Requirements on Kinaesthetic Interfaces for Spatially Interactive Sonic Art

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ABSTRACT

This paper documents the requirements on tracking technology for spatially interactive sonic arts. We do this by comparing our theorised notion of an ideal kinaesthetic interface to, firstly, the current results of an ongoing online survey and, secondly, the results of our ongoing Workshop on Music, Space & Interaction (MS&I). In MS&I we research the affordances of existing and hypothetical technology to enhance and facilitate spatial interactivity. We give both qualitative and quantitative recommendations for design. While underlining the specific requirements for sonic art in respect to its aural nature, we discuss how and why the requirements elicited from our research can be applied to spatial interactivity in general.

CCS Concepts

•Applied computing → Performing arts; •Human-centered computing → Ubiquitous and mobile computing design and evaluation methods; *Virtual reality;*

Keywords

Kinaesthetic Interface, Interfaces for Musical Expression, Human Computer Interaction, Embodied Digitality

1. INTRODUCTION

Despite the regular occurrence of tracking technology in works of sonic arts [39, 12], multimedia [19] and a keen interest in its development in gaming [21] and virtual reality [8, 13], no specific tracking technology has established itself to date in an ubiquitous way like GPS has done for outdoor navigation, for example. Existing technologies are adapted and appropriated from motion capture [10], mechanical industries [23] and from the mainstream gaming technology with wii [26] and Kinect [36]. Of course smart phones, as location aware devices, are generally believed to provide ubiquitous tracking technology which could be used for interactive art. There are examples for such applications [18, 2], but they have in common that actual tracking abilities are quite constrained.

Nota bene, there is practically no academic work which suggests that the tracking or positioning technology implemented in an interactive artistic application was not a success. On the contrary, most authors of papers describing artistic applications using positioning or tracking technology assert that their use of technology was successful. However, this might be more to do with the fact that in many artistic practices it is common to work with the limitations of a technology rather than let the technology's shortcomings be the end of the artwork. Artworks are rarely akin to laboratory experiments where a technology's performance can be tested as to success or failure to provide conclusive answers in this vein. What is more, technological failure is often incorporated into the aesthetics of an artwork, an can even produce whole genres, as in the case of *glitch* [28]. But, the successful use of a technology is rarely the condition *sine qua non* of an artwork.

Here we also have to consider that the evaluation of technologies in an *artistic* context is more often than not a subset of technology evaluation in a *psychophysical* context: All arts rely on sensory experiences evoked by some technique or technology, the evaluation of which demands some very refined methods [20, 15], even without accounting for artistic intentions and aesthetic considerations [6].

Hence, instead of evaluating technology as to its applicability *post*-design, we believe it to be crucial - here even more than for many other design implications, to gain insights into the requirements on the technology as part of the design process, or *pre*-design. The apparent triviality of the previous sentence does not make its premise less urgent, as for artistic applications only appropriated technology is available; post design evaluation the only possible path.

The difficulty in acquiring requirements on technologies for artistic purposes is the nigh impossibility to predict any of them. In respect of spatial interactivity in sonic arts, however, with our workshop on MS&I, (occasionally referred to as just *workshop* in the rest of the text), we hope to have access to an experimental practice which is general enough to provide findings which are applicable to more than just isolated artworks.

We thus imply the existence of common denominators for spatially interactive artistic practices in form of gestural movements, trajectories, and changes of positions of objects and participants; in short, moving in a meaningful, expressive way. In this description of the notion of kinaesthesia, we draw on Carrie Noland's work Agency and Embodiment

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[24], wherein she asserts that kinaesthetic experience, - *feeling the body move*, as a corporeal performance of gestures, allows for experimentation, modification, and, crucially, rejection of gestural routines. From this she infers a non-constructivist account of agency: A gestural movement is, in this sense, embodied agency.

With a numerical recording of this movement, we thus yield information which is highly correlated to the actors intentions: Such a kinaesthetic interface[1] records the embodied, or individualised, kinaesthetic quality of the gesture by computing the aforementioned trajectories and changes of positions, namely, the whole physical movement the gesture consists of in space. This movement might be reducible to key points like in motion capture, based on the known, limited, affordances of joints and members, or to relative positions of objects to each other. but it should be able to describe one embodied movement as distinct from another even if it belongs to the same gestural routine. This can, so we claim, only be possible if the interface does not introduce another whole set of modifications to the gestural routine: The ideal (kinaesthetic) interface should not need to be evaluated directly, as it is not experienced! We elaborate on this notion of the invisible interface in more detail elsewhere[2], but suffice to say, Researchers at Xerox PARC argued for invisible interfaces as early as 1994 [42].

