The ZKM | Institute for Music and Acoustics

LUDGER BRÜMMER

Institute for Music and Acoustics, Center for Art and Media Karlsruhe (ZKM), Lorenzstr. 19, 76135 Karlsruhe, Germany
E-mail: lb@zkm.de

The ZKM | Karlsruhe has been producing work now for 20 years. The Institute for Music and Acoustics in particular has commissioned, produced or co-produced approximately 400 works in this time. The Institute's work takes place within a very active but also very complex environment in Germany, one which often repudiates the use of technology and its accompanying shift in the aesthetic paradigm. The following text will shed light on the work of the ZKM | Karlsruhe in general and the various activities of the Institute for Music and Acoustics (IMA) in particular. These activities encompass the areas of production, presentation, publication and research. To this end, the article will touch upon the IMA's primary research projects, in particular the archiving project Mediaartbase (Brümmer, Heidenreich, Haecker et al. 2009), the development of software and hardware in the context of spatial music, and a number of interface developments. Reasons will be discussed that substantiate the significance of spatial music with regard to the reception of music in the future, and the role of new interfaces in future musical activities will be described.

1. THE ZKM AS A DIGITAL BAUHAUS

The ZKM | Centre for Art and Media in Karlsruhe is one of the few centres that bring together exhibition spaces, media studies research, production facilities (the Institute for Music and Acoustics and the Institute for Visual Media) and performance facilities all under one roof. The centre was founded in 1989 and took up new quarters in a former ammunition factory in 1997. The focus of the ZKM is the artistic and content-related integration of art and digital technology. The current complex consists of 16 departments. It houses the Museum for Modern Art and the Media Museum, the productional institutes – the Institute for Music and Acoustics and the Institute for Visual Media, the Institute for Media, Education and Economics – as well as the Film Institute and the Laboratory for Antiquated Video Systems. It also includes the departments of the Media Library, Exhibition, Museum and Exhibition Technical Services, Press and Public Relations, Museum Communications, Publication, Events, the Museum Shop and the EU Coordination Office. In addition to these departments, a number of artist groups have been working at the ZKM for extended periods, such as the Robotlab and the development team Susigames (Susigames.com 2007). The large number of groups and topics here clearly indicates the diversity of activities at the ZKM, including art production, presentation, research and communication. Within this kind of a museum structure, the artistically active departments in particular find themselves working in a rather unconventional context, one that is further extended by the neighbouring College of Arts and Design. The institutes are able to focus on their research and production activities and are involved neither in museum management nor in the clearly defined educational responsibilities. They direct their attention to professionally active, more or less established artists who could not realise their projects without the aid of institutional support. The ZKM works within international networks in order to carry out this role. The productions developed at the ZKM are performed and presented internationally. In addition, the museums collaborate with international curators and present a large number of exhibitions of different sizes worldwide.

The Institute for Music and Acoustics (IMA) and the Institute for Visual Media are the largest institutes within the ZKM. They especially boost the aspects of research and production, although they are concerned with completely different fields.

2. THE POSITION OF ELECTROACOUSTIC MUSIC WITHIN CONTEMPORARY MUSIC AS A WHOLE

The continued development of musical aesthetics would not conceivable without innovations in instrument construction. A distinction must be made in this context between modifications or even completely new developments in timbre, or in the course of how a sound evolves, and changes or innovations in the interfaces. These developments are joined by new scientific findings that either create the basis for new instruments or influence composers' aesthetic goals, audiences' preferences, and their interaction with music. Yet trends like this also have social consequences. One example of this is the prevalence of piano music in the nineteenth century, which resulted from the popularity of the piano as a concert instrument and a household instrument of the middle classes. Like the piano, the computer has come to be a modern-day instrument of the people. Access to the instrument is not a social filter. Computer music

is therefore far removed from the elite approach to music that is inescapable for the composition of orchestral works. But this also makes it the focal point of aesthetic debates that take place within the electronic platform.

Whereas the innovative impulse for the field of music was formerly initiated through the development of new instruments, in the mid twentieth century this impulse was primarily focused on percussion, and eventually shifted to experimental performance techniques. And while in the 1970s and 1980s no musical work could survive without the inclusion of new performance techniques, that trend too has now run its course. Parallel to these changes, the development of new instruments and sounds has taken on greater significance in the field of electroacoustic music. The process of innovation has increased in speed since the digitalisation of electroacoustic music and the increased availability of computers, and the innovative potential of technological music has been nowhere near exhausted. Sound synthesis and the development of the widest variety of interfaces have been joined by new structural possibilities. Above all, the creation of standardised interfaces and protocols, such as OSC, must be mentioned here. These allow different software applications to be connected to each other, thereby networking video software with music software, for example. New controllers have also been created, which dancers and instrumentalists can use to generate data and thereby control processes (see figures 3–5). As a result of their shared use of technology, electroacoustic music is integrated into new media art, thereby developing new, interdisciplinary forms of expression. Electroacoustic music is found in sound installations, in videos, in the cinema, in dance, in the theatre and of course in the temples of new media art. It has developed specific forms of expression, and as a result also considerably expanded the musical vocabulary.

