The Norwegian Academy of Music
Ivar Frounberg, professor

Project # 199 *Multimodal Sensing in a Polymedial Space*
Research lab for Multimodal Sensing and Polymedial Artwork.

General information

a. Name/title of the research: *Multimodal Sensing in a Polymedial Space.*
b. Scientific discipline: Artistic Research, Transmedial art, Video art, Polymedial Composition, Interactive Music, New Instruments for Musical Expression, Multimodal Sensing, Distributed Performance, Media Technology, Computer Science, Cognitive Theory.
c. Host institution(s): The Norwegian Academy of Music
d. Total cost and time-plan: 9.7 mill. NOK over 5 years.
e. Research infrastructure: Advanced scientific equipment
f. Proposal type: project
g. Localisation of infrastructure: The Norwegian Academy of Music, Oslo
h. Upgrade / existing research: upgrade of *Music Research and Renewal*,
i. Infrastructure network: National facility with international impact.

Vision and scientific goals

We want to create a world-class infrastructure for explorations in interactive art with multimodal sensing and polymedial projection. The idea is to create a physical space where humans can interact at an artistic level with the technology being transparent. Transparency means - in this context - that human beings within the space can act without having to do specific predefined actions to control or interact with the technology. We use the word 'humans' to denote that there will be no separation between the artist and the public, no separation between expert users and occasional users.

The space will be sensing movement (Motion Tracking equipment), visual activities (HD video surveillance) as well as sound (an array of microphones). In response to these 'stimuli' the projection space project back audible and visible actions.

The research will on long term investigate how multimodal stimuli can be integrated and balanced in a unified artistic statement. The projection space will be useful for alternative representation of complex data, 3D modeling, acoustic modeling, large-scale visualization solutions in many other fields of research.

The short term goals are to establish:
a) a common and flexible synchronization of a large amount of networked computers
b) a flexible acoustic system for positioning sound
c) a multidimensional and multimodal sensing system

The proposed research infrastructure will be unique in Norway, and will be among only a few similar infrastructures in the world. It will provide composers, performers, artists and researchers with an engaging environment for artistic research. In the international community for computer music (mainly organized in The International Computer Music Association – http://www.computermusic.org/), the very establishing of such an infrastructure will ensure a high interest and contribute to strengthen the position Norway already possess within the community.

Major challenges will be to

a) keep the technology free of esthetic preferences and prerequisites
b) establish a good and obligational relationship with other art-forms than music (visual arts!)
c) raise interest in other areas of research for other uses than art work
d) establish a user friendly interface for the creative work
e) balance generality versus specificity in the design.

The term 'research infrastructure' is used to denote material and research resources. In this application we apply for the funding of material resources in the form of a large array of computers, activity tracking systems, sound and video equipment, acoustic development of playback and video projection equipment. Research resources are to be provided by the Norwegian State Academy of Music and its collaborators. The 'research infrastructure' will be continued into the 'center for polymedial art work' after the five year project to establish the physical unit the 'projection space'.

The term 'projection space' is used to denote a physical space equipped with the possibilities of tracking activities with different means and respond to these stimuli with audible and visual activity. The 'projection space' will be a result of the research done within the 'research structure'. After the five year project the 'projection space' will be continued in the ownership of 'center of polymedial art work'.

The term 'center for polymedial artwork' is an autonomous unit proposed to continue related to one or more of the funding institutions (for example the Norwegian Academy of Music).

