BazerBows:
Instrument Design and Mimetic Theory

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Abstract

This paper will explore mimetic principles relevant for music performance and instrument design. It will describe elements important for understanding basic interaction between visual, sounding and gestural aspects of experiencing instrument performance and illustrate how music controllers may be enhanced through devising specific design concepts based on mimetic theory. Example instruments designed according to these principles will be presented, specifically the BazerBow and its various prototypes.

1: Background and Context

The experience of an instrument, whether playing the instrument actively, or experiencing as an audience member, will be influenced by gesture and inter-modal aspects. Gesture, although not always, nor necessarily directly connected to the sounds the instrument makes, can convey information important to the performance. It may also alter the perception due to inter-modal effects. Inter-modality describes how our mind creates a single perception from all its senses which may cause one sense to override another. This can cause illusions, such as the familiar optical or mixed optical/aural illusions, e.g. the double-flash experiment (McGurk and MacDonald 1976; Shams et al. 2002).

Davidson has explored the visual components of performance and how they affect perception. Her findings 'emphasise the need to consider visual as well as sound information in psychological enquiries into music perception' (Davidson 1993). Krumhansl and Schlenk gained similar conclusions, from an experiment involving a ballet performance played to an audience with just sound, sound and vision and just vision. They concluded that 'the dance conveyed much of the same emotional and structural information as did the music' (Krumhansl and Schenck 1997). The visual aspect of an instrument is important to the perception of musical performance which is essential for mimetic processes.

It follows that it might be interesting to ask what a new digital instrument would look like if devised using mimetic participation and its related theories? Is it possible to exploit the processes behind mimetic participation to further develop and enhance new musical instrument design to access the imitative, intuitive, and empathetic response of an audience allowing them to fully engage with new designs and musical concepts? Arnie Cox asks 'Do you ever find yourself tapping your toe to music?' and suggests that 'Informally conducting, playing 'air guitar', and 'beat boxing' are similar responses' (Cox 2006). This formidable force that demands its listeners to perform 'air guitar' at the most inopportune moment, if better understood, may give an insight into the relationship between audience, performer and instrument. With greater discernment of these relationships, design factors can be honed to create new digital instruments that, although maybe unfamiliar, can connect with both audience and performer allowing for an immersive and shared empathic experience.

2: Instrument Efficiency

In our modern world of endless possible designs and readily available technologies, the more important questions relate to expressiveness and the impact of acquiring performance skills. Jorda's work on digital instrument design (Puig 2005) attempts to find a method to compare the infinitely contrasting designs and their capabilities and define how to measure instrument efficiencies, applied in his creation of the 'Reactable'[1].

It is commonly agreed that for a new instrument to become popular in a similar fashion to guitar or piano it needs to be instantly playable by a beginner but have sufficient complexity to need time to develop necessary skills to master the nuances of the instrument. However there is no commonplace measurement for an instrument's complexity, nuances, or the skills needed to perform on the instrument. Jordà attempts to reconcile these issues in an efficiency formula which allows new instruments to be compared with established instruments such as piano (see Equation 1, (Jordà 2004)).

$$\text{Music Instrument Efficiency}_{\text{Corrected}} = \frac{\text{Musical Output Complexity} \times \text{Diversity Control}}{\text{Control Input Complexity}} \quad (1)$$

Although this might be considered a simplistic view of a complex process there is some merit in considering it as a starting point. However, the formula focuses on the instrument and its relationship with the player without consideration of the effectiveness of the instrument with an audience. Using this formula an instrument design may prove to be very efficient and so be popular to play, but it may also prove to be very inefficient at relating to, and communicating performance components such as gesture.

Thus the areas of affordance, gesture and mimesis are underplayed in their importance and impact on the perceived quality and experience of an instrument. It may be the case, as in the case of the BazerBow, that mimetic design criteria conflicts with the proposed parameters for instrument efficiency. Therefore it is logical to include mimetic principles into any instrument efficiency models.