Beyond the fields of new media art and sound art, electroacoustic music has only been integrated into the realm of contemporary music to a limited degree. The field of contemporary music has not wanted to diverge from the paradigm of instrument and notation. The limitation to the sound vocabulary that accompanies this adherence – such as thinking in pitches and equal temperament, and the use of a clearly contained catalogue of instruments – is in opposition to the more comprehensive aesthetic of electroacoustic music. These differences express themselves in the form of an active exclusion of electroacoustic music, especially acousmatic music, from concerts. At the same time, approaches to live electronics have developed which concentrate on the processing of sounds that have been produced in conformity with the paradigm. This tone-based electroacoustic music is more a part of the New Music

world in Germany, as well as in other European countries, while acousmatic music moves within a self-contained environment of performance and production.

The strengths of live electronics lie in particular in the development of new forms of interaction between sound and machine; those of acousmatic and algorithmic music lie more in the further development of structural and tonal semantics. Both strengths form the basis for continual innovation in the tonal and structural repertoire of new works, as well as in the manner in which music is performed. An example of this can be seen in the author's compositions *Move* and *Temps du Miroir*. In these pieces, the piano functions as a kind of super-instrument, whose sound triggers new sounds, controls videos, and influences the granulation phrases of its own sounds through the tones it plays. A fixed layer of the works is based on algorithmic structures, while the live electronics and the live video connect the different layers with each other. Both compositions are an example of how an instrument's capabilities can be extended by technological means, so long as one engages oneself with the design and reception of new tonal and visual layers.

When observing the extremely rich German scene at contemporary music concerts and festivals, it can be stated that the composers have a greater interest in electroacoustic music than do those responsible for the programming. Electroacoustic music spans various contexts in an interdisciplinary manner and distinguishes itself through diversity and variability. It is already omnipresent in the arts and has long since been received by the audiences. It expresses itself in the most diverse musical language, and is therefore formidable, and yet, unfortunately, it is not always in the foreground as a genre.

It is precisely this electroacoustic music, situated between an immense potential and the necessity of defining its position, that is the focus of the Institute for Music and Acoustics at the ZKM.

3. THE ACTIVITIES OF THE IMA

Together with the Institute for Visual Media, the IMA is the largest institute within the ZKM. It is involved with the development of music and sound art in a technological context. It can be regarded as one of the most active German production facilities for electronic music. Its activities primarily consist of the production of new works, the presentation of these works in concerts both within and outside of the ZKM, the publication of music or research results, and the support of productions through innovative technological research. Tied in with this is the communication of technological and professional aspects, which is carried out by means of symposiums, workshops and lectures. The following passages will briefly portray the most important projects of the IMA.

3.1. The guest artist programme

The IMA invites as many as 35 composers to work in its music studios and ateliers each year. The duration of their residencies is not limited, and lies between two weeks and two years. The composers are able conduct their experiments with the greatest possible attention to detail, with much time and optimal hardware. Moreover, the studios offer continuous access and excellent acoustics.

In addition to the guest artists, academic guests also work on their own research projects at the IMA. The artistic and scientific topics explored at the IMA span from digital sound synthesis, algorithmic composition and live electronics to radio plays, interactive sound installations and audiovisual productions, as well as works for the stage. Wolfgang Rihm produced one of his few works for electronics at the ZKM, for which dancers from the Karlsruhe State Theater provided choreography in 2008 (Movie example 4).

3.2. Productions

The artistic use of technology is an essential component of the works produced at the IMA. The compositions are developed by the composers in cooperation with technicians and sound engineers. The material necessary for the performance of the works, consisting of software and sound files, is produced either solely at the IMA or in cooperation with other institutes of the ZKM or external collaborating partners. Professional recordings are also made of the compositions in order to publish them on CD or DVD, or on the Internet. The support provided by the IMA spans from help with the programming to assistance with the technical realisation of the project.

3.3. Publication

The productions of the IMA have been published on the Wergo label in the series *Edition ZKM* (Wergo 2009) since about 1997. The goal here is to document the work of the ZKM and make it accessible to the public, thereby providing those interested with the opportunity to hear these works outside of the concerts as well. During 2009, the IMA produced about 10 publications. Among these are new audiovisual recordings by Garth Knox and Brian O'Reilly (Movie example 7), by Marco Blaauw and Kyriakides (Movie example 8), by Melvyn Poore and Cort Lippe (Movie example 9), and the DVD *trans_canada*, with works produced at the ZKM by Robert Normandeu, Gilles Gobeil (Sound example 1), Francis Dhomont, Barry Truax, Hildegard Westerkamp and other Canadian artists. Apart from Wergo, the ZKM also collaborates with empreintes DIGITALES, with the Japanese label Fontec, with the New York label Mode Records, Sargasso, Sony BMG, and with the German label col legno. The ZKM also has its own webradio station for the realm of broadcasting. This station is hosted at the ZKM and supplied with content by the IMA in conjunction with the German Society for Electroacoustic Music (DeGeM). The IMA uses the broadcast to introduce the guest artists and their productions in the form of concert recordings or completed productions (Degemradio@zkm 2009).