Dourish and Bell [11] however, extend this notion of the invisible, or ubiquitous, to technology which we don't notice anymore, as we are used to it. This is an understanding also mirrored in Bruno Latour's description of the *technical* in[17]. Hence it could also be argued that any old technology will do, as we will eventually adjust our habits to accommodate its shortcomings. We are not able to refute this argument at this stage, but we appeal to common sense; that the design goal for new technology should be for *best possible solution* not *make-do*[3].

From this understanding of technology as something elusive - at least while it works, follows that in order to study the techniques and technologies of a practice we need to study the practice itself. So, in order to design interfaces for spatial interaction, which is the aim of that study, we need to study spatial interaction artistic practice *per se*, and develop technology with the least impact on that practice. This is, essentially, an ethnographic approach and explains why anthropology became an indispensable partner to design in the development of Human Computer Interaction. Yet, for interaction design for the sonic arts, the advice to approach design from situated practice [38, 3] was heeded only by few, for example [14, 41, 25] amongst others.

We made our case here so far under the tacit assumption that implementations of tracking technologies specific for interactive arts are necessary. Indeed, we have not yet come across an implementation which matches the requirements we are about to describe. To clarify our rationale: We do not claim that existing principles are not capable of providing the required functionality with some case specific development. But we believe some principles lend themselves better to the scenarios of our concern than others and for some we see potentially systemic issues.

1.1 Tracking Technology: A Short Overview

The following is a summary of our findings in [29] also summarised in [35]. We mainly focus here on what we see as limitations for our intended use and do not account for the many useful applications these technologies have, of course, for other applications.

1.1.1 Radio Frequency: RFID, GPS

Despite the ubiquitous availability of radio frequency based positioning technologies in form of Wireless Local Area Networks, (WLAN) its most common occurrence, Radio Frequency Identification tags, (RFID) has comparatively low update rates. The Global Positioning System only works outdoors, Ultra Wide Band (UWB) technology is very expensive. Systems relying on radio signal strength indication are particularly unreliable, as the design aims behind WLAN technology are not for the provision of stable signal strength but for highest strength possible, which is a dynamic principle conflicting with the requirements for a measurement signal.

1.1.2 Inertia - methods

Inertia measurement methods, like accelerometers and gyroscopes are ubiquitously present in almost every smart phone. However, they don't provide an absolute position, so errors cumulate if used without repeated references to known positions. For smart phone tracking, inertial methods are usually combined in a hybrid way with RF methods via WLAN.

1.1.3 Acoustic Localisation

Acoustic localisation in form of ultrasound requires expensive, specialised equipment. In form of Doppler, it relies on line of sight between signal emitter and tracked object. Systems using signals inside the audible frequency range rely on the presence of microphones and loudspeakers. We believe that this is not a hindrance for applications in sonic arts where audio technology is often present anyway. Further, we see potential for non-line of sight applications due to the ability of sound to diffract around objects. However, this technology does not work device free, the object to be tracked has to be either a microphone or a sound source. For transparency's sake we state here that in other and future work we are actively researching acoustic localisation in the audible frequency range as a solution for sound art applications [29, 35, 30, 32, 33].

1.1.4 Optical Tracking

Optical systems, the most commonly applied tracking technology in spatially interactive arts, have the use of cameras in common, be it systems of type Kinect [43], Wii [44] or more elaborate systems for motion capture like Vicon [40]. Despite the use of multiple cameras to add depth information, cameras, intrinsically, are 2 dimensional sensors: When tracking movement in 3 dimensional space, the resolution decreases with increasing distance: a moving object close to the camera causes more change in pixels than an object far away [30]. The applicability of cameras for tracking purposes is also limited by the necessity of line of sight between a tracked object and the camera.

[1] Many kinaesthetic interfaces already exist and are part of mainstream technology, *e.g.*, touch sensitive (musical) keyboards. Still, we feel it helpful for a general discussion to conceptualise them.