3: Affordances

How the efficiency of an instrument might be affected by affordance becomes clear when comparing two very different instruments, the Kalimba and the Theremin. Jordà concludes that instruments that have obvious affordances, such as the Kalimba 'will probably not yet reach the 'expressiveness' of the violin or the piano, but they can surely be much more 'efficient' than traditional instruments tend to be.' (Puig 2005:176). However, when considering the example of the Theremin, with its easy production of sound, it could be seen to be initially 'efficient' like the Kalimba, but it is considered (and perceived by audiences) as very expressive, especially when time has been spent mastering the instrument. Billinghurst believes the Theremin is successful because 'there is a direct mapping of hand motion to continuous feedback, enabling the user to quickly build a mental model of how to use the device' (Billinghurst and Buxton 2011). This corresponds with the 'inevitability' design criteria, that Machover describes as allowing a new player of the instrument to instinctively 'know' how the instrument produces and affects sounds (Machover 2002). However, Jordà reasons that in the case of the Theremin 'that all types of difficulty may be rewarding for the performer and guide to better results. Could expressiveness be perhaps related to difficulty or effort?' (Puig 2005).

Tanaka describes affordance as: 'a concept fundamental to interaction design practice. Arising from Gibson's seminal work in perceptual psychology, it maps potential action relationships between subject and object based on qualities of the object and capabilities of the subject' (Tanaka et al. 2010).

Unlike acoustic instruments, digital instruments usually need a mapping interface which connects the gestures with the sound generation, and this integrates or exploits aspects of affordances. Paine argues that 'interfaces need to communicate something of their task and that cognitive affordances (Gibson 2014) associated with the performance interface become paramount if the musical outcomes are to be perceived as clearly tied to real-time performance gestures' (Paine 2009). This points towards the inclusion of mimetic participation in design considerations, with 'musical outcomes' being mapped to 'real-time performance gestures' (Paine 2009).

Dix, writing from a HCI perspective, suggests there are 'three "use" words that must all be true for a product to be successful; it must be: useful (accomplish what is required: play music, cook dinner, format a document); usable (do it easily and naturally, without danger of error, etc.); used (make people want to use it, be attractive, engaging, fun, etc.) (Dix et al. 2004). Relating this to music, Cano describes a similar mimetic process in his 'Proposal for a typology of music affordances'. He describes 'Executant mimesis' as 'Imitating the playing of musical instruments and other actions producing sounds as well as any associated kinetic activity.' (Cano 2006). He goes on to say that these imitations include: 'Imitations of a solo guitar player from a rock band or imitating the gestures of singers by singing along with them. Incipient music lovers belong to this category when they imitate the gestures of a conductor by moving a finger as if it were a baton while listening to the music. It also includes imitating the gesticulation often employed by musicians while playing their instruments.'

The mimetic process can thus be seen to be closely related to affordance theory.

4: Mimetic Principles

Trevarthen and Malloch have shown how important early musical mimesis is to cognitive and social development, (Malloch and Trevarthen 2009) and describes how this process may facilitate improved social empathy. Rabinowitch et al have been looking at emotional empathy in school children and whether empathy may be improved by a specially devised 'musical group interaction' (MGI) programme. The MGI programme consisted of interactive musical games using empathy-promoting musical components (EPMCs) (Rabinowitch et al. 2013). The results support the hypothesis that these musical programmes can increase empathy. This is supported by studies into early child development and the musical content of motherese which babies use to elicit a social, empathetic response from their primary caregiver (Malloch 2000b).

The concept of empathy overlaps with ideas of intuition and mimesis, except that in the case of empathy the process is in relation with another person or people, where intuition and mimesis may involve self and surroundings without invoking someone else. However, mimesis, unlike imitation may involve emotional and social understanding, and empathy. In discussing the premise of his mimetic hypothesis, Cox states that 'part of how we comprehend music is by way of a kind of physical empathy that involves imagining making the sounds we are listening to' (Cox 2011). Both mimesis and empathy may share similar mechanisms. Studies show that one of the functions of mirror neurons is mimesis or imitation (Rizzolatti1 and Craighero 2004). However Rizolatti states that 'evidence has been found that the mirror mechanism is also involved in *empathy*'. Molnar-Szakacs and Overy suggest that the motor process involved in the expression of emotion involves mirror neurons: 'Emotion, especially as communicated by the face, the body and the voice is an active motor process. Emotion and action are intertwined on several levels, and this motor-affective coupling may provide the neural basis of empathy' (Molnar-Szakacs and Overy 2006). Using the example of 'air guitar', mimetic participation allows the listener to imagine and imitate physically and/or verbally 'playing' the guitar, but may also produce an imagining or empathising of the emotional state of the performer. This empathy may play an important role in the proportion of mimetic effect experienced by the listener.