Progress is also currently being made on the publication of the interactive software *Making Small Fish*, by Kiyoshi Furukawa and Wolfgang Münch, which enables the design of computer games for children and adults (Furukawa, Münch and Fujihata 1999). Publication of the book *Produced@zkm* is also under way. The latter is a documentation of all of the works that have been produced at the institutes of the ZKM.

3.4. Prizes

Electroacoustic music is far from being well represented in the landscape of German prizes and competitions. To counter this, the IMA currently organises two prizes.

3.4.1. The Giga-Hertz Prize

The IMA places particular focus on interdisciplinary projects, including technologically assisted music, interfaces and spatial music. The Giga-Hertz Prize was introduced to support work in this field. The prize carries the largest cash award of any electroacoustic music prize worldwide. It was initiated by Peter Weibel and the German state of Baden-Württemberg, with funding from the City of Karlsruhe, and is awarded in conjunction with the Southwest German Radio's Experimental Studio in Freiburg. Prominent juries determine the recipients of a main prize of €15,000 and four sponsorship awards of €8,000 each, for which the contenders can apply (giga-hertz 2008). The first jury consisted of Pierre Boulez, Horacio Vaggione, Peter Weibel and Wolfgang Rihm, as well as the director of the Donaueschingen Music Festival (Armin Köhler), studio director Detlef Heusinger, and the author himself.

3.4.2. The ZKM Walter Fink Prize

In addition to the Giga-Hertz Prize, the ZKM also promotes the interactive use of technology, especially in stage productions. Contemporary dance in particular has held a prominent position in this area in the past. The Fink Prize, sponsored by Walter Fink, will therefore be announced for the first time in 2009. The prize will sponsor and present an award for stage works that have been collectively developed by composers, dancers and new media artists (Fink 2009).

3.5. Symposiums

3.5.1. Linux Audio Conference

The IMA sponsors specific trends that are of key importance for the electroacoustic music scene. In this context, the Linux Audio Conference (LAC) was founded at the ZKM and held there on an annual basis from 2003 to 2006. The conference was initiated in order to optimise the pace of development and the quality of open-source projects. Having been organised four times by the IMA, the LAC is now held by different institutions, primarily within Europe, due to the continually increasing interest in the conference.

3.5.2. The next_generation festival

While electroacoustic music is largely absent in the concert scene, there is great interest in the field within the educational programmes of German and German-speaking music colleges. Nearly every music college has an electronic studio, and therefore either its own degree programme for electroacoustic composition or a compulsory course in electroacoustic music as part of a composition degree. The festival and symposium next_generation was initiated in order to make this creativity tangible. It was first organised in 2005 and has taken place on a biennial basis since then. The events also strive to stimulate discourse on educational programmes, and to get the studios out of their sometimes isolated position within the universities. Around 25 studios and 150 students and college teachers regularly participate in the festival. The Swiss and Austrian studios as well as college teachers from Holland and Belgium have long since integrated themselves into this gathering. They present their newest works, lead technological and aesthetic discourse with each other, and discuss various approaches to presentation. With its lively atmosphere, this festival certainly belongs to the most remarkable initiatives related to the education of composers and artists. Overseas guests are also invited to attend, to report on the specific conditions of the music in their respective regions.

3.6. Concerts

The IMA puts on more than 70 events each year. A list of the most important of these events would reveal that the concert activities of the IMA, in addition to presenting the repertoire, also represent the latest aesthetic and technological trends.

The works created at the IMA are either performed in the Media Theatre (15 by 23 metres), the Cube theatre (Kubus) (14.5 by 20 metres), or in cooperation with festivals such as the Donaueschingen Music Festival, the MaerzMusik festival in Berlin, the Eclat in Stuttgart, the Witten New Chamber Music Festival, or the Hamburg Klangwerkstatt, as well as through the various broadcasting corporations.

The Media Theatre, which is slightly larger than the Cube, provides a very flexible infrastructure that is more geared towards theatre productions, while the Cube possesses extraordinary acoustics and is equipped with the permanent installation of the 47-channel Sound Dome (*Klangdom*). The space is also used as a recording studio, and its fixtures and fittings have therefore been optimised for musical presentations.

3.6.1. Piano+

In addition to several concert series that focus on the music of instruments with electronics, the Piano+ festival has the greatest degree of continuity and presence. Following in the footsteps of the Tuba+, Viola+, Trumpet+, and Harp+ concerts, Piano+ takes place annually, with five concerts of both the most recent works as well as the classics of the piano literature. The festival has been curated by pianist Catherine Vickers together with the author since its inception in 2004.

