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Perspectives on gesture from music informatics, performance and aesthetics

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Abstract: This article chronicles the research of the Nordic Network of Music Informatics, Performance and Aesthetics (NNIMIPA), and shows how the milieux bridge the gap between the disciplines involved. As examples, three projects within NNIMIPA involving performance interaction examine the role of audio and gestures in emotional musical expression using motion capture, the visual and auditive cues musicians provide each other in an ensemble when rehearsing, and the decision processes involved when a musician coordinates with other musicians. These projects seek to combine and compare intuitions derived from low-tech instructional music workshops that rely heavily on the use of whole-body gestures with the insights provided by high-tech studies and formal logic models of the performing musician, not only with respect to the sound, but also with regard to the movements of the performer and the mechanisms of group coordination.

Keywords: music informatics; music performance; aesthetics; philosophy; interaction; logical models; game theory; decision theory; UML; gesture; motion capture; research network.

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Søren R. Frimodt-Møller received his PhD in Philosophy from the University of Southern Denmark, and prior to this, his MA in Philosophy and Visual Communication. His PhD dissertation, entitled 'Playing by the rules? A philosophical approach to normativity and coordination in music performance' (2010), dealt with the role of following rules in the coordination processes of performing music ensembles, and involved methods from modern epistemic logic, as well as traditional music philosophy. He is the Managing Editor of *JMM: The Journal of Music and Meaning* and Assistant Professor in Medialogy at Aalborg University Esbjerg.

Cynthia M. Grund contemplated a career as a Professional Accompanist (piano) before deciding to concentrate on an academic career. She received her training in the USA, Sweden and Finland. She defended her doctoral thesis in 1997 at the University of Tampere and has published widely on topics dealing with the interrelationship of aesthetics, technology and musical practice. She is currently an Associate Professor of Philosophy at the Institute for the Study of Culture, University of Southern Denmark, where she directs The Aesthetics of Music and Sound (http://www.soundmusicresearch.org) and NNIMIPA (http://www.nnimipa.org). She is also the Editor-in-Chief of *JMM* (http://www.musicandmeaning.net).

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1 Introduction

All projects within artistic research will at some point spark cooperation between different disciplines: if one is interested in the expressive power of a painting, this may lead one to work not only with theorists of art, but also with practitioners such as the painters themselves, curators, audiences, etc. For the members of the Nordic Network for the Integration of Music Informatics, Performance and Aesthetics (NNIMIPA), which has its origins in local research networks and milieus dating back to 2001 (see Section 2 below), the need for cross-disciplinary approaches has been evident from the start. A prominent field in current music research is the development of models for how we interact with music (whether as listeners or as performers). Such research involves the insights of, among others, musicians, composers, musicologists, and computer scientists. NNIMIPA has from the start tried to combine the insights of the various disciplines and professions dealing with music performance in order to develop a better foundation for discussing questions related to how we interact with music. In the following, some of the research conducted within NNIMIPA will be presented in order to show how the cross-disciplinary nature of a network can benefit the specific research projects of individual researchers.

Section 2 contains a history of the network, while Section 3 and its subsections consider three different perspectives on performance interaction: The expressive means a musician has at his disposal when interacting with an audience (3.1), ways of modelling interaction between musicians during rehearsals and performances when these are recorded on video (3.2), and formal schemes (borrowing methods from epistemic logic, game theory and decision theory) for describing the cognitive background for the decisions made by musicians during the process of coordination throughout a performance (3.3). By combining state of the art audio/video technology with methods from philosophy and computer science, this three-part project yields new perspectives on the role of gestures in the aesthetics of performance.

2 The history of NNIMIPA

The driving motivation behind the establishment of NNIMIPA has been to explore the voltage field that is created when music informatics, performance and areas traditionally dealt with by philosophical aesthetics interact. It complements and supplements two Danish networks devoted to interdisciplinary studies involving music – NTSMB – Netværk for Tværvidenskabelige Studier af Musik og Betydning/ network for cross-disciplinary studies of music and meaning (established in 2001 with funding from the Danish Research Council for the Humanities (http://www.ntsmb.dk) and *the Aesthetics of Music and Sound: Cross-Disciplinary Interplay between the Humanities, Technology and Musical Practice*, a research programme based at the University of Southern Denmark as part of the Institute of Philosophy, Education and the Study of Religions since 2006[1]. In addition, many NNIMIPA members are active as contributors, peer reviewers and members of the editorial board and/or staff of *JMM*: the *Journal of Music and Meaning* (http://www.musicandmeaning.net), an international, peer-reviewed online journal. *JMM* was founded in 2003 as an outgrowth of the activities within NTSMB.

NNIMIPA was officially established during the 2007–2008 academic year, when funding provided by the University of Southern Denmark at Odense was matched by Nordplus in order to establish this Nordic cooperative initiative. The charter members were

1 University of Southern Denmark
2 Academy of Music and Music Communication, Esbjerg, Denmark, as of 1/1-2010 renamed Academy of Music and Dramatic Arts, Southern Denmark after merging with the Carl Nielsen Academy of Music, Odense and The School of Dramatic Arts Odense
3 Aalborg University Esbjerg
4 University of Tampere, Finland
5 Sibelius Academy, Helsinki
6 Royal Institute of Technology, Stockholm, Sweden.

Nordplus continued to provide funding for NNIMIPA activities held during the 2008–2009 and 2009–2010 academic years in the form of grants which were matched by the participating institutions. The University of Oslo became a member in 2009. NNIMIPA became a research network under NordForsk (ttp://www.nordforsk.org) on September 1, 2010, with funding during 2010–2013. In 2010 Bifröst University, Iceland, and University of Iceland, Reykjavik, Iceland came on board, as well as Malmö Academy of Music, Lund University, Sweden, and Grieg Academy, Bergen University College, Norway. The most recent addition to NNIMIPA has been Aalto University, Helsinki, Finland, which became a member in early 2012. The decision to award the grant was made by the director of NordForsk following an evaluation carried out by a panel of independent experts.