Intuition is also a very elusive concept. The Oxford dictionary defines intuition as 'a thing that one knows or considers likely from instinctive feeling rather than conscious reasoning'. It is certainly an area of keen interest for scientists and a rather too complex area of study to explore in more depth in this paper. In part intuition draws on experience and on memories, and the emotional states stored within those memories. In any given situation those memories will play an important part, especially when there is time for those memories to be fully considered and processed with the incoming information necessary for decision making. When there is little time for those memories to be fully processed decisions need to be made with less consideration (McCraty et al. 2004). Making a decision without due consideration may be interpreted as 'intuitive', drawing on the ability to preempt, predict and envisage a response outside of experience. Depending on the situation this may draw upon mimetic participation to allow mental preparation for a new physical response, and mimetic empathy if a judgment is needed. It may be that intuition plays a part in mimesis, and a better understanding of intuition may allow a better understanding of mimetic participation.

New techniques, such as in fMRI (functional magnetic resonance imaging) are providing an increasing body of evidence for understanding how intuition, empathy and mimesis works. With one hundred billion neurons in the brain (Philips 2006), each making connections with tens of thousands of other neurons, there is interesting evidence surfacing that the heart is also surrounded by approximately 40,000 neurons, (McCraty et al. 2001) thus of a similar scale to that of a small part of the brain. Up until now it has been thought that all cognitive processes occur in the brain, now experiments are beginning to show that the whole body, in particular the heart, has an impact on cognitive function. It seems that the heart plays an important role especially in intuitive decisions. During an experiment to test intuition (McCraty et al. 2004:133–143), brain and heart scans demonstrated that during intuitive decision making the heart responds before the brain, sending signals to the brain first. Further tests have shown that the heart's magnetic field can influence not only our own brain waves but others close by. Another experiment (McCraty et al. 2001:25) demonstrated that when two people hold hands the brain waves of one tend to synchronize with the heart pulse of the other. These early experiments seem to back notions of intuition and empathy which many people have experienced, specifically in collaborative live music making, but been unable to explain. As the mimetic is closely linked with intuition and empathy this new area of research may also begin to partly explain the biological and psychological processes behind mimetic participation.

The definition of mimesis in the Oxford dictionary is 'imitation, in particular: imitative representation of the real world in art and literature' with imitation being defined as to 'take or follow as a model; copy (a person's speech or mannerisms), especially for comic effect'. Most people are familiar with imitation, whether that is through consciously mimicking or impersonating someone, or by sub-consciously finding yourself following someone else's movements and gestures such as yawning, or crossing your arms. The boundaries become thus blurred between imitation and mimesis. However mimesis is a term frequently used in art works and religion to describe a process that is more than just a copy. Describing Mimetic Theory, Hardin says: 'Mimetic theory asserts that all desire is taught to us, 'mediated' by an Other. We only want what is first modeled to us as desirable. Of course, it is easy to recognize that this is precisely the way the advertising industry works by getting us to want what celebrities have. It is more difficult for each one of us to see this work out on a personal level since we would all prefer to believe that desire arises from within us autonomously[2]. Hardin goes on to say that 'Mimetic theory acknowledges that we are all interconnected'. This interconnected-ness leads toward the theories of empathy, discussed above.

Although mimesis may be directly translated or defined as imitation, it has connotations of something more than a purely physical copying. Mimetic Theory was disregarded in the 1970's when first postulated by Rene Girard, but has recently gained popularity within various areas of research[3]. Girard declares mimesis as a human trait, and describes how all human desire is mimetic and consequently is the force behind violence in society[4]. 'When you say 'imitation', everybody thinks of being sheep-like, gregarious, following people, and so forth. This is true in many instances, but what is also true is that imitation not only affects your gestures, your words, or ideas; you also imitate desires[5]'.