3.6.2. Quantum Leaps

The festival Quantum Leaps is put on twice a year by the outstanding musicians of the International Ensemble Modern Academy. Modern classics as well as the most recent compositions produced at the IMA are performed at these concerts with the highest level of musical interpretation. These concerts offer the opportunity to get to know the classics of electronic music, from Boulez's *Dialogue de l'hombre double* to Berio's *Sequenza* and Stockhausen's *Kontakte*.

3.6.3. ARD Radio Play Days

In addition to the festivals organised and initiated by the ZKM itself, the ARD Radio Play Days are held in conjunction with the entire ZKM and draw more than 9,000 visitors over five days. The Southwest German Radio of Baden-Baden initiated this festival in 2006 with several competitions and the principle theme of Ars Akustika, and has conducted it on an annual basis since then. All of the ARD radio stations in Germany participate in this festival. It is the largest such gathering of the German scene.

4. RESEARCH AND DEVELOPMENT AT THE IMA

In addition to smaller, independent research projects led by guest researchers, the IMA also realises more extensive projects with larger project teams over a time period of several years. The three largest and most important former projects will be introduced

here as an example of the numerous development projects undertaken at the IMA.

4.1. The mediaartbase archive project

The institutes of the ZKM possess a rich compendium of works and conglomerates of collections that have been completed or purchased over the past 20 years. Some of these productions have already been published. Others were introduced to the public through publishers and the composers themselves. The majority of these productions have been stored in the ZKM archives and are optimally protected against deterioration in air-conditioned rooms. However, reliable long-term archiving is only possible when the works are regularly copied or are stored on mirrored hard drives. Moreover, the stored data continually undergo changes. However, the function of an archive does not only consist of the conservation of its holdings. The capabilities of the Internet and the public's interest are resulting in the increased desire to make the treasures stored in the archives visible to the outside for research and publication. The IMA is endeavouring to put this idea into practice through a joint project with the documenta archive in Kassel, the Kassel Documentary Film and Video Festival and the European Media Art Festival of Osnabrück. The project is being sponsored by the German Federal Cultural Foundation. A modular data bank is being developed for the project, which makes its data available not only within the internal archive, but also in the given Media Library and on the Internet as well. The project will need to achieve a maximum compatibility with the normal standards for metadata in the field of archive management, and a modern approach to object description is to be developed that will be appropriate for digital objects.

These metadata models, which resemble keyword indices, must in part be newly developed for the area of new media art, primarily because the field involves heterogeneous media. Moreover, numerous materials that were originally created in analogue format must be digitised and entered into the new data banks in order to make them available on the Internet, for example, or to be able to preserve them for the long term. Once this has been done, the next step is to guarantee a shelf-life that is designed for an extended period of time. This is a problem that equally applies to all genres of art, whether music, film, installation or happening.

An example from the area of electronic music illustrates the problem. The archiving and digitising project *IDEAMA*, which was conducted to a large part by the IMA, contains approximately 550 historically important works. In 1992, the team of curators, consisting of top composers and experts, labelled 708 works produced between 1929 and 1970

as being particularly valuable. Of these, only 570 could be located. The remaining 138 works had already been lost or destroyed. The existing works have now at least been salvaged. Today they can also be acquired as a data bank by libraries and universities.

4.2. The Sound Dome (*Klangdom*) project and its background

For as long as sound-producing instruments and acoustic spaces have been used, music has been directly confronted with technological issues. Acoustics, style and aesthetics have evolved in parallel to the history of instrument development, changing interactively with advancements of the technological resources employed. The influence of electronic technology on music in the twentieth century propelled significant changes both in the physical properties of the instruments and in the way music was received on the whole. By breaking the paradigm of binding the instrument to the physical necessities of sound generation, the sound itself was liberated to the point of complete dematerialisation, becoming pure vibrations in air. The implementation of newly developed interfaces and new forms of interaction with the sound only became possible through this change.

Of the new possibilities for presenting sound, space is currently being emancipated as a separate parameter, significantly changing the way we think about sound. Concert spaces with 'loudspeaker cathedrals' already exist, and the reception of music is developing more and more into an immersive sensory experience. The pronounced use of technology also captures the composers' sense of aesthetics. They are capable of evoking technological changes on the basis of new requirements on their part. The conception of new forms of interaction with these 'sound machines' alters the creation process considerably. A new breed of performers is joining forces with the already highly specialised instrumentalists. They see their instruments as flexible, functional objects that follow their own ideas, and they creatively transform them accordingly.

4.2.1. Historical overview

Spatiality in music is more than a parameter for the realisation of aesthetic concepts. Spatiality aids in the presentation, the perception, and also the comprehension of music, and is thus by no means an end in itself.