The educational, lecture and research activities of the network are documented by means of the website (http://www.nnimipa.org) which was launched in February 2010.

3 Research

The following three subsections present some of the research projects conducted within NNIMIPA. All of them have performance interaction (whether between musicians or between musician and audience) as their nexus.

3.1 Music, meaning and movement

One area of investigation that engages all who are active within NNIMIPA is that which deals with the ways in which music may be regarded as meaningful.

A low-tech approach to the exploration of the relationship between music and meaning took centre stage together with a high-tech motion capture approach during the NNIMIPA coordination meeting held at the University of Oslo, February 18–19, 2010. William Westney, Paul Whitfield Horn Professor of Piano, Browning Artist-in-Residence School of Music, Texas Tech University demonstrated techniques he has been developing for over 25 years in order to encourage musicians to find ways of keeping their playing (or singing) fresh and invested with personal engagement.

Westney's workshop is known as *the Un-Master Class* (UMC)[2] and was originally intended to address the problem that many musicians, despite high levels of training, deliver performances that come across as rather lifeless and generic. While it still functions in this way, it has become increasingly apparent that the presuppositions behind the UMC raise deep questions involving the locus of meaning in music and what the character of this meaning might be.

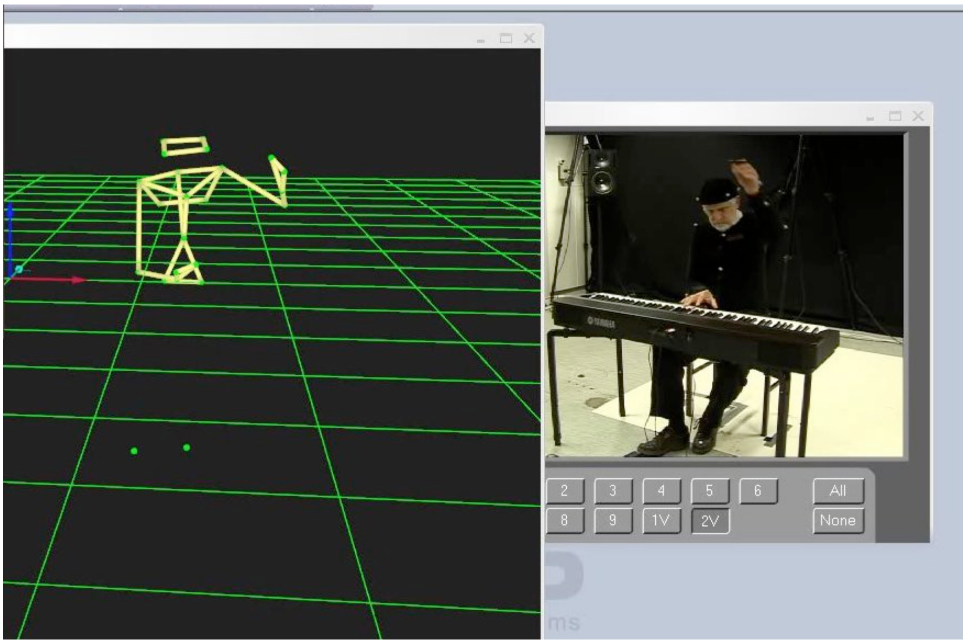
Westney's work is thus of key interest to Cynthia M. Grund, Associate Professor of Philosophy, University of Southern Denmark (SDU) at Odense, Project Manager for NNIMIPA, and Editor-in-Chief for *JMM*: the *Journal of Music and Meaning*. The two have embarked upon an extensive research cooperation, which became woven into the fabric of NNIMIPA when Westney was named Hans Christian Andersen Guest Professorial Fellow at IFPR-SDU for a six-month period during the 2009–2010 academic year. Grund and Westney write:

> "One of the signature features of the UMC is the innovative integration of the audience within its pedagogical and aesthetic framework, which is constructed in stepwise, interactive fashion during the first hour of the two-hour session. All participants listen to instructions about the forthcoming "warm-up," during which audience and performers will be on equal footing as they participate in carefully constructed and sequenced exercises. The warm-up is designed to create a specific experiential context for the second hour, when instrumental and vocal musicians will offer live performances."
>
> "The exercises consist largely of expressive, gestural activities. Their conceptual basis owes much to the seminal theories of Emile Jaques-Dalcroze, to which Westney was introduced as a child. Later, as a university professor and performer, Westney revisited the Dalcroze approach to education with a specific question in mind: how to teach rhythm in a more integrated and effective way in the studio. After reacquainting himself with the work of Dalcroze as an adult, however, Westney began to develop new ways in which similar techniques could be applied in broader contexts involving authenticity in interpretation and the performer-audience dynamic." [Grund and Westney, (2010), pp.34–35]

An important part of Westney's approach thus involves movement and gesture, which function as non-verbal embodied vehicles for capturing and remembering nuances of interpretation and performance. This emphasis dovetailed in a very relevant fashion with the high-tech approaches being developed and employed in the fourMs Laboratory (http://www.fourms.uio.no/) by, among others, Professor Rolf Inge Godøy and postdoctoral researcher Alexander Refsum Jensenius. These approaches employ a complete state-of-the-art Qualisys motion capture system. This consists of a nine-camera Oqus 300 system, a MEGA ME6000 Wireless EMG and a 200 fps greyscale point grey camera. Data can be streamed in real time through OSC-protocol via UDP/IP to MAX/MSP/Jitter software and synchronised through a MOTU time piece allowing synchronous playback of analogue, motion, video and audio data (Morander, 2010; Jensenius et al., 2010a) [for those interested in this type of research, Rolf Inge Godøy and Marc Leman, Professor at the University of Ghent, present a body of work on the implications of an array of IT-approaches to the study of the connections between sound, movement and meaning in Godøy and Leman 2009, as does Alexander Refsum Jensenius in Jensenius (2009)].

