacher, & C. Bergomi (Eds.), The implications of embodiment: Cognition and communication (pp. 151–171). Exeter: Imprint Academic.

Koch, S. C. (2006). Interdisciplinary embodiment approaches. Implications for creative arts therapies. In S. C. Koch, & I. Bräuninger (Eds.), Advances in dance/movement therapy. Theoretical perspectives and empirical findings (pp. 17–28). Berlin: Logos.

Koegel R.L., Koegel L.K., McNerney E. (2001). Pivotal areas in intervention for autism. Journal of Clinical Child and Adolescent Psychology. 30(1)

Krueger, M. W. (1985). VIDEOPLACE: A Report from the Artificial Reality Laboratory. *Leonardo*, *18*(3), 145-151.

Laban, R. v. (1960). The mastery of movement. London: MacDonald & Evans.

Laban, R. v., & Lawrence, F. C. (1974). Effort: Economy in body movement. Boston: Plays. Originally published in 1947.

Leekam, S. R., Prior, M. R., Uljarevic, M. (2011) Restricted and Repetitive Behaviors in Autism Spectrum Disorders: A Review of Research in the Last Decade. Psychological Bulletin, American Psychological Association 2011, Vol. 137, No. 4, 562–593

Levin, G. (2006). Computer vision for artists and designers: pedagogic tools and techniques for novice programmers. *AI & Society*, *20*(4), 462-482.

Levin, G. (2007). Vision. In Reas, C., & Fry, B. *Processing: a programming handbook for visual designers and artists*. Mit Press

Miranda, E. R., & Wanderley, M. M. (2006). *New digital musical instruments: control and interaction beyond the keyboard* (Vol. 21). AR Editions, Inc..

Muller, P. and Warwick, A. (1993). 'Autistic children and music therapy: the effect of maternal involvement in therapy.' In: HEAL, M. and WIGRAM, T. (Eds) Music Therapy in Health and Education. London: Jessica Kingsley.

Murray, D., & Aspinall, A. (2006). Getting IT. London: Jessica Kingsley Publishers

Murray. D (1997), Powell. S and Jordan. R, ed, 'Autism and Information technology: therapy with computers', Autism and Learning: A Guide to Good Practice, David Fulton Publishers, London

Murray, D, Lesser, M and Lawson, W (2005) 'Attention, Monotropism and the Diagnostic Criteria for Autism' in Autism, Vol. 9, No. 2

Noble, J. (2009). *Programming Interactivity: A Designer's Guide to Processing, Arduino, and Openframeworks*. O'Reilly Media, Incorporated.

Ozonoff, S. Strayer, D. L., McMahon, W. M., & Filloux, F. (1994). Executive function abilities in autism and Tourette syndrome: an information-processing approach. *Journal of Child Psychology and Psychiatry, 35,* 1015–1032.

Quill, K., Gurry, S., & Larkin, A. (1989). Daily life therapy: A Japanese model for educating children with autism. Journal of Autism and Developmental Disorders,19(4), 625-635.

Quill, K. A. (2000) *Do-Watch-Listen-Say: Social Communication Intervention for Children with Autism.* Baltimore: Paul H. Brookes Publishing Co

Reas, C., McWilliams, C., & Barendse, J. (2010). *Form+ code in design, art, and architecture*. Princeton Architectural Press.

Report of the Secretary-General of the United Nations (2010), "Keeping the promise: realizing the Millennium Development Goals for persons with disabilities towards 2015 and beyond, July 26, 2010; Sixty-fifth session, Item 27 (b) of the provisional agenda; Social development, including questions relating to the world social situation and to youth, ageing, disabled persons and the family.

van Rijn, H., (2012) Meaningful Encounters. Explorative studies about designers learning from children with autism. Doctoral thesis TU Delft.

Rosenthal-Malek, A., & Mitchell, S. (1997). Brief report: The effects of exercise on the self-stimulating behaviors and positive responding of adolescents with autism. Journal of Autism and Developmental Disorders, 27(2), 193-202.

Rowe, R. (1992). *Interactive music systems: machine listening and composing*. MIT press.

Drummond, J. (2009). Understanding interactive systems. *Organised Sound*, *14*(2), 124-133.