The shamans of the Yanomami, which the ZKM visited in the context of the Amazonas project planned for the 2010 Munich Biennale, tell of the vital importance of spatial hearing for survival in an impenetrable jungle that is overgrown with trees and plants. Their explanation makes sense: the hostile

creatures in a jungle region can be detected more quickly by the sounds they make than by their visual appearance. In addition to the identification of a noise, the correct perception of direction determines their success or failure in the hunt, and can also be a matter of life and death.

This underlying aspect of perception is also reflected in cultural activities. A visitor that spent seven days in the jungle with the Yanomami told of nightly ritual dancing and singing. The darkness made the dancing impossible to see, yet the many moving voices created a musical scenery that made direct use of motion and spatial distribution as a musical resource.

The intentional incorporation of spatiality into the composition of European art music was first undertaken by Francesconi Ruffino d'Assisi in the sixteenth century and was continued by Adrian Willaert at St Mark's Basilica in Venice (Blankenburg 1995: 771). The spatial division and distribution of the voices that were invented in these contexts led to the emergence of concepts that incorporated the effect of spatialisation into the musical experience. Examples of this include experiments by various composers with distant orchestras or sounds from neighboring rooms, and so forth.

The topic gained particular relevance with the emergence of electronic music, through the introduction of the loudspeaker as a universal sound converter. There were various currents in this area, from Pierre Henry and Jacques Poullin's *Pupitre d'Espace* in 1951 to Stockhausen's rotating loudspeaker in 1958 at the West German Radio, or the approaches that encompassed the Philips Pavillon in Brussels, built by Le Corbusier and Iannis Xenakis for Edgar Varèse's electronic work *Poème électronique* (Meyer 2006: 345), and the spherical auditorium at the World's Fair in Osaka, which altogether extended the tonal dimension of music into space. Soon afterwards, John Chowning first developed the method of simulating motion in sound by using digital algorithms.

These developments in the 1960s and 1970s constitute the precursors for a global trend around the turn of the century. The primary focus of research and reception was no longer found in sound synthesis, but rather in how sound is performed and initiated. Consequently, the most important innovations in the development of new interfaces, which will be addressed in more detail later, are found in virtual acoustics and especially in spatial music.

All of the indications point to the increased use of space in future music. Many concert halls now have multichannel audio systems at their disposal. Multichannel hi-fi systems are regarded as standard in the consumer domain. Decisive developments have taken place in computer hardware. While there were only a few professional interface systems with multichannel

sound at the end of the 1980s, most sound cards today are equipped with at least six channels. Moreover, a comprehensive series of affordable production tools, storage devices (such as DVDs and hard drives), and playback technologies, such as 8-channel amplifiers, now exist. Multichannel functionality is now considered an industry-standard prerequisite for acoustic projections in space. This development alone, which was no doubt initiated by the film industry, shows that spatial hearing has verifiably moved more into the focus of the consumer. As a result, the listener gains a greater capability for experiencing spatial perception. The latest cinema productions already display astonishing precision in the positioning and motion of sounds. It is therefore not surprising that research institutions and artists – spurred on by these circumstances – increasingly strive to include and make use of the parameter of spatiality and push the possibilities of perception to their limits both technically and acoustically.

On the basis of this historical and practical body of knowledge, a team of software and hardware engineers at the IMA developed the concept of the Sound Dome under the direction of the author between 2003 and 2009. The composers' need for straightforward usage, in conjunction with the concrete conditions of the routine concert environment, played the most important role in the project's conception. The spatialisation software must be able to easily adapt to different spatial conditions and changing loudspeaker installations for the sake of the concert setting.

The result was the Sound Dome, installed in the Cube theatre of the ZKM, and the interactive control software Zirkonium (Brümmer, Goßmann, Ramakrishnan and Sturm 2006: 3; Brümmer, Ramakrishnan et al. 2007/08; Ramakrishnan, this issue). The Sound Dome in the Cube is composed of 47 loudspeakers that surround the listeners in the shape of a dome. Using Zirkonium, it is possible to send sounds across any given room with unprecedented precision, for example, or to have the sounds circle around the listener. The audience is surrounded by sounds, as they would be in any natural environment. A detailed description of Zirkonium can be found in the article by Sekhar Ramakrishnan in this issue.

Composer Karlheinz Stockhausen often expressed his visions and conceptions of spatial music during the production of his work LICHT-BILDER at the ZKM. These were put into practice for the first time in high quality. Unfortunately, he was never able to use the Sound Dome.

4.2.2. Why space?

In order to pursue this question, the term 'space' must be more specifically defined. Firstly, sound is not possible without space. Every tonal process, from

the vibration of the string and the sound board to spatial sound, is an articulation of space.

In addition to sound synthesis, spatial phenomena exist that are most commonly subsumed under the concept of acoustics. The size of the room, its geometry, and the reflecting surfaces are perceived in the form of reverberation and echo. The size of a space is ascertained by the time interval between the direct sound and the first reflection (Neukom 2003: 85), as well as by a few other parameters, such as how the reverberation progresses. If this interval is short, the listener in effect intuitively develops the sense of a small room.