Grund produced an online multimedia document (Jensenius et al., 2010b) assisted by and with input from Alexander Jensenius, Kristian Nymoen, Ståle A. Skogstad and William Westney in order to provide some perspectives on where an approach combining state-of-the-art IT, concerns attendant to issues of live performance and concerns from philosophical aesthetics might lead. Grund and Westney soon hope also to explore the investigative possibilities afforded by markerless motion capture in the study of movement as it relates to musical meaning, and they are still analysing the implications of the data provided by the February 2010 Oslo session, aided by Josué Moreno and Dāvis Ozoliņš, who through their affiliations with the Sibelius Academy have had occasion to attend courses offered by NNIMIPA at the Master's level (http://www.nnimipa.org) and to do NNIMIPA-funded work at the fourMs Laboratory.

Figure 1 (a) William Westney performing wearing point-light markers, and (b) the resulting digital model of his movements (see online version for colours)



(a) (b)

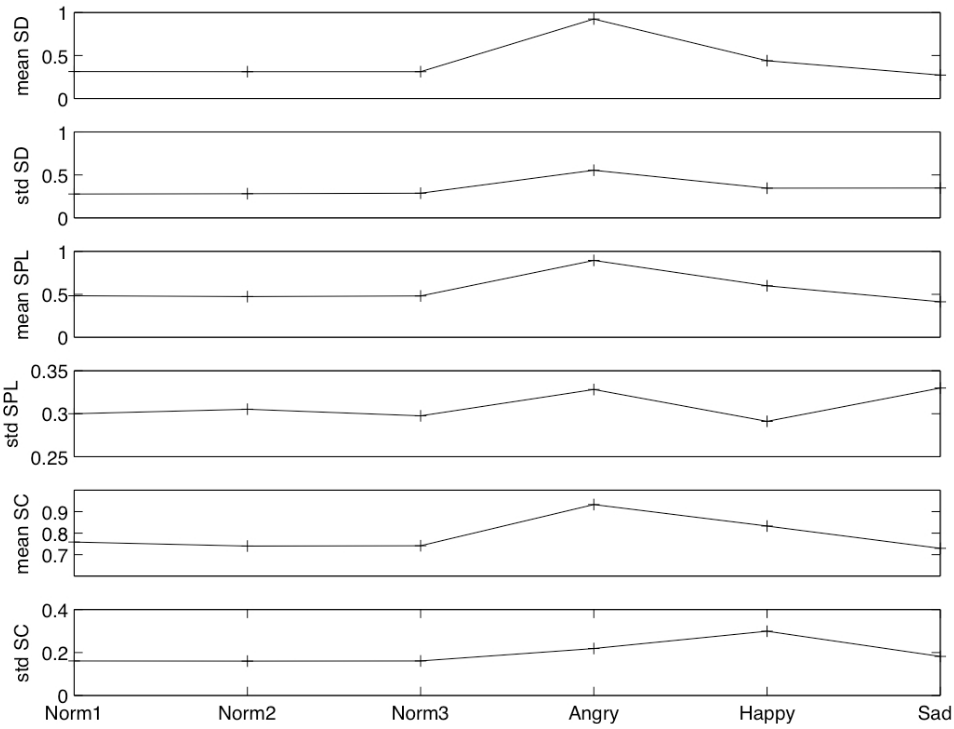
Source: Still photo from Jensenius et al. (2010b)

Of particular interest in this analysis are the recordings of one piece of music, 'That Old Black Magic' (written by Harold Arlen, arranged for the piano by Cy Walter), in different versions. Westney performed six versions of the piece using the MoCap system, three 'normal' versions, and three, where Westney was asked to shape the performance according to the emotional categories, 'angry', 'happy' and 'sad'. The video recordings, the audio, and the MoCap data of 23 different points on Westney's body are available.

3.1.1 Audio analysis

First, the audio was analysed. For this, three different features were estimated from the sound files: the sensory dissonance (SD), calculated as the sum of all overtone pairs that cause fluctuations (that is, when the overtones are close enough to be perceived together), weighted with the amplitude of the overtones (Sethares, 2003); the sound pressure level (SPL), according to the ISO-226 standard (2003); and the spectral centroid (SC). The SD is related to the musical tension, the SPL is related to loudness, and the SC is related to brightness. In Figure 2, the mean and the standard deviations of the SD is shown, alongside the means and standard deviations of the SPL and the SC, as calculated from the six performances of 'That Old Black Magic'. It is clear that the three normal performances have very much the same values of these features, while the 'emotional' performances have varying values. In particular, the 'angry' performance has higher SD, SPL and SC, the 'happy', performance has slightly higher values throughout, while the 'sad' performance has lower dissonance, loudness and brightness than the normal performances. The standard deviation is a measure of how much variation there is in the features. It is interesting to observe that Westney has performed the 'happy' emotion with only slightly more dissonance, loudness, and brightness, but with significantly more brightness variation. This may have to do with variations in the quality of Westney's touch on the keyboard.