Secretariat for the Convention on the Rights of Persons with Disabilities (2012), Department of Economic and Social Affairs, United Nations (2012), Retrieved 16.12.2012 from http://www.un.org/disabilities.

Siegel, W., & Jacobsen, J. (1998). The challenges of interactive dance: An overview and case study. *Computer Music Journal*, 29-43.

Siegel, W. (1999). Two compositions for interactive dance. In *Proc. of the Int. Computer Music Conf.(ICMC99)* (pp. 56-9).

Siegel, W. (2009). Dancing The Music: Interactive Dance And Music. In R. Dean (Ed.), *The Oxford Handbook of Computer Music* (pp. 191-2013). Oxford University Press

Steuer, J..(1992) "Defining virtual reality: Dimensions determining telepresence.". Journal of Communication, 42 (4) (Autumn, 1992), 73-93. http://www.presence-research.org/papers/steuer92defining.pdf. (Acessed April, 2012)

Szeliski, R. (2010). *Computer vision: Algorithms and applications*. Springer.

Watts, E. (1977). Towards Dance and Art. London: Lepus Books.

Wechsler, R. (2006). Artistic Considerations in the Use of Motion Tracking with Live Performers: a Practical Guide. *Performance and Technology: Practices of Virtual Embodiment and Interactivity*, 60-77.

Wechsler, R. (2012). Applications of Motion Tracking in Making Music for Persons with Disabilities. Proceedings of the 4. Workshop of »Innovative Computerbasierte Musikinterfaces«, Mensch&Computer, Konstanz, Oldenbourg Wissenschaftsverlag.

Wimpory, D., Chadwick, P. and Nash, S. (1995). 'Musical interaction therapy for children with autism: an illustrative case study with two-year follow-up' (Brief Report), Journal of Autism and Developmental Disorders, 25, 5, 541–52.

Winkler, T. (1995). Making motion musical: Gesture mapping strategies for interactive computer music. In *ICMC Proceedings* (pp. 261-264).

Winkler, T. (1997). Creating interactive dance with the very nervous system. In *Proceedings of Connecticut College Symposium on Arts and Technology*.

Winkler, T. (1998). *Composing interactive music: techniques and ideas using Max*. MIT press.

ADDITIONAL READING SECTION

Bevilacqua, F., Naugle, L., & Valverde, I. (2001). Virtual dance and music environment using motion capture. In *Proc. of the IEEE-Multimedia Technology And Applications Conference, Irvine CA*.

Bradski, G., & Kaehler, A. (2008). *Learning OpenCV: Computer vision with the OpenCV library*. O'Reilly Media, Incorporated.

Bevilacqua, F., Schnell, N., & Alaoui, S. F. (2011). Gesture capture: Paradigms in interactive music/dance systems. *Emerging Bodies: The Performance of Worldmaking in Dance and Choreography*, 183-193.

Cadoz, C., & Wanderley, M. M. (2000). Gesture-music. *Trends in gestural control of music*, 71-94.

Camurri, A., Hashimoto, S., Ricchetti, M., Ricci, A., Suzuki, K., Trocca, R., & Volpe, G. (2000). Eyesweb: Toward gesture and affect recognition in interactive dance and music systems. *Computer Music Journal*, *24*(1), 57-69.

Camurri, A.; Mazzarino, B.; Volpe, G.; Morasso, P.; Priano, F.; Re, C. (2003).“Application of multimedia techniques in the physical rehabilitation of Parkinson'spatients”. Journal of Visualization and Computer Animation 14 (5). 269-278.

Davis, W.; Gfeller, K; Thaut, M (2000). Introducción a la musicoterapia. Teoría ypráctica. Barcelona: Boileau.

Dodge, C., & Jerse, T. A. (1997). *Computer Music: synthesis, composition and performance*. Macmillan Library Reference.

Kestenberg Amighi, J., Loman, S., Lewis, P., & Sossin, K. M. (1999). The meaning of movement clinical and developmental assessment with the Kestenberg Movement Profile. New York: Brunner-Routledge Publishers.

Koch, S. C., Morlinghaus, K., & Fuchs, T. (2007). The joy dance. Effects of a single dance intervention on patients with depression. The Arts in Psychotherapy, 34, 340–349.