[2] Journal article for submission later in 2016

[3] This doesn't mean that the solution has to be high-tech: in fact, we think the simpler the solution, the more pervasive it will be.

2. METHODS

We described our theorised notion of the Kinaesthetic Interface in the Introduction and will pick up on it again in the discussion, where we use it as a framework to validate the data we acquired from an online survey and our workshop on MS&I. Before that we would like to clarify our terminology in respect to some key concepts, followed by a more detailed description of the two contrasting types of methods we used, one an online questionnaire, the other ethnographic interpretative field notes of an interdisciplinary improvisational practice.

2.1 Definitions

2.1.1 Interaction

In our enquiry into spatial interaction we use interaction generally to mean *human - human* interaction. In fact, it is our believe that *human computer interaction* is also essentially *human - human* interaction. To make this less anthropocentric, we can generalise interaction as an exchange of information between actors [16, 17]. We explicitly use interaction in this very general understanding, and crucially not merely as human - computer interaction.

2.1.2 Interface

As opposed to the very broad, notional way we use the term interaction, we are referring to a very concise idea of interface in the context of this article[4]: We refer to interfaces as sensors which allow the digitalisation - and therefore processing - of measurable and thus quantifiable phenomenons. It is a bit tricky not to fall into the tautology here to define as a phenomenon only what is quantifiable. To circumvent an albeit interesting but lengthy discussion on phenomenology we would like to acknowledge that, via an interface, we record a reference to a phenomenon, not the phenomenon itself, *reference* used here in a Latourian sense [17]. With an interface we aim to measure something correlated to what entails the experience of the phenomenon in the hope that what we record, reproduce and process in the digital still correlates to that experience once we re-instate it in the phenomenal, real, or analogue world.

2.1.3 Sonic Arts

In sonic arts we would like to include all arts which are sonic in any way. They include music, sound art, multi media art. But our theorising also applies to sonic aspects of theatre, video art, audio visual displays, short, wherever audio material is used in an aesthetic way.

2.2 Notes on Survey

The online survey on User Requirements On Positioning Systems for Audio Applications was started in January 2012 and informed our previous research into existing positioning technologies . The survey has remained open and has currently had 40 respondents [31]. The design of the survey is fully documented in [29]. Originally designed to represent stakeholders in all areas where positioning technology might be used for audio applications, a sample number of 66 was considered to be representative based on industry numbers. For the comparatively small field of professionals in spatially interactive sonic arts, a smaller sample would be applicable, but this also applies to a smaller proportion of respondents, if we presume the total of respondents to be a cross-section of the population. As no absolute numbers are available, we suggest caution as to how valid these results are quantitatively.

In contrast to our previous work, we are less interested here in how respondents evaluated particular technologies but in respondents' requirements for, and expectations on, tracking and positioning technology.

2.3 Account of Practice

In MS&I, we apply Interdisciplinary Improvisation [1] and participatory design principles [37] to develop a prototypical practice from which new techniques and technologies for spatial interaction emerge. We are describing this approach in concise detail in a longer article to be published later in 2016 but we will summarise relevant aspects here.

The idea behind a prototypical practice is to create an experimental practice in which participants encounter a set of problems for which there might be technical solutions. As these problems arise in a performative, situated, improvisational setting, immediate, simple solutions can be found, often from within the group of participants, *ad hoc*. If a solution can not be found, requirements can be formulated based on the participants experiences. Essentially, we elicit user requirement as a participatory activity.

To gather data in MS&I we mostly used a field note approach described for ethnomusicology in [5]. This is an explicitly interpretative approach which we apply in a highly situated manner, as we write the field notes in conversation with the other participants in the discussion rounds which follow every session.

The research questions for MS&I are directly concerned with technical solutions to spatial interactivity:

- How do we interact musically with space in improvisation?
- What do we want from technology to increase spatial interaction in musical performances?
- What can new technology provide that cannot be provided by old technology?
- How does existing technology impact on spatially interactive practice?