Sound synthesis and architectural acoustics are complemented by the determination of the position of a sound in space. The process of determining position is made up of the perception of the distance and the direction from which the source sound is emanating. Human hearing is capable of simultaneously perceiving several independently moving objects or detecting groups of a large number of static sound sources and following changes within them. Spatial positioning is thus well suited for compositional use. While the acoustics of different rooms cannot be perceived simultaneously, the parameters of position and movement can be polyphonically used in highly complex formations.

What persuaded musicians to orchestrate sound events using different spatial locations and movement? The observation that nearly all sound sources in our environment are in motion is of particular interest in this context. The most diverse moments or objects can serve as examples for this, such as birds, automobiles, speech or song; the sources of these sounds cannot be attributed to a fixed position. Smaller movements or gestures in space – such as are carried out by strings, woodwinds, and so on, as an element of their musical interpretation – are constantly perceptible during the production of sound. As a result of this movement, the sound obtains a constantly changing phase configuration (Roads 1996: 18), which gives rise to a vitality in the sound. In contrast, static, immobile instruments appear uninteresting; their sound seems flat and unreal. This problem is even compensated for in an organ through the slight detuning of its pipes, thus creating beats. A similar technique is used in the tuning of a piano, whereby the piano tuner detunes the strings slightly amongst themselves in order to achieve a stronger and thereby fuller sound. These aspects indicate that the movement of sounds and the accompanying phase shifting belong to the normality of acoustic perception. This leads to the conclusion that the movement of sounds in space most certainly corresponds to our acoustic patterns of perception, and that the use of these parameters therefore naturally suggests itself for musical contexts.

The use of spatial information within a composition clearly has an impact on compositional decisions. Examples from the sixteenth century demonstrate a clear logic in the use of these parameters. Spatial information aided in providing additional form to musical information and helped to structure the course of the music far more effectively than phrasing, articulation and instrumentation. The best example for the use of spatiality within a compositional structure is a duet, or the concerto grosso (Scherliess and Fordert 1997: 642), whose compositional form is perceived as being clearly structured through the use of spatiality in conjunction with instrumentation. The expanded and more differentiated approach to the spatial area available to the sound, and the integration of motion allow new possibilities to emerge for the dramatic development of a composition.

A further aspect that speaks in favour of the deliberate use of spatiality has its foundation in the fact that human hearing is capable of perceiving more information when it is distributed in space than when it is only slightly spatially dispersed. The reason for this phenomenon lies in the fact that sounds are capable of concealing or masking each other (Bregman 1990: 320). For example, if one plays back the signal of a loud bang and the signal of a quiet beep at the same time, the bang would normally completely conceal the other signal. If both sounds are equally loud, they would blend together in the ideal case. However, both sounds would remain separately perceptible, without merging with or masking each other, if they were to be played back on the left and right sides of a listener's head. This example can be multiplied, until a sound situation arises in which 20, 30 or more sounds are audible, distributed throughout the space. Spatially distributed, such a situation sounds transparent and clear, while the stereophonic playback of the same sounds would appear muffled, with little detail. The listener would be capable of geometrically grouping different events and perceiving spatial formations. This 'active listening' would have various alternatives depending on the position of the listener, resulting in multiple variants of how the sound is received. In addition to this, the brain also has the ability to focus on specific sound objects, in what is called the 'cocktail party effect' (Roads 1996: 469). However, the brain only has this ability in conjunction with spatially positioned sound objects. If the listeners are ideally surrounded by sounds, they are able to dissect complex sound structures, in a sense. This is impossible even for the frontally spatial setup of an orchestra.

If one summarises the various acoustic and psychoacoustic aspects of human hearing, it becomes clear that the ear's ability to differentiate sounds increases considerably with the use of spatial information. If sounds are distributed over a large area, complex sound information can be designed in a transparent

and easily audible manner. The listeners are thus able to grasp more acoustic information and flexibly structure their listening.

4.2.3. The Sound Dome project

The Sound Dome of the IMA (figure 1) is based on strategies that were inspired by the spherical auditorium of Osaka in 1970 (Frisius 1996: 196). In this specific spatial arrangement, the listener is immersed in a dome-shaped loudspeaker installation which allows sounds to be placed throughout the entire area of the concert hall. The reticulated configuration of the loudspeakers enables the continuous movement of sound sources around the listener using the Vector Based Panning method (VBP) (Roads 1996: 459), irrespective of the size of the space and the number of loudspeakers (figure 2). The aforementioned software Zirkonium provides the interface between the flexible loudspeaker array and the unvarying sound choreography.

Particular attention was paid to the development of the sound manipulation. Until now it was a challenge to control, for example, 50 or 60 loudspeakers together with 38 sound sources at once. A great deal of effort was put into the design of the interface, in order to make it intuitively understandable.

