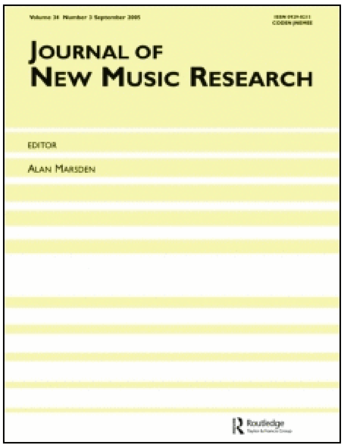

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The Language of Action and Cyberaction-based Music: Theory and Practice

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The Language of Action and Cyberaction-based Music: Theory and Practice

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Abstract

Action can define, guide and inform all aspects of compositional process and foster musical expression. This article formalizes a language of action-based music in the physical world and cyberspace. Typologies of actions form lexica from which such music emerges. Physical modelling synthesis is an excellent vehicle for conceptualization of actions and instruments in the digital domain, yielding replica extended, hybrid, and abstract cyberinstruments and cyberactions. Compositional examples situate proposed theoretical principles in musical practice.[1]

1. Introduction

In his seminal work *The Senses Considered as Perceptual Systems* (1966), James J. Gibson, the founder of ecological psychology, proposed a novel approach to perception based on detection rather than sensation of the information in the everyday world.[2] Information about any environment is revealed to the observer through a set of parameters such as energy, ratios and proportions. For example, we may detect an object through its temperature, size, shape, material, and the object's distance in relation to other objects. These parameters assist us in identification of the object's *affordances* or opportunities, functions, and values.[3] For instance, a hollow object can afford filling.

Research studies in the auditory domain have demonstrated that we use ecological information to detect relative hardness of percussion mallets (Freed, 1990), gender of a walking person (Li et al., 1991), various lengths of dropped wooden dowels on hard surfaces (Carello et al., 1998), hollow and solid iron, aluminum and wooden bars (Lutfi, 2001), the object's material properties (Avanzini & Rocchesso, 2001), and size of an impact object when it drops on a resonant plate (Grassi, 2005). Such studies often derive their methods using what the British ecological psychologist W. Gaver defined as *everyday listening* (Gaver, 1993a,b). Gaver made a distinction between *everyday* and *musical* listening to explain the ecological approach to aural perception. Gaver observed that people describe the sounds they hear in terms of their sources:

> Your experience of hearing 'a single-engine propeller plane flying past' is an example of *everyday listening*, the perception of sound-producing events. The experience of 'a quasi-harmonic tone lasting approximately three seconds with smooth variations in the fundamental frequency and the overall amplitude,' on the other hand, is an example of *musical listening*, the experience of the sounds themselves. (Gaver, 1993a, p. 387)

An ecological approach essentially focuses on perceiving forms of actions between objects and phenomena in

[1]This article is based on my dissertation research (Kojs, 2008).
[2]Ecological psychologists and psychoacousticians such as W.D. Heine, W. Gaver, R. Guski, M. Kubovy, J. Neuhoff, D. Van Valkenburg, N.J. Vanderveer and others later developed Gibson's propositions.

[3]*Affordances*, a term invented by Gibson, refers to the relationship between the abilities and needs of the observer and capacities of the environment (Gibson, 1966).

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the environment. In music, interaction between a performer and instrument epitomizes such actions. For example, a violin scratch tone—the exaggerated frictional sound of the bow scraping across the strings of a bowed string instrument—reveals not only the source of the sound production (a string instrument) but also an action type (scraping). Interaction between the performer's bow and the instrument's strings therefore not only fosters sound production, but also inspires our understanding of the sound production means and modes.

Tactile contact plays a crucial role in such relationships. Research suggests that the physical interaction between the performer and the instrument guides development of skills and stimulates musical expressivity (Adams, 1971; Chafe, 1993). Studying haptic feedback has forwarded our understanding of the performer-instrument relationship and prompted design of haptic controllers and virtual simulations of musical instruments in the digital domain (Cadoz et al., 1990; O'Modhrain, 2000; Amstrong, 2006; Essl & O'Modhrain, 2006).

Can actions such as scraping the string then *afford* ground for musical exploration and creation of artistic context? Repeated string-scratching can indeed result in the generation of musical patterns. Repositioning the bow on the string and varying the pressure can inspire timbral explorations. Paired with other performative actions such as bowing on the bridge and the body of the instrument, scraping actions can yield a complex musical context.

My work explores how these actions can be musically engaged in the digital domain. What kind of music making does coupling physical and digitally simulated actions suggest? The following sections show how vocabularies of and syntactic bonds between various actions can construct an expressive language of action-based music in the physical world and cyberspace.