Scientific and technological environment

The Norwegian Academy of Music is a frontrunner in artistic research among the Scandinavian countries. One of the main focus areas is research in music composition, interaction on different levels between composers, musicians, audience and technology regarding performance and esthetics. A number of ongoing projects, and several projects in preparation, involve multimodal sensing and polymedial output in an artistic context. The idea of polymedial composition goes back to the composer Richard Wagner's ideas about the total integration of senses in multimodal performance ("Gesamtkunstwerk"). Among more recent influences is Nicolas Bourriaud's idea of 'relational esthetics' in which there is no separation between the artwork and the artist (as a person), as well as a blurred separation between the artist and the audience. New technologies allow for exploring relationships between (1) the performer and the audience, (2) the artwork itself and the instruments used to perform it, and (3) to transcend the boundaries between different art-forms (transmedial art). The strategic research area *Music Creation and Renewal – Interactions and new Timbral Possibilities* at the Norwegian Academy is currently focused in these fields (1)-(3) (http://www.nmh.no/fou/731).

A pilot project performed during the 2009 Vinterlyd-festival functioned as a small scale polymedial projection space surrounding the audience with quadraphonic sound and video-projection on four screens. The main artistic topic: *Counting, Memory and Interrogation* was investigated in three aspects: recalling factual information (*Interrogation*), referencing mythic memory (*Memory*) and the conflict between daily life and highly concentrated music performance (*Counting*). The performance space for the musicians and a dancer was situated like a boxing arena in the mid of the audience. The video screens formed four artificial 'walls' surrounding the audience. By changing the traditional directionality between stage and public, we were able to include the audience as a

part of the play. In a metaphor the setting as a whole functioned as a 'brain' linking outer stimuli (the video screens) with inner reflections (the musician/dancer performing in the arena).

A number of other recent artistic outcomes of the research includes two concerts with the Tromsø Symphony Orchestra (Tromsø 19.03.09 and Narvik 20.03.09) and a video projection with a live music performance by research fellow Victoria Johnson on the roof of the new opera in Bjørvika (Oslo 28.04.09). Documentation and reflection on the outcome is under construction at the time of writing this application.

Artistic research as a interdisciplinary field.

Artistic research is a relative new field and navigates between *Scylla* and *Carybdis*: on one hand there must be a focus on high quality artistic expressions being judged by their artistic value. But on the other hand experiments on more other levels must be formulated and evaluated systematically. This application will *not* extensively address the artistic side of our research. The sketched projection space will indeed be a facility for investigating artistic problems - but at the core there are a number of technological issues that have to be systematically researched, which are also the main issues of this application for the research infrastructure.

The technological research (software and algorithmic development) in the above examples include,

a) interface design for laptop instruments (build on a generalized rhythmic model),
b) synchronization of a small number of computers on airport network (a simple conductor-musician metronome model)
c) extreme slow live video-transformation (imperceptible changes over long time)
d) various digital signal processing algorithms for interactive response on the playing of a musician (dynamically changing processing of audio-signals depending on the input).
e) tracking the pulse from a live audio-signal (sound from a performing musician)
f) tracking harmonic content from a live audio-signal (as above).
g) real-time instrumentation of the harmonic content for a string orchestra (musicians playing from interface on notebook-computers placed on the note-stand)
h) real-time composition through instructions distributed on the notebook computers.

Description of the Research Infrastructure

Synchronization issues.

Main research focus will be dealing with *time-critical operations*. When musicians play, timing is highly critical often within the range of 20-50 milliseconds. While playing every musician has an 'inner metronome' counting the beats of the music. The 'inner metronome' is however not stabile, but adjusts to changes coming to the musician through visual contact and auditory perception. The technology has to adapt to a similar flexibility before it becomes useful as a partner to the musician. Synchronization algorithms exists and allow for a transmission time for synchronizing signals down to under 10 milliseconds for a small scale network of computers. However the transmission time is highly variable and thus not very reliable. Since we want to find a way to synchronize a large-scale computer network we have to develop a more reliable model of synchronizing. Problems will arise when we want to synchronize computers that are not physical adjacent (for example when we want to synchronize internet-distributed performances). When computers are synchronized we also know that the internal clocks are not stable enough to keep the computers synchronized over even a relative short time-span of for example 30 minutes.