Thus, for the first time in the complex development process, Zirkonium represents an instrument that can be used to flexibly perform spatial music, even with practicable resources and a small number of loudspeakers. Whereas composers were dependent on a proprietary format or a strictly set loudspeaker arrangement up to this point, it is now possible for them to adapt to the individual conditions of the performance space and to work on corresponding productions without being tied to the specific location. This system has already been used internationally, at concerts in Budapest, Munich, Cologne, Hamburg, Vilnius, Wiesbaden and Karlsruhe. Moreover, an increasing number of concert halls possess multi-channel sound systems that can be transformed into a sound dome environment with little effort. The existing loudspeaker installations can play back spatial sounds with little technical effort. An example can be seen in a setup at the Stuttgart State Opera, in which the loudspeakers were reconfigured into a sound dome for the occasion of a theatre festival in less than one hour, without moving a single loudspeaker!

Zirkonium's basic conception and development took place from 2003 to 2008, and it is currently being further developed by the ZKM | Karlsruhe in conjunction with the University of Montreal. The goal is to motivate composers, developers and institutions to get involved in its collective, open-source development.

New kinds of reception are also possible with such a multichannel environment. For example, orchestral music can be made into an immersive experience with

Figure 1. The Sound Dome in the ZKM's Cube theatre, with 47 loudspeakers. Photo: Bernhard Sturm © ZKM 2007.

Figure 2. The smaller 24-channel dome in the studio. Photo: Bernhard Sturm © ZKM 2007.

the assistance of a sound dome. Instead of positioning the whole sound frontally, as is the case in the concert setting, the entire orchestra can virtually be placed above the audience. This makes it possible to step through the individual instrument groups while the work is being performed. The secondary lines suddenly become perceptible. The listener can move from the first to the second violins, to the woodwinds and brass, thus experiencing the music interactively and analytically. This new kind of listening leads to an 'active' reception of music, which makes the construction of complex musical works perceptible in a new way. It is even possible to take it one step further and separate the polyphonic structures of, for example, Glenn Gould's interpretation of the Goldberg Variations, expressing it as sound architecture by placing and moving the motivic threads in space.

Kindled by the possibilities of digital control, and in parallel to the consumer domain, multichannel

technology has especially made itself heard among composers of electroacoustic music. It is clearly evident that new approaches are being tried out, as well as being adapted for the normal concert setting. In addition to the Sound Dome, the traditional Acousmonium (Jaschinski et al. 1999: 551) and wave field synthesis (Roads 1996: 252) must be mentioned here. The potential that is introduced to music through spatiality is only at the beginning of its development. The ability to consciously listen using space will continue to be developed in the future, and larger installations will become more flexible and more readily available overall. This will make it easier for composers and event organisers to animate and challenge the audience's capacity for experience.

4.3. Research and development of interfaces

To the same extent that electronics have liberated sound from its physical requirements, thereby enabling the existence of sounds that are freed from their place of origin, technology has also broken down the physical connection between interface and sound generation. The specific physical properties of the piano keyboard result to some extent from the assignment of each of the strings and hammers to one individual key. Such physical requirements led to the development of a different interface for the harp, for example, from that for the flute. Through the introduction of electronic pulse generation, these dependencies can be dissolved, and sounds can be controlled using any kind of interface. If sounds are triggered by abstract control signals alone, performers and composers have the freedom to explore within the use of instruments and sounds.

A future endeavour consists of the development of interfaces that accommodate the intuition and physical capabilities of the users, while at the same time allowing for nuanced musical results. The design and implementation of interfaces presents a very lengthy and complex undertaking, one which is influenced by traditional aspects as well as technical and solely human factors.

How long did it take to develop the technology necessary to change the size of an object by spreading two fingers, such as is possible with the iPhone? The development of such seemingly natural correspondencies requires much experience, intuition, and cutting-edge technical resources.

Other examples of advanced development can be seen in the artificial use of lasers: Through the use of laser light, dancers can produce sounds by touching the light beams, thereby translating their movement into sound, as was done in the author's work *Shine* (figure 3 and Movie example 3). Another example of the use of cutting-edge developments can be seen in violinist Stevie Wishart's use of a controller to manipulate

Figure 3. Csaba Horvaáth and Andrea Ladanyi in Ludger Brümmer's *Shine*. Photo: Yvonne Mohr © ZKM 2007.

Figure 4. Multi-sensor system: Todor Todoroff, *Around and above, weightless…* Photo: Yvonne Mohr © ZKM 2007.

electronics. Using sensors on their bow hands, the performers can communicate with the computer and continue to play the piece even though their bow is not touching the strings (figure 4 and example 1). Todor Todoroff controls the computer using accelerometers and positioning sensors together with a theremin. Through the simultaneous use of several controllers, he creates complex patterns of control data like those of Stevie Wishart. These data patterns allow the performer to achieve an intricate operation of the computer, thus enabling the generation of a vibrant sound pattern (figure 5 and Movie example 2).

At the IMA in 2002, Bernhard Sturm enhanced a large number of controllers and combined them for the opera project Heptameron by Gerhard Winkler

Figure 5. Sensors on the wrist: Stevie Wishart, *The Sound of Gesture*. Photo: Yvonne Mohr © ZKM 2007.