2. Action-based music

Action-based music emphasizes the artistic exploration of mechanical actions which are used to control all aspects of composition, including its conception, form, instrumentation and instrumental design, performance and score.[4] Actions applied to sounding objects and actions of environmental phenomena thus can become the principal means for musical expression. The composer prioritizes exploration of performative actions as opposed to investigation of particular sonic parameters in the creation of this music.

In a simple example, a composition rooted in the action of rolling is conceptually action-based. Temporal arrangement of the events can be derived from the deceleration and periodicity features of the rolling gesture. Instruments used to perform such a piece may include Bocci balls, bicycle wheels, percussion mallets, or uniquely designed rolling mechanisms. The score of such a composition would perhaps consist of diagrams, graphic icons, and verbal instructions which explain *what to* perform as shown in Figure 1.

While performing action-based music, the player is, in fact, often instructed about *how to* and *what to* perform rather than what sonic effect to achieve. Graphical choreography of actions in the notation often mirrors the physical movement of the performer. The graphical gesture of a circle, for instance, will suggest circular motion of the arm on the instrument as can be observed in Figure 2. The performer's contact with the instrument is thus often embedded in action-based music's notation.

Luigi Russolo, John Cage, Mauricio Kagel, Fluxus musicians, and Scratch Orchestra associates were among the first to develop graphical and verbal instructional choreographies which suggest musical actions. Concert music composers such as Luciano Berio, George Crumb, Helmut Lachenmann, Gyorgy Ligeti, and Salvatore Sciarrino have also cultivated instructional languages which combine traditional notation with verbal and graphical directions. As opposed to the graphic notations that symbolize the type of sounds to be produced (e.g. in music of Earle Brown and Krzysztof Penderecki), the notations of these composers tend to suggest choreographies of movements to be performed.

2.1 Typology of actions

In physical terms, the bow can initiate a performative movement; a hammer and air can stimulate other actions. Strings and bores are the resonating media in which actions develop. Whereas some actions involve sustained excitations, others require only single excitation gestures. Action is continuously developed on vibrating structures such as bowed strings, which need a constant energy supply in order to sustain a sound. On the other hand, an initial energy stimulus will set a self-sustained oscillator such as a bell in motion.

We can group actions involving two rigid objects into the following categories: bouncing, bowing, hitting, plucking, rolling, rubbing, scraping, cutting, and shaving. Dripping and pouring suggest fluid bodies in action. Blowing means that air initiated the action. Shaking and stirring can combine liquids and solids. Such musical vocabularies have their own morphological characteristics, but they can all be considered part of one

[4]Instances of such pure action-based music are difficult to locate, however music which engages action with intensity is discussed later in this article.