Child psychologist Colwyn Trevarthen has explored mimesis in new-borns, infants and young children, and how the process affects social and cognitive development. He shows that mimetic interaction between the child and its family and care-givers is essential for healthy growth and maturation (Trevarthen 2004). This interaction is complex and subtle but instinctive and innate for most people. From the moment we are born we have the ability to communicate with our primary care-giver through mimetic participation. This is essential for our immediate survival as we are not capable of providing the necessities of life for ourselves and so rely on the relationships with the people around us. This ability stays with us and is involved in our daily interactions with others, sub-consciously influencing our decisions and choices, the way we respond and empathise in order to interpret and respond to people and situations around us.

Trevarthen's work has been studied by Steven Malloch, an audiologist, analysing audio recordings of protoconversations for musical content. He has found strong elements of rhythm and melody in motherese, concluding that the instinctive communication between mother and baby is a delicately complex balance of precise intonations and rhythms, alternating between mother and child. Malloch describes this process as 'communicative musicality' and believes it an important part of cognitive and social development (Malloch 2000b). The conversations involve imitation and call and response, where the baby responds and imitates the sounds and gestures of the mother, who in turn responds and imitates the baby. Malloch's theory makes convincing links between the mimesis and the musicality of these early communications and has found evidence to link infant directed speech (IDS) and its musical nature. Using spectrographic analysis and other audio analysis techniques Malloch has found musical patterns in rhythm (pulse), melody (pitch and narrative) and timbre (quality) and concludes that this musical content is essential to successful and effective IDS: 'We have discussed communicative musicality in terms of pulse, quality and narrative. We have seen that in these areas systematic movement occurs between mother and infant — movement that allows mother and infant to express themselves in ways that are sympathetic with the other. Movement — gestural, vocal and emotional — is what allows communicative musicality to occur. When this movement is constrained or impeded, communicative musicality suffers, and companionship suffers' (Malloch 2000b).

These studies involve a range of ages including new born babies, which suggests that the aptitude for communicative musicality is inherent and innate, without learning or experience. However, learning and experience will improve the ability and generate memories from which the mimetic process can draw on further in future development. Malloch states that 'It appears that the mother's intuitive behaviour supports the infant's innate communicative capacities'. It is this innate mimetic ability that is attempted to be exploited within specific instrument design criteria that led to developing the BazerBow instruments described in the next section, enabling empathetic, intuitive mimetic participation.

5: Mimetic Participation and Instrument Design

The specific term of 'mimetic participation' is used in various areas. Biology uses it to refer to cell imitation (Gabius et al. 2004), and religious writings refer to it as an experiential sensation (Garrels 2011). In music and music performance mimetic participation can be seen as the driving force behind the familiar 'air guitar', which has become such a common phenomenon with annual 'air guitar' championships attracting thousands of entrants worldwide[6]. In child psychology Colwyn Trevarthen and Steven Malloch have found that mimetic participation occurs from the moment a baby is born, to establish a necessary relationship with a primary caregiver, and so mimetic participation is an intuitive ability that most people are born with (Trevarthen 2004). This innate ability is drawn on throughout our lives in most circumstances we find ourselves in, especially social situations, and is affected and evolves with experiences and memories. This mimetic process allows us to predict and make decisions about new situations by using mimetic participation to anticipate and visualise any given scenario, enabling us to mentally 'practice' and role-play the situation before committing to a decision. This process improves as memories are developed and can be drawn on, and mimetic participation can draw these memories together in such a way that situations may be pre-empted 'instinctively'.

Mimetic participation not only relates to movement and gesture. As Cox says 'we do more than visibly move to music; we also sing along, in real time and in recall, aloud and in our heads'. These mimetic vocalisations point towards a theory that any mimesis of gesture may include vocal mimesis. As Billinghurst says 'Gesture is also intimately related to speech, both in it's reliance on the speech channel for interpretation, and for its own speech like-qualities (Billinghurst and Buxton 2011)'. Cox says that 'it should not be surprising that we would draw on vocal imagery to understand instrumental musical sounds generally' (Cox 2006:49).

In terms of musical instruments, the listener through experience, has an understanding of their physical surroundings and the materials around them, and how these materials react when interacted with, such as concepts of hardness, density etc., and how these materials might 'sound' when plucked, hit or struck. Using this knowledge the listener can imagine what will happen when a string is plucked, and the type of sound that the string might produce, without having ever experienced a guitar-like instrument before. With this anticipatory knowledge, and having an understanding of their own motor-neuron system and how their body will need to impart appropriate forces to pluck the string, the listener can imagine playing this stringed instrument without any prior experience or knowledge, an important principle when devising new instruments.