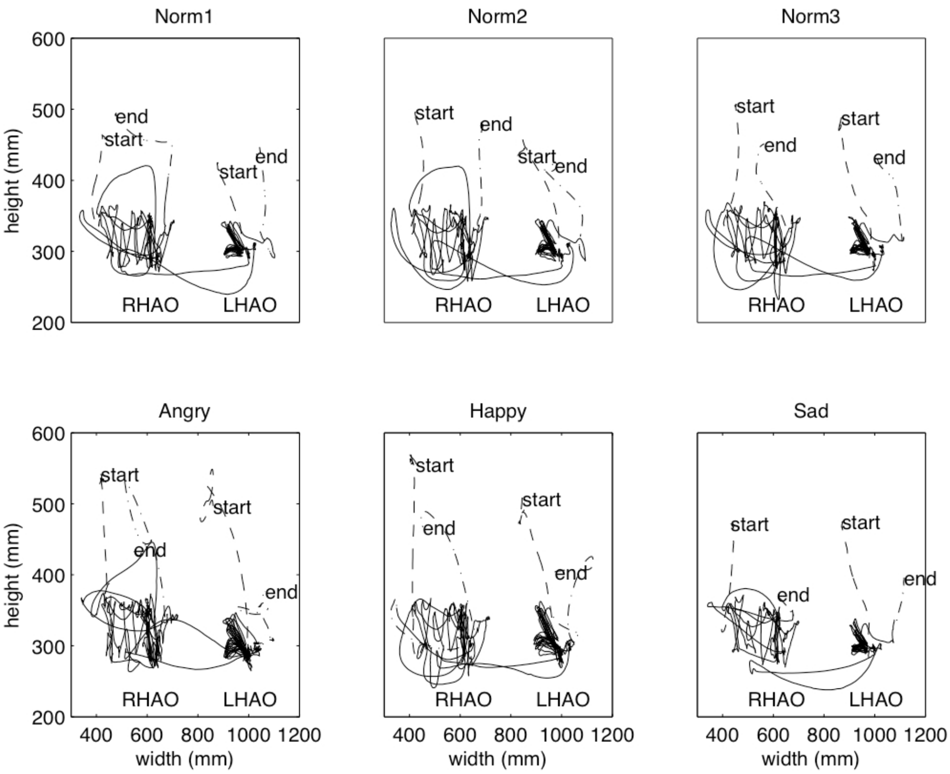
Figure 2 Means and standard deviations of SD, SPL and SC



3.1.2 Video analysis: hand motions

A second analysis concerns the movement of the hands of William Westney during these six performances. For this, the RHAO and LHAO markers of the motion capture system are investigated. These are the right and left hand outwards markers, placed under the little finger of each hand. The movements of these are shown in Figure 3 for the six performances. Again, the three normal performances seem to have approximately the same gestures. These are, for the pianist, both ancillary and related to the performance of specific notes. For the emotional performances, the left hand movement is larger for 'angry' and 'happy', but smaller for 'sad', supporting the idea that 'angry' and 'happy' prompt more lively gestures in the performance than 'sad' does. The 'angry' and 'happy' performances also seem the have more preparatory movements at the start and end of the performances, again supporting the idea of 'angry' and 'happy' as more lively gestures than 'sad'.

Figure 3 Movement of RHAO and LHAO markers



'Pointy' edges in the graphs suggest that the pianist plays more staccato, that is, moves his hand away fast after the attack, whereas softer edges indicate a gentler movement. In order to assess this trait of the motion capture data, the Euclidean speed and the curvature has been calculated for the different markers (low curvature correspond to a high degree of 'pointiness' in the graph). The mean and standard deviation of the speed and curvature for the two hand markers are shown in Table 1. With regard to the speed, it is clear that the performances corresponding to the intended emotions 'angry' and 'happy' each are played at a higher speed in comparison with the normal performances, while the 'sad' performance is played at a lower speed. The curvature values are markedly lower for the 'angry' and 'happy' performances than for the other performances. While there is much noise in the curvature values (c.f., the standard deviations), intuitively, the curvature values seem reciprocal to the speed. This is related to the 1/3 power law (Lacquaniti et al., 1984), that states that, for a specific gesture, the angular speed is equal to a constant (k) multiplied with the radius to the power of one third. As the curvature is the reciprocal of the radius, it is normal to expect the curvature to be inversely proportional to the speed. The constant for a gesture in a specific performance (calculated as the mean of the speed multiplied by the curvature to the power of one-third) is found to be proportional to the arousal value of the emotion, as the 'high arousal'-emotions 'angry' and 'happy' (Russell, 1980) are found to have a constant higher than in the normal performances while the 'low arousal'-emotion 'sad' has a constant below the normal performances. It is interesting to observe how the speed and the one-third power law constant (k) are systematically lower for the left hand. This is probably related to the fact that the left hand has less general movement, but whether this is further related to the music performed here, or a potential right-handedness of the performer is a matter for further studies beyond the reach of this work. In short, when Westney plays in the 'happy' or 'angry' modes, the speed is higher, and the curvature is (necessarily) lower.

Table 1 Mean values for speed (S0) and curvature (K0), and 1/3 power law constants (k)

	Mean S0 (std)	*Mean K0 (std)*	*1/3 power law constant (k) (std)*
Norm1 RHAO	1.50 (2.00)	2.41 (30.44)	0.58 (0.42)
Norm 1 LHAO	1.31 (2.18)	2,77 (50.67)	0.53 (0.39)
Norm2 RHAO	1.63 (2.20)	1.80 (14.59)	0.60 (0.45)
Norm2 LHAO	1.36 (2.20)	1.62 (7.48)	0.55 (0.38)
Norm3 RHAO	1.54 (2.02)	1.82 (11.59)	0.59 (0.42)
Norm3 LHAO	1.32 (2.18)	1.55 (6.23)	0.54 (0.37)
Angry RHAO	3.13 (3.71)	0.73 (5.71)	0.99 (0.67)
Angry LHAO	2.73 (3.30)	0.56 (6.75)	0.93 (0.52)
Happy RHAO	2.36 (2.76)	0.88 (6.10)	0.79 (0.53)
Happy LHAO	2.25 (2.93)	0.64 (5.18)	0.80 (0.44)
Sad RHAO	1.09 (1.61)	3.27 (19.47)	0.49 (0.37)
Sad LHAO	0.93 (1.84)	4.58 (83.02)	0.43 (0.34)