Koch, S. C., Glawe, S., & Holt, D. (2011). Up and down, front and back: Movement and meaning in the vertical and sagittal axis. Social Psychology, 42(3).

Laban, R. (1973). Foreward, chapter in: Labanotation, or Kinetography Laban: The System of Analyzing and Recording Movement, Ann Hutchinson, pages xiii-xvi. New York: Theatre Arts Books.

Louppe, L. et al. (1994). Traces of Dance: Drawings and Notations by Choreographers. Paris: Editions Dis Voir.

Lye, L. (1929). Tusalava. Animated film. Screened at the exhibition, Len Lye, Melbourne: Australian Centre for the Moving Image (ACMI), 2009.

Malagón, J. (2007). “Actualizaciones en neurología infantil. La parálisis Cerebral”,

en Medicina. Vol. 67, nº 6/1, páginas.

Mulder, S. (1994). *Human Movement Tracking Technology. Hand Centered Studies of Human Movement Project, Simon Fraser University*. Technical Report 94-1, July.

Ng, K. (2002). Sensing and mapping for interactive performance. *Organised Sound*, *7*(02), 191-200.

O'Sullivan, D., & Igoe, T. (2004). *Physical computing: sensing and controlling the physical world with computers*. Course Technology.

Paradiso, J. A., & Sparacino, F. (1997). Optical Tracking for Music and Dance Performance. In *Fourth Conference on Optical 3D Measurement Techniques, ETH, Zurich*

Reas, C., & Fry, B. (2007). *Processing: a programming handbook for visual designers and artists*. MIT Press.

Roads, C. (1996). *The computer music tutorial*. MIT press.

Schacher, J. C. (2010). Motion to Gesture to Sound: Mapping for interactive dance. In *Proceedings of the 2010 International Conference on New Interfaces for Musical Expression (NIME 2010)*.

Schneider, S.; Schönle, P.W.; Altenmüller, E; Münte, T.F. (2006). Using musical instruments to improve motor skill recovery following a stroke", Journal ofNeurology xx, 1-9.

Sparacino, F., Davenport, G., & Pentland, A. (2000). Media in performance: Interactive spaces for dance, theater, circus, and museum exhibits. *IBM Systems Journal*, *39*(3.4), 479-510.

Tsuruta, S., Kawauchi, Y., Choi, W., & Hachimura, K. (2007, November). Real-time recognition of body motion for virtual dance collaboration system. In *Artificial Reality and Telexistence, 17th International Conference on* (pp. 23-30). IEEE.

Wanderley, M., & Battier, M. (Eds.). (2000). Trends in gestural control of music. Ircam.

Wechsler, R., Weiß, F., & Dowling, P. (2004, March). EyeCon--A motion sensing tool for creating interactive dance, music, and video projections. In *Proc. of the SSAISB Convention*.

Winkler, T. (1997, March). Creating interactive dance with the very nervous system. In *Proceedings of Connecticut College Symposium on Arts and Technology*.

KEY TERMS AND DEFINITIONS

Interactive composition: a musical composition based on the design of computer algorithms which interpret in real time a live music performance and respond by transforming it or by generating new music material

Computer vision: the extraction of useful information through a wide range of computer algorithms from sensed images

Digital Music Instrument: an electronic music instrument that contains a gestural interface and a sound synthesis engine

Mapping: the term mapping in the context of interactive visual art and interactive composition denotes the association of human body gestures to sonic or visual parameters that control the generation or the modification of audio-visual content by the computer

---

[1] http://www.cdc.gov/obesity/adult/causes/index.html
[2] http://www.palindrome.de/content/award
[3] http://www.openframeworks.cc
[4] http://opencv.org/
[5] http://processing.org/
[6] http://cycling74.com/products/max/

[7] http://puredata.info/
[8] http://www.infomus.org/eyesweb_ita.php
[9] http://eyecon.palindrome.de/
[10] http://www.motioncomposer.com
[11] http://steim.org/product/junxion/
[12] The Table of Human Movement Mapping is the work of the author R.Wechsler. Developed over 25 years of making interactive dance works for the Palindrome Dance Company, the list represents a distillation from the scores of mappings which were explored between 1992 and today. Most were rejected, either because they involve technologies that were too costly or cumbersome or, more often, because they were not palpable -- either to the audience or to the performer.