6: Mirror/Sympathy Neurons

In neurological studies in sports, it has been discovered that actions involve neurons that fire when participating in the action, but also when only imagining the same actions. 'Mirror neurons are a particular type of neurons that discharge when an individual performs an action, as well as when he/she observes a similar action done by another individual' (Rizzolatti 2005).

This is believed to also occur with musical gesture and actions related to playing instruments but has yet to be confirmed. Molnar-Szakacs and Overy hypothesise that: 'the powerful affective responses that can be provoked by apparently abstract musical sounds are supported by this human mirror neuron system, which may subserve similar computations during the processing of music, action and linguistic information' (Molnar-Szakacs and Overy 2006).

These neurons allow the brain to prepare for actions that have never been performed before, which is essential in evoluntionary terms as the body needs to be ready and prepared for 'fight or flight' at any moment and able to act intuitively and able to improvise to survive. This neurological process may be the mechanism behind mimetic participation allowing the imagining of playing an instrument never previously played before. Molnar-Szakacs and Overy say that: 'The connection between music and motor function is evident in all aspects of musical activity-we dance to music, we move our bodies to play musical instruments, we move our mouths and larynx to sing.' (Molnar-Szakacs and Overy 2006).

Colwyn Trevarthen prefers to refer to mirror neurons as sympathy neurons: 'It might be better to call these the neural mechanisms of *sympathy*, which is a Greek word meaning 'moving and feeling with' (Trevarthen 2004). Not only may these neurons provide an understanding of the mechanics and physical processes of playing an instrument, it may also allow a connection or empathy between performer and listener facilitating a more complete understanding of the musical performance not confined by purely the visual gestures. Using the term sympathy may be a more applicable term as it suggests a more empathetic process: 'We intuitively get into other persons' minds by actively sensing the impulses to action in their brains that enable them move the way they do' (Trevarthen 2004).

7: The BazerBow: Prototype 1[7]

The BazerBow was developed to exploit mimetic theory, and thus to address some of the limitations in commercially available controllers, such as limited simultaneous control of independent parameters. The BazerBow first prototype, (the first of 3 designs so far) has a varied range of sensors to accommodate the independent manipulation of several controls simultaneously, as well as controlling the initiation, length and pitch of the notes. The integration of physical body/movement gestures rather than limiting gestures by using knobs, buttons and faders, allows a full range of small, medium and large gestures creating a much wider range of gestural movement to control the sounds[8].

The BazerBow design is based around the guitar and a modified version of Delalande's classification of gesture (Wanderley and Vines 2006), as discussed above, has been used to help develop the gestural elements of the BazerBow:

1. Initial gesture: this is the gesture that begins the sound wave transient, and is quite often percussive. With an acoustic instrument's sound this transient is quite often important for the recognition of the timbre (Malloch 2000a). The initial gesture requires the 'plucking' to initiate the sound, and the positioning of the 'fret board' hand to alter the pitch.

2. Modulating gesture: these are gestural movements that occur after the sound has been initiated, that modulate parameters that affect the sound in some way. Synthesisers generally have many parameters that may be changed during the sound production, and so there are several modulating gestures to complement these synth parameters. These modulating gestures may be split into three sizes: small, medium and large. Small gestures are difficult to see but affect the sound; medium gestures can be seen from a small distance; large gestures are movements that can be seen from distance.

3. Inter-modal gesture: this includes all components/features of the BazerBow that do not affect the sound but have a visual presence. Although the gestures do not directly change the sound, taking the McGurk effect (McGurk and MacDonald 1976) into account, they influence the perception of them.

An important visual aspect of the BazerBow is in the way that it looks and feels, attempting to create a device more like an acoustic instrument than a typical controller. It is made mainly from wood and great effort has been made to hide the technology where possible. This is not only so the performer may feel more like they are performing with an instrument, but so that listeners may be given the impression of a musical instrument similar to a guitar.

For the BazerBow, there is a compromise between a shape suited to synthesised sounds and one influenced by theories of mimesis, that will promote mimetic participation. The guitar base should afford users to know how to initially generate sounds from the BazerBow, which should in turn improve mimetic understanding of the instrument thereby enabling mimetic processes. The BazerBow is an attempt to balance many facets of instrument design: a unique digital instrument/controller vs traditional acoustic form; small nuance based performer orientated gestures vs large spectacle audience orientated gestures; ease of play for beginners vs complexity of play for mastery; simplicity of design and use vs complexity and flexibility of control. These facets are pulled together with the common thread of mimetic participation.