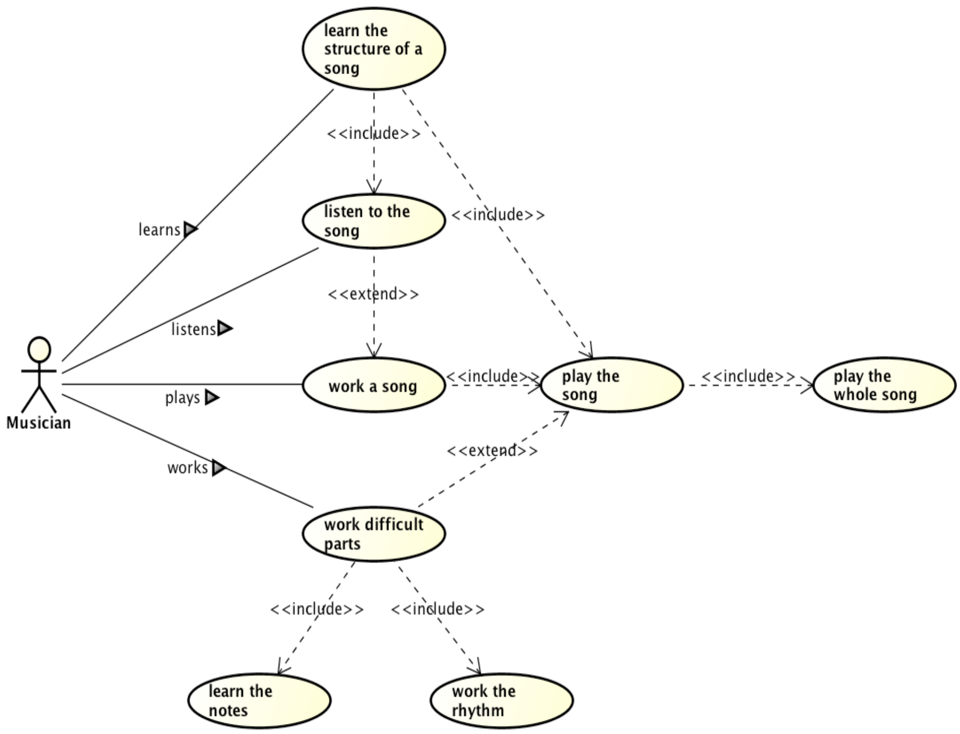
3.2 *Models of interaction*

One of the aspects of the interaction of musicians that is important within the NNIMIPA network is how the musicians communicate during the performance. Three different modes of communication may occur: *verbal*, i.e., when the musicians talk to each other; *non-verbal*, e.g., when the musicians nod, smile, etc., at each other, and *musical*, i.e., when the musicians give each other signs via their instrumental sound production. It is assumed that musicians act in a manner similar to the belief-desire-intention paradigm of Bratman (1999), in which beliefs and desires combine to form intentions. Of course, decisions and planning steps must be included if a full model is to be described, but these steps are usually not externalised to a level where they can be observed. Only the individual musician is able to know the exact nature of her own belief-desire-intention process, but musicians may obtain knowledge about belief-desire-intention processes of other musicians via information gathered in the interaction process, i.e., by observing the other players.

Several experiments have been performed by Kristoffer Jensen, Associate Professor, Department of Architecture, Design and Media Technology, Aalborg University Esbjerg, in order to observe and describe the interaction between musicians. One important conclusion has been drawn from the initial observations: at the level of professional performance, a performance of music based on notation (scores, parts, etc.) contains very little visible communication. Therefore, subsequent observations have been made in connection with either improvised music, in collaboration with guitarist Fredrik Søgaard during his improvisation classes at the conservatory in Esbjerg, and with the rehearsals of amateur musicians.

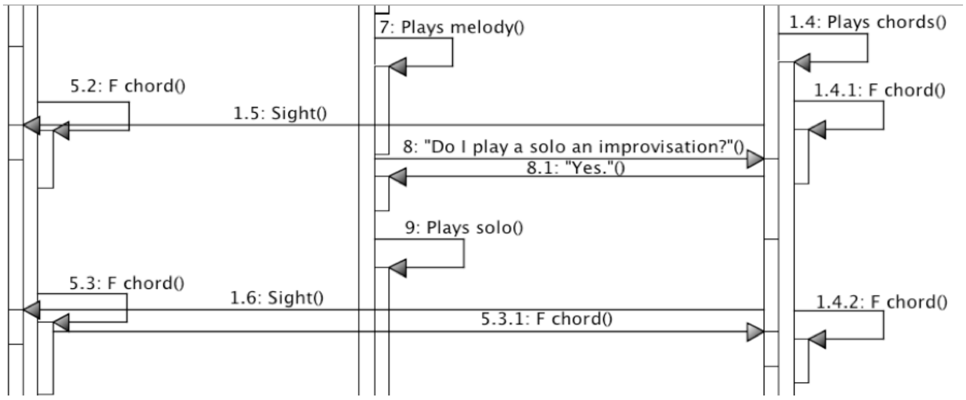
Unified Modelling Language, UML (Larman, 1997) is used in the field of object-oriented software engineering. UML diagrams are graphic notations of systems, and many different diagrams exist. In the case of interacting musicians, *use cases* model the dependencies between the musicians and their goals. *Use cases* can be further developed to *state machine diagrams*, and *class diagrams*, if the goal is to implement the system, but for observation and modelling studies, however, the *sequence diagram* is of particular interest. In the *sequence diagram*, the vertical lines correspond to each musician or other agent, and the arrows correspond to the messages between the musicians or other actor, and the arrows correspond to the messages between the musicians.