In contrast to other approaches to technology design using mock ups or improvisation for prototyping [9], the workshop does not presuppose any given technology whatsoever but tries to engage with spatial concepts through the physical spatiality of sound and the movement of the human body within space and the sounds which are created by this movement. Over the duration of the workshop's existence a few scores or exercises proved to be particularly helpful and became part of a repertoire, of sorts. These include scores or rules like *Use no instruments or tools other than your body*, or *use the room as a found instrument* or *Start at the centre of the room and disperse while getting quieter*. Besides the field notes many participants take for their own study all are encouraged to write down their thoughts as contributions to the workshop blog [34].

Participants range from musicians, composers and dancers to scenographers, landscape architects, painters, poets, video

[4]For some cultural theorists, e.g., Manovich [22], interfaces can be whole types of media, say films, or books, for others, interfaces refer to keyboard, mouse and monitor only.

artists, lighting designers sculpturists and others. The workshop has been running since 2014 and takes place on 3 - 4 weekends per term. The group size varies, there are usually between 6 - 12 participants.

2.3.1 Interdisciplinary Improvisation

The Research Group on Interdisciplinary Improvisation [1] from whom we borrowed elements for our approach, seeks to find the common ground between the various disciplines represented in the different academies of the University of the Arts Helsinki, namely music, sound art, theatre, painting, drawing, performance art, dance, film and video through free improvisation. The group's understanding of freedom in improvisation is based on the conscious awareness of its relativity between maximum freedom and maximum constraint, and also stretches to the understanding that a performer can experience freedom through constraint. The group is also aware that certain set of rules still tend to apply, however free a practice is, even if it is just the agreement on where and when to improvise.

The aspect of Interdisciplinary Improvisation we believe to be important here, is that a common vocabulary in respect to spatiality across disciplines can be developed, which doesn't rely on an abstract analysis from outside the practice but on an organically grown metalanguage which evolves from within.

3. RESULTS & DISCUSSION

First, we look at some results of the ongoing online survey, which we consequently compare to the findings from the workshop on MS&I. We then compare the combined findings with the notion of the kinaesthetic interface.

3.1 Survey Revisited

As mentioned in the section on method, the survey was originally launched for our previous work in [29], but is revisited as it provides interesting data relevant for our current enquiry. Since our earlier analysis, the number of respondents has increased to 40. The full wording of all survey questions can be found in the survey itself, as it remains open, on http://creativemusictechnology.org/survey.html. Looking at the answers to survey question Q4, *"Into which of the following fields would your audio application fit best?"* we see that despite the original aim to get a cross-section of stakeholders in localisation technology in all areas of spatially interactive audio applications, a great proportion has an interest in sonic arts applications, be this directly, through performance art (14 respondents) spatial music (13), and interactive art (12), or indirectly via recording technology (14). Other fields were gaming (7) multimedia (9) Education (10) assistive technologies (4) and manufacturing (1), home theatre (1) and surveillance (0).

From Q5 *"What scenarios apply to your application?"* we know that a majority (18) expects their applications to happen indoors, and a third also in crowded surroundings (9), and about half expect their application to be in a public setting (17).

From question Q7 *"Presuming that the user is being tracked as part of your application, what sort of technical interaction with the system would you consider acceptable for your application?"* we get direct answers as to what sort of impact of the technology is acceptable to the respondents summarised in the following table 1

Device (e.g., mobile phone)	acceptable	(96%)
Earphones	acceptable	(76%)
Hat or cap	acceptable	(66%)
Calibration before use	unacceptable	(54%)
backpack	unacceptable	(58%)
Backpack, earphones & glasses	unacceptable	(68%)
Repeated Calibration	unacceptable	(92%)

Table 1: Impact of equipment, 30 respondents, answers in second column

In question Q8, we asked directly for respondents' requirements in numerical values for a series of sub questions. Firstly, we asked respondents what *accuracy* was required for their application in metres[5], which, as a conversational question is clear enough, but for statistical purposes leaves a lot of room for interpretation, due to the undefined use of the notion of *accuracy*. To be able to trust the answers more confidently we would have needed to ask something like *"How far away from the actual position can the measurement be 95% of the time for your application to still be working?"* Under the assumption that this was what we implied in our original phrasing, we got quite conclusive answers, after discarding what we considered to be an extreme answer as an outlier. However, A further *caveat* here is needed as to what comprises an outlier, as the expectation on accuracy realistically follows an inverse exponential curve towards an error free measurement. To illustrate this, let's suppose there was a measure for "technological effort": To improve position accuracy from 20 metres to 1metre probably needs the same effort as, say, improving it from 1m to 5mm, as an arbitrary example.