It is our hypothesis that the model - from which the algorithms will be deduced – must be close to the situation with musicians sketched above, where synchronization is performed occasionally and the 'inner' metronome only is allowed in shorter time-spans. However that model can probably be challenged too. Especially when dealing with continuous tempo modification on large level (*accelerando*, *ritardando*) or – even more dramatically - on small level (*agogic* phrasing), where modification of the synchronization conflicts with latency of the synchronization itself.

Research in synchronization of net-distributed computers will be of great interest for the electronic game industry. The research will cast new insight into a number of disciplines within computer science. Keywords here are: distributed computing, algorithms, near real time response. The Verdione project (The World Opera - http://www.theworldopera.org/) will be another beneficiary of the knowledge obtained and the realization of synchronizing algorithms.

The issue of simultaneity.

Another core issue for the research is the notion of *simultaneousness*. When distributing sound over a range of hundred loudspeakers physically distributed at different places and with different angles and distances to each other we collide with the precedence-effect (approx.1 millisecond): the first sound-ray captured be our sensory system is given all cognitive attention, masking other secondary rays for a short moment. We will have to develop a strategy for circumventing the effect.

There has been developed a range of sound diffusion formats (stereophony, Dolby 5.1, Ambisonics, vbap ao.) some commercial, others experimental, some works as dynamic balancing of signals, others on the phase-content. They are however all defined to work successfully only in a specific position in relation to the speakers (the 'sweet spot' in which the precedence-effect is minimized).

The above mentioned sound diffusion formats all requires loudspeakers with a controlled neutral frequency response within the hearing range and in a fixed positioned in relation to the listener (the exception be the so-called 'sub-woofer', which are specialized for low frequencies). At le Groupe de Recherches Musicales (GRM/INA) in Paris the *Acousmonium* was constructed by the composer Francois Bayle during the 1970's. Later – during the late 1980's - the BEAST-project was launched at the electro-acoustic Music Studios at Birmingham University as a comprehensive sound diffusion system for the performance of electro-acoustic music.

The *Acousmonium* worked metaphorically speaking like an orchestra: many specialized individuals (the 'musicians') controlled from a center (the 'conductor' i.e. the mixing console) and dispersed - in bundles - over a performance space (the 'podium'). The BEAST loudspeaker setup is mostly in stereo pairs or octaphonic grouped, each group in a fixed relation to the audience, and surrounding the audience at different altitudes and distances. Both of these systems are dealing with a variety of non-neutral specialized speakers.

Our suggestion is to regard loudspeakers as acoustic reflectors spaced in a 'virtual' space where sound events take place. A challenge here is to 'model' the virtual space. Acoustic simulation-models requires a high amount of computing power. A second thought along these lines will be to develop a specialized loudspeaker, which disperses different frequency ranges in different angles (like a musical instrument do). The projection space will allow us to do experiments and evaluate how successful different approaches are.

Research in this field will be of great interest for movie-theatres, planetariums and science centers, the science of acoustics, acoustic room simulation, digital signal processing.

Motion Tracking.

A small number of motion tracking systems are commercially available. Generally there are only a few approaches to motion tracking in a 3-dimensional space. Systems can be based on different sorts of devices put on the object to be traced. It can be visual markers or it can be mechanical sensors sending their information through an airwave network.

The visual markers is said to be passive when they reflect light-beams emanating from a sender close to the camera lenses. For 3-dimensional objects more cameras are needed to cover the 3-dimensional information. Active markers are emitting light themselves which is then captured by the cameras. Both systems are triangulating the position in space of the markers. Since markers have no individual identity the computer must calculate their probable traces in order to give a proper representation. Visual markers do work best in an environment where light is sparse and controlled. Artistically they are less interesting because of this constraint, and because they have a visual impact. Mechanical sensor systems do work under 'normal' natural light conditions, they can be more precise, but they still have the unwanted visual impact on the viewer.