Figure 4 *Use case* of musician learning to play music (see online version for colours)



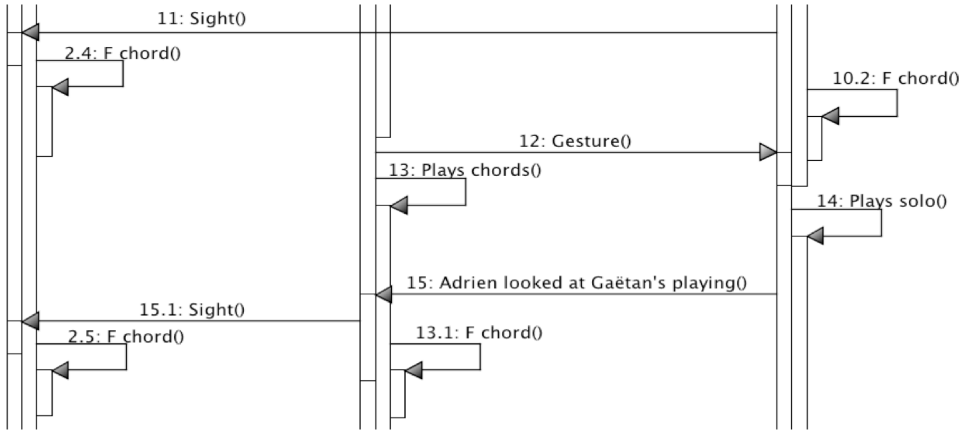
In Figure 4 an example of a *use case* is shown, in which the musician rehearses a piece alone, and in Figures 5 to 7 a detail of a *sequence diagram* is shown in which three musicians rehearse a jazz tune. The UML diagram is useful and easy to access, as many software systems exist, and software students and engineers often have knowledge about UML and may gain further experience through the modelling of musicians interacting through UML. It is clear that the information obtained through UML modelling can be used to corroborate the formal logic models described below in Section 3.3. For instance, in the *sequence diagram*, the decision as to who will play next solo can be observed. This is done either through verbal communication or through unilateral decision by one musician.

Figure 5 *Sequence diagram* of musicians in a rehearsal (detail)



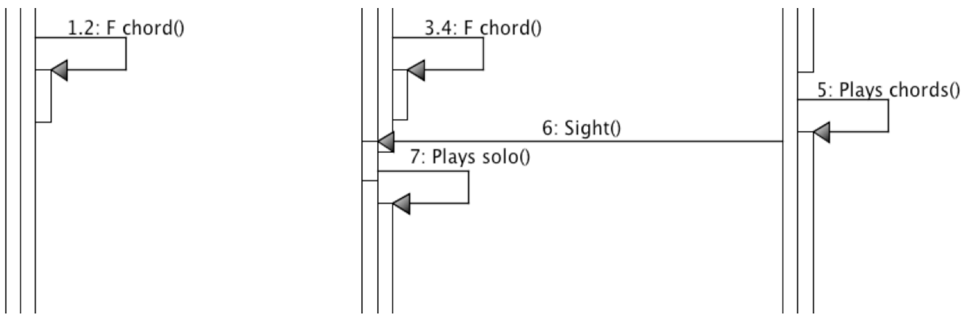
Note: Verbal communication at point 8.

Figure 6 *Sequence diagram* of musicians in a rehearsal (detail)



Note: Gesture at point 12.

Figure 7 *Sequence diagram* of musicians in a rehearsal (detail)



Note: Guitarist looks at keyboard player at point 6.

Often, musicians are so skilled, that they only communicate with each other musically. In order for non-verbal and musical communication to take place in an ensemble, the musicians must feel themselves linked to each other and the group as a whole. It was found that the smaller the group is, the stronger the link will – and must – be, and the more accurate the musicians will be. In such a situation, there is a real communication process between musicians.

We will now look specifically at a situation where the musicians have to decide on the order in which the musicians get to play the next solo in a piece of jazz music. The music in this observation study was 'Caravan' by Duke Ellington, played by three amateur musicians on bass (leftmost player in the UML diagrams), keyboard (middle player in the UML diagrams) and guitar (rightmost player in the UML diagrams), respectively. As they had not rehearsed this music together before, the rehearsals were a natural way for them to gradually master the piece. Through the observations and annotated videos from the rehearsals, together with self-reports from the three musicians, three different modes of communication have been identified with respect to synchronising the task of who is to play the next solo. In the first rehearsals, this communication mode was verbal, as can be seen in the detail of the UML sequence diagram (Figure 5). In the beginning, the musicians sometimes stop and discuss something before continuing. The second model of communication is gestural, i.e., via a hand gesture, as illustrated in Figure 6, or by looking at the person you believe should play the solo (Figure 7). Finally, as the musicians gradually agree on the structure of the music and get to know it enough, communication is gradually replaced by a mutual awareness of this structure. The awareness of structure (e.g., with respect to taking turns) reduces visual communication between musicians and allows them to focus more on playing music. Thus, in a jazz performance, the ideal for the ensemble is to agree on a general structure, which allows the individual musician to locate herself in relation to the others, but without impeding the possibility of improvisation within this structure.

3.3 Formal models for decision processes in the performance without the aid of direct communication

As stated at the beginning of 3.2, the interaction between musicians during a performance is not only dependent on verbal and non-verbal signalling between musicians, but also on the 'signs' communicated via the music being performed by the individual musicians. Interpreting such musical signs is, however, not a trivial matter when other modes of more direct communication are unavailable, e.g., during a performance in front of an audience. Here, the decision-making process for an individual musician rests on her expectations for how the other musicians are going to conceive of the situation at hand, e.g., what they might consider an to be agreement that everyone will follow, their own tendencies to play in certain ways, and their intentions for the specific performance. These deliberations become even more important, when the musicians face a coordination problem that they quickly have to solve. As part of his PhD dissertation (Frimodt-Møller, 2010), Søren R. Frimodt-Møller, Managing Editor of *JMM*: the *Journal of Music and Meaning*, has discussed how performing musicians make decisions not only as a result of their individual intentions for the performance, but also as a result of their assumptions regarding the intentions of the other performers, and as a result of how they conceive of the norms inherent in the performance context at hand. In order to describe these decision processes, Frimodt-Møller has considered three different yet associated modelling schemes:

1 Coordination based on *common knowledge*: Common knowledge of some fact *p* in a group of people *G* involves not only that everyone in *G* knows that *p*, but also that everyone in *G* (potentially) knows that everyone in *G* knows that *p*, that everyone in *G* knows that everyone in *G* (potentially) knows that everyone in *G* knows that *p* and so on ad infinitum. Common knowledge as described by, e.g., Fagin et al. (2003, p.9) is typically approximated as a situation where *p* is a public announcement to *G*. In the music ensemble, a type of information that might attain the status of common knowledge is that consisting of the agreements that are verbalised (and thus made 'public') during the rehearsals. Should a coordination problem occur, that is, should the musicians suddenly not be synchronised in accordance with their initial plan for the performance, the musicians will by default try to follow the general strategies they consider to be common knowledge in the ensemble, based on how they remember the rehearsals. Using classical epistemic logic as a modelling tool, it can be shown that in situations where common knowledge in *G* of *p*, notated $C_G p$, has not been established before the performance, $C_G p$ is actually unattainable during a performance due to the unreliable nature of non-verbal communication and symbolic communication through the music itself.

2 Game theory with variable frames: In situations where 'new' common knowledge of any kind is unattainable, musicians may still be able to make decisions when facing a coordination problem, if they consider how their co-players are most likely to act in the situation at hand. *Coordination games* are games in which two people who are not allowed to communicate will get the highest pay off upon simultaneously choosing the same object when a choice of several objects is possible In the branch of game theory developed by Bacharach et al. (2006) called *variable frame theory*, coordination games are described as a reasoning process where one considers how the opponent 'frames' or, in other words, categorises the different options at hand, and thereby how likely she is to consider particular choices more 'salient' than others. The better the participating players know each other in advance, the more accurate their expectations for each other's' choices will be. This seems to be paralleled by the fact that musicians often are more comfortable playing with musicians whom they already know well.

3 Decision theory with intentions: As has been mentioned in 3.2 above, intentions play an important role in a musician's decision-making process. Roy (2008) has discussed – with regard to decisions in general – the role a person's intentions play in the formation of plans. Transferred to the domain of music performance, the general idea is that in a given situation, the musician can choose to follow a strategy in line with a strategy profile (a combination of strategies, one for each musician in the ensemble) chosen from a limited set of possible strategy profiles. The musician chooses a strategy profile that has one or more possible outcomes that she intends to achieve. If the musician has reason to believe that the other musicians are not following the same strategy profile, she will have to search for a new profile that is in accordance with what she considers to be the possible intentions of the other musicians, but *ceteris paribus* still in accordance with her own intentions. What the formal model based on these ideas shows is that if we disregard the possibility of

unintended actions, the musicians should gradually better their chances of coordination with each new step of searching for a new profile (as they will be able to rule out certain strategy profiles at each step).

The chief reason for exploring the formal models above is to highlight the importance of following rules during the performance and especially the importance of remaining sensitive to the actions of the other players. In short, this research project provides a set of formal descriptive tools to capture some of the intuitive insights regarding interaction that performers already possess. Combined with the insights of Kristoffer Jensen's research described in 3.2, this project may be a step towards a comprehensive understanding of performance interaction in general. The following paragraphs provide examples of how the models may be relevant in relation to the problem of deciding who plays the next solo in a jazz performance:

1 *Coordination based on common knowledge*: Once the musicians in the ensemble, e.g., the three person jazz ensemble of the examples in 3.2 – have reached a mutual awareness of the structure of the piece, this mutual awareness helps them solve certain synchronisation problems, because they often can assume that the general structure of the piece is, indeed, common knowledge within the group. Even when in fact it is not, the heuristic of simply doing what you think everyone has agreed on is likely to improve coordination, since it is likely that others will also reason according to this heuristic by default.

2 *Game theory with variable frames*: Suppose that initial verbal communication was not an option, e.g., if the three musicians sat down at a public jam session and were to perform together without having rehearsed the relevant piece in advance. In this case, it would affect a musician's predictions with respect to how likely one or the other player is to play the next solo, how he considers it possible that they categorise the different possible orders of taking turns to play solo. For instance, it might be that a musician considers the possibility that one of the other players will monopolise the task as soloist, insisting on playing solo at each possible slot in the piece, but it might also be that he considers it likely that everyone will have the idea that the three musicians should take turns to play solo, and that the solos should occur in a very common order, e.g., guitar first, keyboard second and bass third. Each musician may consider these possibilities to varying degrees, but what really matters is how likely the other musicians find the musician's consideration of a given possible interpretation of the structure of taking turns. In short, the choices of the musicians depend on their expectations for each other. These expectations may of course be influenced by prior rehearsals in other contexts, i.e., if the musicians in fact know each other in advance – ideally this should make their predictions of each other's actions more accurate.

3 *Decision theory with intentions*: If a musician has an intention to play solo in the next slot, he might in some cases simply try to go for playing the solo, once he approaches the solo spot. In the meantime, he may, however, suddenly realise that someone else has the same intention, e.g., because the other player makes preparatory gestures for commencing a solo, or if – in the worst case – they start a solo at the same time. In this case, the musician needs to find a new global strategy in which to play his part, namely one that will make sense of the other player's behaviour, e.g., a strategy profile where the first musician does not play solo in the

initially intended spot, but waits until the next one. In general, the role of intentions is, however, more apparent in situations where there are more than one way in which a musician's initial intention can be realised, e.g., if the musician has an intention to incorporate a particular type of phrase at *some point* in the performance.

4 Conclusions and further perspectives

NNIMIPA has moved from being a research network in the sense of a group of researchers networking (e.g., meeting and discussing their products) to being a research network in the sense of a network conducting research. Inspired by the research of Godøy and Jensenius (see 3.1), Jensen, Grund and Westney, along with other members of NNIMIPA, continue to explore cross-disciplinary approaches that allow examination of the role of gesture from the point of view of the performer as well as of the audience with the aid of digital modelling. For Grund and Westney, this provides exciting new perspectives on issues of music and meaning that they have found intriguing from their respective vantage points as concert musician and philosopher. The collaborations between Jensen and Frimodt-Møller concerning the interaction process of performing musicians may similarly lead to an improved platform for discussing matters related to musical interaction.