So here are the generalised numbers for the answers as to the expectations on position accuracy

- Range of answers: 1mm - 20 metres
- 58% of answers lie between 0.1 - 2 metres
- Arithmetic mean = 2.6 metres.
- Median = 1 metre

We presume the median to provide the most meaningful number. Ignoring outliers (15%) the range is from 0.1 - 5 metres, of which the majority (76 %) requires 0.1-2 metres

Just over half of respondents require vertical information. The survey did not clarify if this means 2 dimensional tracking vertically oriented, or actual three dimensional tracking.

In the expectation on what area needs to be covered by the tracking system, again, the median might give the most conclusive answer, which is 100 square meters. (Values range from 1 - 2000 square metres)

Unfortunately, answers to the question on latency was inconclusive, as we asked for answers in seconds, not allowing for answers in the for audio application typical lower millisecond range, which would have been more informative.

3.2 Interacting Through Space

What makes the workshop so interesting as a growing bed for spatial interaction is its situatedness through improvisation: Arguing with Suchman [38] that situated interaction

[5]we used the phrase *The accuracy required for my application is...*

can neither be wholly projected or planned, nor exhaustively described on hindsight, we acknowledge that an improvisational practice can only ever be anything but situated. It provides a prototype in itself for the study of spatial interaction, possibly for all types of interaction.

Exploring a space just for its acoustic qualities, as a found instrument, or as an augmentation of an existing instrument, allows for experimentation with spatiality as a means of expression. From this starting premise we would like to follow the threads which distinguished themselves in our data, the field notes: Firstly, space as a change in position over time, secondly space as a sound, thirdly, space as a visual entity and lastly, space as a representation in a semiotic sense. The last thread has only indirect bearing on requirements, but our cultural associations with space still influences our experience of it, thus impacting on the situation the interaction takes place in. We try to account for this influence in all of the following subsections, but will not look at it separately, as we believe these representations to be a negotiated outcome of the precedent interaction, which in turn is based on primordial motor behaviours, as Noland convincingly argues with Merleau-Ponty [24].

3.2.1 Space as Dynamic, Multiple Positions

Moving sound sources, movement as sound sources, gestures in a scale from the plucking of a string to cartwheeling through the room make up the dynamic tools of spatial interaction in form of trajectories, displacements, oscillations. Many participants from non-prominently moving disciplines, for example, composers and some visual artists found it at first daunting to experience themselves as moving bodies. But the common ground established via the kinaesthetic experience of moving as a function of a particular discipline, like moving a brush, a pen, a bow, a plectrum, and so on, provided a shared vocabulary which helped to overcome initial inhibitions. Participants with a background in performing arts like dance or theatre discovered in turn how their movement has a sonic quality too, be it in the form of steps or the sound of props. From this shared understanding the evolving interdisciplinary practice made use of every available spatiality: Musicians who's instruments are light enough to be played while moving did so. Non-mobile instruments were often temporarily ditched for more mobile ones. If a ladder was in the room, it got incorporated, as did adjoining rooms, galleries and staircases. As a consequence, the space became a narrative: To experience a particular event somewhere in this extended performance area, one just had to happen to be there, as at another end one would have missed it: Every participant had her or his own experience of his or her trajectory, laced with nodes of interactive encounters with others. But even when the overall event was an assembly of micro performance, it was always experienced as a coherent whole.

In view of our research questions towards existing and potential technology to enhance or support this interaction, we made some astonishing findings: Audio technology in form of standard loudspeakers in a surround set up proved to be cumbersome, as they did not portray any correlation between the positions of the sound sources they represented, on the same token all sounds coming from laptops were situated remotely from the acoustic sources, creating an abstracted space many participants found very hard to relate to from a spatially dynamic perspective. Some interesting low-tech *ad hoc* solutions were the use of very long cables allowing loudspeakers to become personal sound sources, carried around by the performers.