Besides devising a series of fun and effective instruments to play, based on mimetic principles, the BazerBow will in the future hopefully provide evidence for the success of Mimetic Influenced Instrument Design.

8: Conclusions & Future

The expansion and intensification of research in the field of new digital musical instruments and controllers has given rise to conferences and publications dedicated to the subject, such as NIME and ICMC conferences and journals such as Organised Sound and Computer Music Journal. Similar control technologies are also being developed for homes allowing full control of lighting, heating, infra-red devices, etc., directly from 'smart' devices or with gestural control (Leap Motion) or voice command (Apple iPhone).

Many areas of this research are already being explored including gesture, modality and mimesis, including mirror/sympathy neurons. However, the current instrument designs do not seem to give full credence to the potential influence of mimetic theory on instrument use and the potential considerations for design. Mimesis, as discussed above, overlaps with and draws in principles of inevitability, gesture, inter-modal perception, instrument efficiency and affordances, processes which are usually important to instrument design, and although it may contradict with ideas of instrument efficiency, it balances this theory allowing the incorporation of the relationship with audience-instrument-performer as well as only instrument-performer. The theory also pulls on other areas such as, empathy, intuition and heart-brain interaction, and sympathy/mirror neurons which may not have otherwise been considered in instrument design, but could lead to new developments which may have otherwise been missed.

Girard states that: 'All scientists know that many scientific innovations consist in importing into a neighbouring area something which has been invented elsewhere, something which has not only worked and produced things, but suddenly illuminated a problem that until then was totally obscure' (Garrels 2011:238). Importing these mimetic theories into the design and development of music control devices may lead to a new class of innovative digital instrument and controller.

Whilst there is still more scope to quantify the effectiveness of the BazerBow during its ongoing developments, this paper has explored how mimetic participation can be exploited in conjunction with more established design theories and principles and may enhance the ability of digital instruments to communicate and engage with an audience.

To date, two fully functioning prototypes have been built, another one in progress, all based on mimetic principles. Future areas of research are planned:

1. To look at the relationship of mimetic participation and instrument design through the use and exploitation of these devices through composition and performance, in varied performance situations and instrumentation/ensembles.

2. The mimetic theories may not only affect instrument design for purely musical performance, there may be a potential for the use of mimetically designed instruments to be useful in music therapy. Malloch and Trevarthen's work (Malloch 2000b; Trevarthen 2004) suggests that a lack of communicative musicality at an early age can affect cognitive and social development. These issues are currently being tackled with music therapy, with good success but with traditional instruments. A specially designed instrument which harnesses mimetic participation may prove even more successful in music therapy, supplying the 'communicative musicality' and mimesis which was lacking earlier.

3. To attempt to measure the effectiveness of mimetic principles by more empirical means. The theories of mimesis and mimetic participation may be explored through a series of musical 'experiments' using different devices and controlled environments/audience. These experiments have the potential to include sophisticated tests looking at brain function when experiencing mimesis, searching for mirror/sympathy neurons.

The BazerBow needs to be fully examined as a 'new instrument', further exploring key areas of instrument performance such as the capability/flexibility to improvise, the ease of initial use and further mastery, and also to confirm whether or not performances induce the 'air BazerBow' effect.

Developed as a performance device a mimetic controller such as the BazerBow, will give access to the control and performance of more complicated synthetic sounds. This may allow a greater audience appreciation of the instrument, performer and performance, in turn giving the perception of an instrument rather than a piece of control technology and possibly creating an opportunity for amalgamating new music synthesis with traditional instrumentation.

The BazerBow project has only just begun to scratch the surface of Mimetic Influenced Instrument Design and will endeavour to improve the efficaciousness of the mimetic effect of its new instruments.

9: Acknowledgements

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Notes

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6. Air-Guitar, "Air Guitar World Championships," 2010. [Online]. Available: http://www.airguitarworldchampionships.com/. [Accessed: 27-Aug-2012].
7. Due to ongoing patenting processes, only general features are described in this paper.
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