The studies of a piano performance played with different intended emotional expressions showed that the loudness increased for the emotion 'angry', while the brightness increased for 'happy', and no differences were found between the sad and the normal expression. In the hand movement of the performer, the angry and happy expressions had higher speed, while the sad expression had lower speed, as compared to the normal expression.

In the study regarding the decision of who should play the next solo in a jazz piece, three mechanisms emerged in the rehearsal: First verbal communication was used; later, when the musicians got to know the piece better, gestures (hand and eye) were used; and eventually, the solo decision was made according to the musicians' awareness of the musical structure. When musicians cannot communicate directly, e.g., in the actual performance, they also rely on their expectations as to how the other musicians conceive of the situation, a decision process that may be clarified by the use of formal models.

In the future, NNIMIPA members continue to explore not only the interpersonal interaction in the music performance, but also the interaction between musician/listener and environment, or, more broadly speaking, context. The various ways in which the specific context (encompassing physical as well as social and cultural aspects) of the performance affects the audience's experience and the immediate decisions of the musician, provides a rich field of theoretical problems that necessitate further collaboration between researchers in music philosophy and technology and performing musicians.

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References

Bacharach, M., Sugden, R. and Gold, N. (2006) *Beyond Individual Choice: Teams and Frames in Game Theory*, Princeton University Press, Princeton.

Bratman, M. (1999) *Intentions, Plans and Practical Reason*, CSLI Publications, Leland Stanford Junior University, USA.

Fagin, R., Halpern, J.Y., Moses, Y. and Vardi, M.Y. (2003) *Reasoning about Knowledge*, The MIT Press, Cambridge, Mass.

Frimodt-Møller, S.R. (2010) *Playing by the Rules. A Philosophical Approach to Normativity and Coordination in Music Performance*, PhD dissertation, Institute of Philosophy, Education and the Study of Religions, University of Southern Denmark, Odense.

Grund, C.M. and Westney, W. (2010) Music, Movement, Performance & Perception: Perspectives on Cross-Disciplinary Research and Teaching within NNIMIPA – Nordic Network for the Integration of Music Informatics, Performance and Aesthetics, An essay in words and pictures recounting the NordPlus-sponsored Coordination Meeting for NNIMIPA held at the University of Oslo, February 18–19, Text: Cynthia M. Grund and William Westney. Photography: Cynthia M. Grund. Odense: The Institute of Philosophy, Education and the Study of Religions at the University of Southern Denmark and NNIMIPA: Nordic Network for the Integration of Music Informatics, Performance and Aesthetics, a network supported by NordPlus [online] http://www.nnimipa.org/CM.html (accessed 26 September 2012).

Godøy, R.I. and Leman, M. (Eds.) (2009) Musical Gestures*: Sound, Movement, and Meaning*, Routledge, New York and London.

Jensenius, A.R. (2009) *Musikk og Bevegelse*, Unipub, Oslo.

Jensenius, A.R., Glette, K.H., Godøy, R.I., Høvin, M.E., Nymoen, K. Skogstad, A.v.D. and Tørresen, J. (2010a) 'FourMs, University of Oslo – Lab Report', in Rowe, R. and Samaras, D. (Eds.): *Proceedings of the International Computer Music Conference*, June 1–5, New York [online] http://www.duo.uio.no/publ/IMV/2010/103430/103430-fourms.pdf (accessed 26 September 2012).

Jensenius, A.R., Nymoen, K., Grund, C.M., Westney, W. and Skogstad, S.A. (2010b) 'Video suite – in three movements: Jensenius-Westney-Grund on motion-capture, music and meaning', Multimodal webpage presentation of original motion-capture video with accompanying audio, including original documentary-and-interview video-and-audio about the motion-capture labwork [online] http://www.nnimipa.org/JWG.html, finalized on April 25, on the website for NNIMIPA. NNIMIPA Webmaster and Network Coordinator: C.M. Grund.

Lacquaniti, F., Terzuolo, C. and Viviani, P. (1984) 'Global metric properties and preparatory processes in drawing movements', in S. Kornblum and J. Requin (Eds.): *Preparatory Processes in Drawing Movements*, pp.357–370, Lawrence Erlbaum, Hillsdale, NJ.

Larman, C. (1997) *Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design*, Prentice Hall, Upple Saddle River, NJ, USA.

Morander, C. (2010) 'FourMs – music, mind, motion, machines: how can knowledge about movement & sound create better technologies?', *Qualisys Newsletter*, May, No. 1, Cover and p.4 [online] http://www.qualisys.com/wp-content/uploads/2011/05/Qualisys_newsletter_2010.pdf (accessed 26 September 2012).

Roy, O. (2008) *Thinking Before Acting. Intentions, Logic, Rational Choice,* PhD thesis, Institute for Logic, Language and Computation, Universiteit van Amsterdam, Amsterdam, The Netherlands, ILLC Dissertation series DS-2008-03.

Russell, J.A. (1980) 'A circumplex model of affect', *Journal of Personality and Social Psychology*, Vol. 39, No. 6, pp.1161–1178.

Sethares, W.A. (2003) 'Local consonance and the relationship between timbre and scale', *Journal of the Acoustical Society of America*, Vol. 94, No. 3, pp.1218–1228.

Notes

1 http://www.soundmusicresearch.org, Please note that Institute of Philosophy, Education and the Study of Religions at the University of Southern Denmark was reconfigured to become part of the Institute for the Study of Culture in August 2012.

2 A documentary about William Westney's Un-Master Class, filmed at Alsion Concert Hall in Sønderborg November 24, 2009 was broadcast for the first time on ALT-Aabenraa Lokal TV during the week of February 8, 2010. To view the documentary, please see http://vimeo.com/channels/musikmedalt.