This led to the descriptions of distinct scenarios for interactive automated panning systems we presented in [32], but also inspired the development of low latency wireless loudspeakers for performance purposes. The use of wireless microphones was embraced by many participants, be it just as a means to record a spatial narrative as a trajectory, or also to amplify quieter moments of sonic activity. Here, using loudspeakers to reproduce sound sources in locations remote from where we performed them, was used artistically by some. But for others it further helped the formulation of the idea for an automatic panning of real-time sound sources as shortly discussed above.

Experimenting with existing technology, we noticed how important it is for the sound to be free of any noticeable latency. An erroneous setting on a sound card, or the latency due to networking made us aware that time delays around 20 ms can be noticeably long. This informed our proposal of low latency gestural interfaces in [33]

We find it worth mentioning that the representational nature of the spaces we used always had an inspiring effect on our experience: The architectural impact on spatiality is of course huge, a sunlit foyer evokes a different session than a black box, as does the presence of props, the reverberation/attenuation over distance, etc. The scenography is paramount for space as a means of expression.

3.2.2 Space as a Sound

The well titled book by Blesser and Salter, *Spaces Speak, are you listening?* [7] explores space as a sounding phenomenon rather than the kinetic aspects discussed above. The spatial interaction within this type of space is therefore quite different. The spatial qualities of sound are a direct result of the space due to the way a space reflects, diffracts or absorbs sound. Every place is different. Spatial interaction in a kinaesthetic sense takes the form of an exploration: Interaction here is quite the listening Blesser and Salter demand. One could presume that the sounding space is a given *a priori* entity, and static: However, every possible position in a room sounds differently, providing a rich and complex texture of possibilities. It is a different perspective: Not the movement itself is of direct interest, but how the sound of the room changes with the change of position of a moving sound source.

Another experience we made is that, due to the *a priori* nature of the sound of a room, the introduction of reverberations superimpose a combined spatiality of the virtual, artificial room and the existing room. The use of, for example, commercial reverb-effect pedals, with their strong representational character, need a very subtle hand not to overpower all other possible spatialities. They set a scene which can not be ignored. From a kinaesthetic point of view, once triggered, there is very little kinetic control over these reverberations. In contrast, electro acoustic feedback, as long as it can be controlled, provides a very engaging kinaesthetic experience, both for the performer as for the listener for whom the gestures for control are obvious and emphatically understandable if performed, for example, with a loudspeaker and a microphone.

To interface space as a sound in a kinaesthetic content, we thus need to adapt the functionality of the interface:

Figure 1: Theatrical Aspects of MS&I. ©Dominik Schlienger

Whereas it senses the movement through space in our previous description, delivering digitalised movement, here we want it to dynamically deliver the digitised audio spatiality of the space, so to speak: A suggestion as to how to do this was to continuously measure acoustic impulse responses from changing positions in the room. This thread in the data is particularly aural and might not find its parallel in a non-audio context.

3.2.3 Space as a visual entity

For a sound art practice it maybe indicative that space as a visual entity did not play a dominant role in the data. Often, the experience of the visual as an expressive factor was only mentioned as an afterthought. Yet, particularly when looking at the photographic documentation[6] it becomes clear that the sessions are indeed theatrical and highly visual too. We believe that this comes out of a situated engagement with the space, more than out of a wish to perform visually: Visuality is just one aspect of the multi modality of interdisciplinary improvisation. For example in Figure 1 we see how a participant wrapped another participant in paper. Primarily they were exploring the soundscape of the paper world they immersed themselves in. The resulting visual aspect then was a cue for other participants to react in a theatrical way, and also prompted the photographer to take the picture.

In sessions in which we had light design as a participating discipline, these visual cues were respectively stronger, strengthening our visual awareness. Light sources, from hand held torches, projectors, to theatre spots, just like sound sources, provided great localised cues and expressive opportunities. As part of the light design also experiments in darkness became part of our practice.

Another visual aspect in connection to kinaesthesia came up in conversation with one of the participating painters. She remarked that the brush stroke, as the result of the kinaesthetic experience of moving the brush, is the embodied trace of this movement. The audio parallel, the embodied playing of an instrument we can hear on a recording, was evident. From here arose the question of what happens to the kinaesthetic experience in electronic music, a subject debated in a range of works, for example in [27]

3.3 The Kinaesthetic Interface

Even more strikingly, in the same discussion, we noticed that, for example, in taking notes with a computer keyboard rather than in handwriting, we lose an embodied, situated inscription of a whole world of things that is otherwise visible from handwriting: From hand written notes, even without the aid of graphology, we can see if the writer was in a hurry, or was taking her time, we see what was scribbled out, also at what point did the writer nod off, or was he excited, and so on. These qualities are lost in typed writing. Our discussion then took a gloomy turn, many participants expressed discontent with the lack of possible kinaesthetic experiences in the digital. It culminated in somebody raising the spectre of modern man being nothing but a disembodied head on a sofa in a digital future.