(Movie example 5). Composer Bernhard Schultheiss and percussionist Michael Pattmann are currently developing promising digital accelerometers using wi-fi communication in a joint project with the Karlsruhe University of Applied Sciences. The digital design of these sensors, together with their small size and light weight, promises an unprecedented precision.

Wind instruments in particular have also been equipped with digital controllers in order to allow the performers to communicate with the computer while they are playing. Bernhard Sturm has already worked with a MIDI flute, a trumpet, and the modification of a tuba. In addition to these extensions to the instruments, guest artists at the IMA and the Institute for Visual Media also use modified versions of various video tracking systems. Finger tracking and advancements in the open-source framework *reacTIVision* (Kaltenbrunner and Bencina n.d.) are of particular note in this context. These are to be used in conjunction with areas several square metres in size for the Amazonas opera project.

5. CONCLUSION

The use of technology to extend the tonally structural vocabulary was a natural component of the avant garde in the past. The accomplishments achieved in this context are still highly regarded today. Works such as Varèse's *Poème électronique*, Stockhausen's *Kontakte* and Henry and Schaeffer's *Symphonie pour un homme seule* are still valid masterpieces. Yet, in the course of the identity crisis that can be observed within contemporary music in Germany, the context of an increasingly consumer-driven orientation is fostering the emergence of a conservative alignment in which overly innovative art, such as electroacoustic music, no longer appears to have a place. Issues of substance are ignored within the discussion of broadcast quotas and mass effectiveness. Even composers do not shrink from castigating electronic music because it merely comes out of loudspeakers. Acousmatic music is still dependent on a specially established context. There are few centres, albeit very dedicated ones, that programme acousmatic music in concerts and festivals. Among these are first and foremost the IMA and the studios of the Technical University and the Academy of the Arts in Berlin, all of which are also open to live electronics.

The Institute of Musicology at the University of Cologne has also committed itself to the research of acousmatic and electroacoustic music with regard to content, representing the involvement of an exceptionally important institution in the field. In addition to valuable analyses and descriptions of new works that will come from the institute's activities, competent reviewers will also be trained for this genre.

The studio landscape is augmented by the Southwest German Radio's Experimental Studio, which works exclusively in the realm of instrumental music. In addition to this studio, which is open for composers, there are approximately 24 studios for the educational instruction of composers at the music colleges.

The IMA at the ZKM defines itself in this context through its interest in new media art that makes significant use of technology. The aspect of interdisciplinarity is implicitly anchored in new media art. Through the consistent linking of acoustic and musical components to visual aspects such as photography or video art, the close interconnection of the perceptible layers becomes a matter of course. The aspect of technology also has a close relationship to new media art, since new media art has always made use of the most recently developed technological instruments. Just as in new media art, the turn towards technologically oriented music leads to pronounced consequences with regard to content. The use of cutting-edge technology logically leads to a paradigm shift, since the artistic content is determined by the capabilities of the available instruments. *Musique concrète*, for example, primarily makes use of the creative resources of recording devices and filters. This led to the development of a specific aesthetic, which examines stored sound objects and

modifies them in their tonal qualities or their temporal structure.

The use of sensors such as accelerometers and video tracking also leads to a change in musical aesthetics. Composers can now determine which movement should produce which desired result, and they are no longer dependent on the physical necessities of sound production. This newly obtained freedom to bring an element of theatrical staging to the act of musical performance is currently gaining increased importance in new media. New media artists and composers in particular are achieving the most exciting results in this context, realising their ideas in direct interaction with technological tools (Movie example 6). The consequential use of technology thus changes the musical language and alters the duties of the musician. The instrument-in-the-machine that is being used is no longer uniform, but rather its properties can be altered. Notation is given a new function, since it is no longer required as a means of communication between the composer and the performer. Instead, lists of data and protocols are created, or interfaces that communicate between the individual programs.

It is evident that these composers are developing in an independent direction. Rejecting the traditional aesthetic and forms of presentation associated with contemporary music, a separate scene is emerging that is bound to a joy in experimentation, and which deliberately distances itself from the established realm of New Music.

The IMA supports precisely this open and curious attitude in composers. It endeavours to promote new trends and requirements as well as providing support to recognised composers of established distinction. Since it is situated outside of a far too narrow aesthetic position, composers with the most diverse aesthetic orientations come to the ZKM to create works of acousmatic music or live electronics. Research and production are brought together at the IMA to achieve this goal, and the results are made audible in the form of concerts and publications. In addition to the development of cutting-edge interfaces, software and hardware, the aspects of media-based orientation and spatial music play a central role. The IMA does not see itself solely as an institution for the promotion of the elite. It assumes a stance of social responsibility in the

form of open-source projects such as Zirkonium, as well as in the festival and symposium *next_generation*, through workshops, and in pedagogical projects with teachers, students and pupils.

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