More confidence from an artistic point of view has the development of computer algorithms for tracing objects from a multiple of optical inputs. Intensive computing is required to let the system recognize forms that can be tracked (for example a face or other body-parts). Massachusetts Institute of Technology (MIT), Stanford University and Max Planck Institute are all doing research in this field.

The projection space.

We envision creating a state-of-the-art projection space along the lines of the *AlloSphere* at the University of California, Santa Barbara (http://www.allosphere.ucsb.edu/).

The *AlloSphere* is a neutral symmetric structure – a spherical space – in which full immersive, interactive, stereoscopic/pluriphonic, virtual environments can be experienced (sic). It accommodates 20 to 30 people at the time, having a height of a 3-story building. The architectural structure is unique and thus highly controllable with regard to acoustics and visual projection.

The projection space we envision, will – ideally - be flexible to fit into different sized and shaped spaces. This in response to an artistic issue: we want to be able to meet the public at close range rather than having the public move to a custom made center. The latter solution requires the build of a physical architectural construct, where our solution seems to be more manageable. The challenges such a decision raises are considerable, but inspiring for the experimenting with untraditional solutions. We must adopt to and take advantage of an existing environment, rather than control all aspects of the situation. However we are attentive to the fact that for example the development of a specialized loudspeaker (outlined above) will have to be done in a small scale controlled environment, preferably in collaboration with a industrial developer.

Generality versus specific solutions.

The dilemma just presented above deals with the prioritizing of generality over a specific solution, which will be at the core of both the technological and the artistic research. Generality can be obtained in several ways. In the case of the construction of a multidirectional loudspeaker, one could postulate that this is a specific solution since frequency-dependent sound-ray radiation will be more specific than a 'neutral' approximated flat response. This postulate can be rejected if we

succeed to control the radiation-pattern detailed and accurately, and thus obtain a new level of generality. Throughout the research we will seek generality as our priority of different solutions.

More specifically we will apply for the following advanced scientific equipment:

- Multimodal sensing
    - Motion capture system for recognizing and tracking people in the space.
    - Multiple video cameras for recording video in 3D to be transmitted and processed.
    - Microphone array for recording sound in 3D.

- Polymedial output
    - Multispeaker sound projection setup for working with 3D sound spatialisation.
    - Motorized acoustic tiles for adjusting the reverberation in the space.
    - Multiprojector setup for working with surround video and projection on shapes.

We will also apply for technical support for setting up the equipment and the development of the solutions necessary for working with the equipment in an artistic context.

Challenge: The abovementioned research involves large multichannel speaker and video projection setups, as well as various types of sensing systems. The main challenge is, that there is currently no permanent space with relevant equipment available in Norway. This severely limits the artistic possibilities of projects and weakens the possible collaborations with international partners.

Plan for access and use, data and knowledge management.

We expect a great international interest on both the technological research and on the artistic research part.

The Norwegian Academy of Music and the National Academies of the Arts in Oslo and Bergen offers research positions for 3 years under the National Norwegian Artistic Research Programme (http://www.kunststipendiat.no/). We will encourage and present relevant applications expecting to have one or two candidates admitted to the program within the first year of operation.

Dissemination of research results will mainly be by papers and presentations at relevant conferences like *The International Computer Music Conference* (ICMC), the *NIME-conference* (New Instruments for Music Expression) held every year. Articles should be published in the *Computer Music Journal*. The artistic research will be published in the form of public performances of art works and in workshops for invited artists (composers, visual arts, dancers etc.). The invited artists may also be presenting their works for the teaching staff and students at the Norwegian Academy of Music and/or the Visual Arts-school at the National Academies of the Arts in Oslo and Bergen. Explicit reflection on the artworks will be presented in relevant fora as for example *compositioNetwork* (a conference for Scandinavian schools that offer composition studies and are committed to artistic research) or articles in various music journals.

Impact on research and innovation.