If, in the consequence of this discussion, we did not come up immediately with a grand solution, it still paved the way for a gradual conception of the importance of kinaesthetic interfaces for an embodied digitality, the requirements for which we are now able to define at least for a general sonic arts practice:

- The kinaesthetic interface might not be able to trace anything else but kinetic events. However, it records those kinetic events at the right resolution, over the necessary distances, at sufficient speeds and with the necessary accuracy to make them *relevant* enumerations and encodings as a parameter correlated to its kinaesthetic experience.
- From both the survey and the workshop on MS&I, we know that the interface shall hinder or impact on the expressive activity as little as possible. It needs to be able to trace the displacements of a human body and its gestures in real-time. For example, if a gesture was to be mapped to a sonic event, there should be no perceivable latency. In many of our sessions meaningful trajectories were three dimensional. The Distances we believed to be meaningful range from the low centimetre range to tens of meters. Here our experiences in the workshop are reflected very closely in the results of the survey.
- In the subsection on Space as Sound, we discussed the possibilities a record of the space in a particular point over time would bring. We believe the capacity of the interface to be able to take impulse responses would enable this. The survey was not able to tell us anything about space as a sounding entity, as the survey design did not anticipate such an outcome.

[6]The photos were taken as part of the improvisation, by a participating photographer

- All scenarios we studied and experimented with, were concerned with interaction with multiple participants in indoors environments.
- Last, not least, from our discussion on visual aspects of space in our practice, we know that this interface can not rely on the presence of light, nor can it rely on line of sight as we describe categorically, multi participant scenarios in three dimensional space.

With the elicited notion of the kinaesthetic Interface, we believe we have found a prototypical concept to integrate many different notions of gestural interfaces. Providing a broader situatedness in our improvisational practice, in the way Suchman recommends for human computer interaction in [38], we believe our findings are applicable also to non-artistic applications. Admittedly this may be due to their general character. This, in turn however, might also point to the unavoidable realisation that every application has its very own situation, a realisation which emphasizes the importance of research into this situatedness, as proposed by Suchman already in 1987, but rarely acted upon by developers until quite recently. In this sense, we hope to have provided an account of a practice which elicits requirements. If our experiences in this practice prove to be general enough to resemble some of the broader artistic communities' experiences, this might indeed help to drive development of technology which meets these requirements. For a summary of our results, see table 2.

	survey	**workshop**
Accuracy	$0.001 - 10\,\mathrm{m}$	0.1 - 0.3 m
Update Rate	continuous	
Latency	not perceivable ($< 20\,\mathrm{ms}$)	
Ubiquity	high	
Cost	low	
Area covered	1 - 1000 m^2	10 - 1000 m^2
Distances		0.01 - 100 m
Speeds	human gestures ($< 40\,\mathrm{m/s}$)*	
Scenario	multi-user, crowded, indoors	

*Fast cricket bowler's ball release- speed according to [4]

Table 2: Summary of Results by Method

4. CONCLUSIONS & FUTURE WORK

We believe to have at hand a useful set of requirements as recommendations for design of a kinaesthetic Interface, the notion of which we have developed here in order to give a better understanding of what spatial interaction in the sonic arts requires from technology. In basing our approach on situated ethnographic methods as well as more traditional ones in form of an online questionnaire, we were able to verify to a certain extend the validity of both approaches, as the data was mirrored in many ways. However, we would also like to highlight that the prototypical practice in the workshop was able to provide unexpected outcomes, answers to questions we did not know we had *a priori*. A questionnaire is a lot more rigid in that aspect.

For future work, we would like to see how these requirements fair when implemented and reintroduced to the workshop in a next cycle of development. We also hope to develop the concept of the kinaesthetic interface much further as a contribution to the discussion on a new, embodied, digitality.

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