The proposed research infrastructure will be unique in Norway, and will be among only a few similar infrastructures in the world. It will provide composers, performers, artists and researchers with an engaging environment for artistic research. The infrastructure will be vital for the strategic research target *Music Creation and Renewal – Interactions and New Timbral Possibilities* at the Norwegian Academy of Music (http://www.nmh.no/fou/731).

The national impact will be that the 'projection space' is expected to unite several minor organizations working with new technology in the performing and visual arts (BEK, NoTAM oa. – see the list below) and provide them with a highly sophisticated technological projection space to be used for artwork and artistic experiments.

The very establishing of such an infrastructure will ensure a high interest in the international community for computer music. We will be able to invite researchers from most major universities dealing with music creation, performance and music-technology. Central units within the universities will be:

The Stanford University Center for Computer Research in Music and Acoustic (http://ccrma.stanford.edu/),
Center for New Music and Audio Technologies (http://cnmat.berkeley.edu/)
The Allosphere Research Facility at the University of California, Santa Barbara (http://www.allosphere.ucsb.edu/).
Music Technology, McGill University, Montreal Canada (http://www.music.mcgill.ca/musictech/)
Music, Mind, Machine Group, University of Nijmegen/University of Amsterdam (http://www.nici.kun.nl/mmm/)
Sonic Arts Research Centre, Queens University, Belfast (http://www.sarc.qub.ac.uk/main.php)
Institut für Elektronische Musik und Akustik, University of Graz, Austria (http://iem.at/services/studios/cube)

Partners and scientific institutions.

The proposed infrastructure will benefit the following ongoing collaborations:

- The World Opera project (http://www.theworldopera.org/): The Worldwide Stage for Artistic Research and Education ("World Opera"), Struer, Denmark & the VERDIONE research project at Simula Lab, Oslo.
- fourMs (Music, Mind, Motion, Machines), University of Oslo: research in music cognition, sensor technologies and machine learning.

The proposed infrastructure will also be a valuable resource for:

- norsk senter for teknologi i musikk og kunst (NoTAM, Oslo) - http://www.notam02.no/
- Bergen Center for Electronic Arts (BEK, Bergen) - http://www.bek.no/bek/
- Kunstakademiet ved Kunsthøgskolen i Oslo
- (http://www.khio.no/Norsk/Om_KHiO/Fakultet_for_visuell_kunst/)
- Composition Network, Scandinavia (http://www.mhm.lu.se/o.o.i.s/16058)
- The international NIME network (http://www.nime.org/). The NIME 2011 conference will be organized in Oslo, and would be a great opportunity to test the new infrastructure.
- We will seek further collaboration with researchers projects in the fields of musicology, informatics, acoustics, architecture, medicine, and psychology.

User groups and international cooperation.

Research in synchronization of net-distributed computers will be of great interest for the electronic game industry and a number of disciplines within computer science: distributed computing, algorithms, near real time response.

Collaboration with the Institute for Informatics at the University of Oslo will be highly prioritized. The main competence area here will be the Distributed Systems Research Group.

The Verdione project (The World Opera - http://www.theworldopera.org/) will be another beneficiary of the knowledge obtained and the realization of synchronizing algorithms. Current status in the field of net-distributed performance is to solely rely on audible feedback, which is a core problem, when the latency generally is more than 100 ms.

Research in positioning sound will be of great interest for movie-theatres, the science of acoustics, acoustic room simulation, digital signal processing.

The projection space will be useful for alternative representation of complex data, 3D modeling, acoustic modeling, large-scale visualization solutions in many other fields of research. Interest groups will be planetariums and science centers. We will encourage other research fields to use the projection space for investigate data collections in new representations in order to obtain deeper knowledge and insight in the phenomena represented by the data.

Collaboration with the Institute for Informatics at the University of Oslo will be highly prioritized. The main competence area here will be the Mathematical Modelling Research Group, especially in the fields of digital signal processing and image analysis.

During the construction period and after its final construction the projection space will be opened for artistic research in the field of net-distributed performance and polymedial artwork. The main focus will be on the systematic development of artworks to be presented for the public. The focus on the 'systematic development' – rather than a unique performance – enables us to be able to develop an extreme high artistic value of the products. It is our experience that any artwork benefits from being accessed again and again by the creator. Thus we will focus on the process more than the work itself!

Two categories of artists would be invited to use the projection space for artistic expressions: commissions will be given to international and nationally highly regarded artist; projects will be invited internationally and on national level for other artist, who want to explore the field of polymediality: sound, visuals, movement, text etc.

Management plan and localization.

The project will be hosted by the Norwegian Academy of Music in Oslo as a part of the research target area *Music Creation and Renewal – Interactions and new Timbral Possibilities*. The field has a 2009 budget of NOK 1.175000 and research positions amounting to 2.4 full-employment.

This research structure lasts for the strategic plan-period 2008-2013 (http://www.nmh.no/87/23489/NMH_strategisk-plan08-13.pdf -> pg. 12-14). Artistic research is highly prioritized by the Norwegian Academy of Music, who wants to achieve international excellence in the field.

Current projects of relevance for this application includes:

NIME: New Instruments for Musical Expression,
post doc. Kjell Tore Innervik (full time),
post doc. Alexander Refsum Jensenius (20%),
professor Ivar Frounberg (20%).

The interactive computer, program structure, representation and performance,
professor Ivar Frounberg (20%)

Improvisation – Interaction – Composition,	førsteamanuensis Peter Tornquist (20%)
Poly-Medial Composition,	professor Henrik Hellstenius (20%)
The electric violin in the digital space,	research fellow Victoria Johnson (100%)

We already collaborate with the FourMs group at the University of Oslo. This collaboration will be strengthened by the FourMs expertise and research within the fields of *Sensing Music related Actions* and *Sonic Interaction Design*. The time-span for their research is from 2008 to 2012.

In 2011 The Norwegian Academy of Music, the Department for Musicology at the University of Oslo and NoTAM, Oslo jointly hosts the NIME 2011 conference (www.nime.org).

One risk factor being hosted at the Norwegian Academy of Music is the difficulty of finding a proper space for research laboratories.

Time plan and deliverances.

The first phase (1. & 2. year of operation):

Establish basal synchronization of a large array of computers.
Research on multidirectional sound-projection.
Research different Motion Capture Systems.
Basal experiments with sound localization and psycho-acoustic tests.
3D recording and projection techniques for the sound.
2D video-projection on curved surfaces.
Research 3D visual recording and projection.
Develop basic algorithms for controlling the components
Determine a scheme for data
- representing outer event in an appropriate language inside the computer.
Prepare the NIME2011-conference in Oslo
Small scale multi-loudspeaker set-up at NIME2011 (in Oslo!)
Artistic tests systematically investigating connections
between the different components
with different esthetic point of departures.

The second phase (3. & part of 4. year of operation):

Test a truly shared net-distributed performance space
Research Motion Control on video- and sound projection
Test of first generation multidirectional speaker.
Present a small scale projection space at NIME2011 (in Oslo!)
Establish a proper user interface for the projection space.
Determine needed acoustic regulation and noise insulation.
Find a proper space for the full scale projection space
Performances of small scale artworks of different esthetic
(systematically investigating relations between sound and visuals)
Commision full scale art works for the full scale projection space

Third phase (second part of 4. & 5. year of operation):

Develop second generation of multidirectional speakers.
Establish a full scale projection space
install acoustic regulation,
install sound- and video-projection
install motion capture systems.
First full-scale performances of commissioned art works
at the formal openening of the *Center for Polymedial Art Work*

Budget and funding plan

Ivar Frounberg, professor,
manager of *Music Creation and Renewal – Interactions and new Timbral Possibilities,*
Norwegian Academy of Music, February 2009.