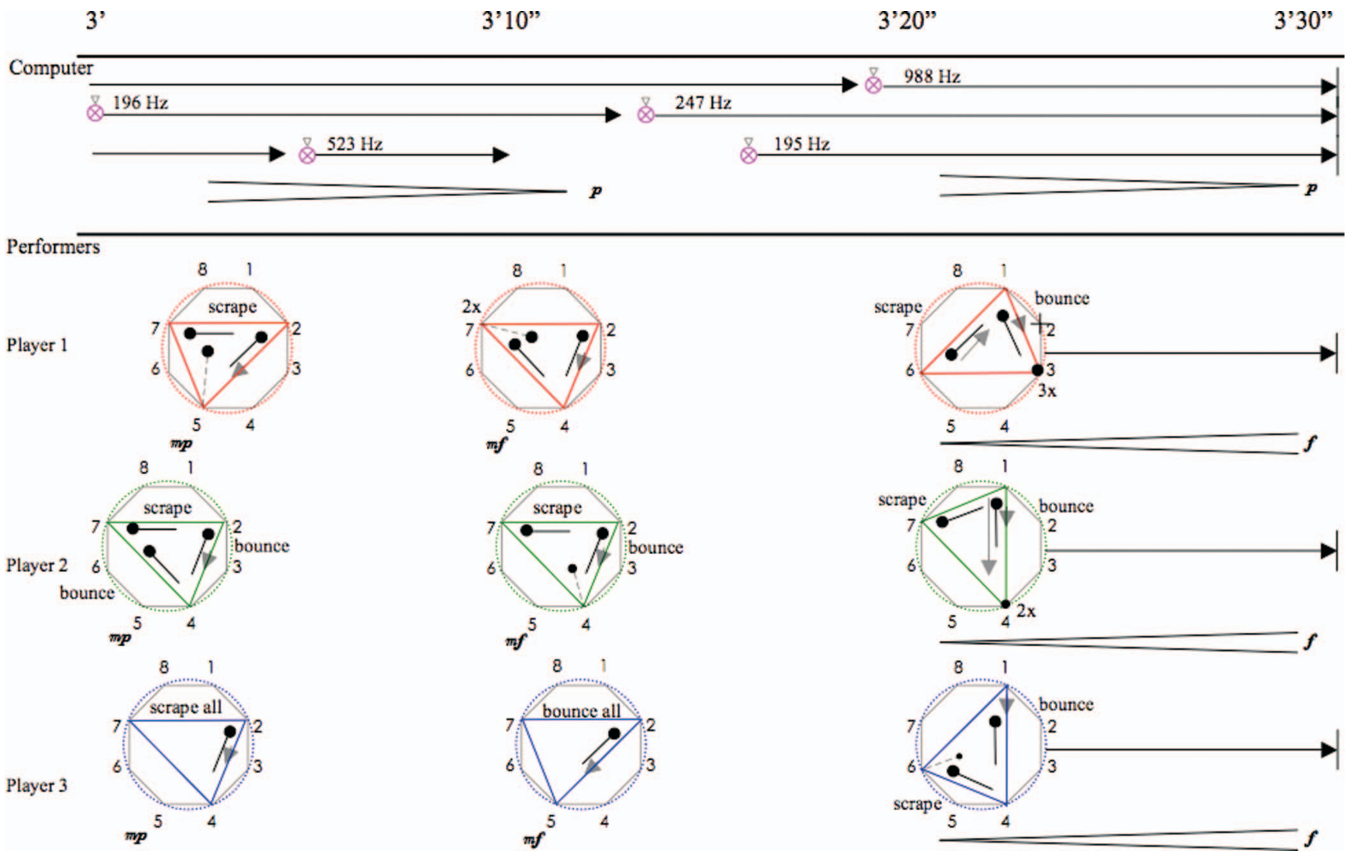

Fig. 1. An example from *Revelations* (2005) for circular toys, resonant plates, and electronics. Actions such as scraping, bouncing, and rolling are notated via a set of verbal and graphic instructions.

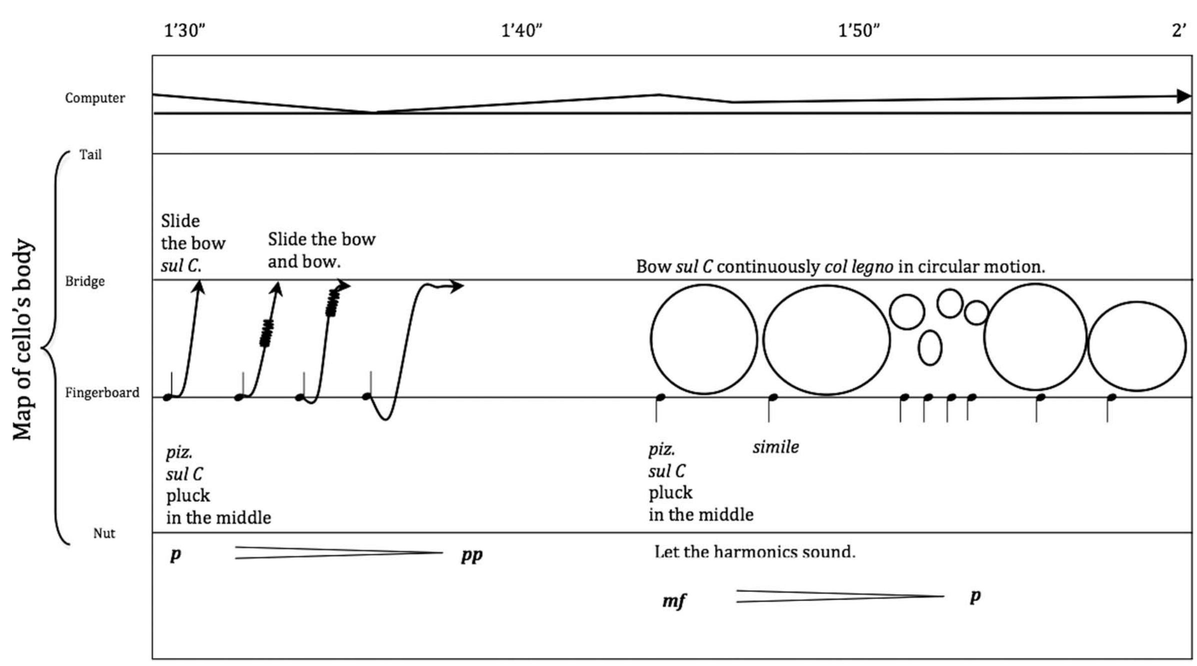

Fig. 2. A segment from *To Where He Waited* (2006) for cello and electronics. Graphical circular gesture directly translates to the circular physical action performed with the bow on specific locations of the instrument's body.

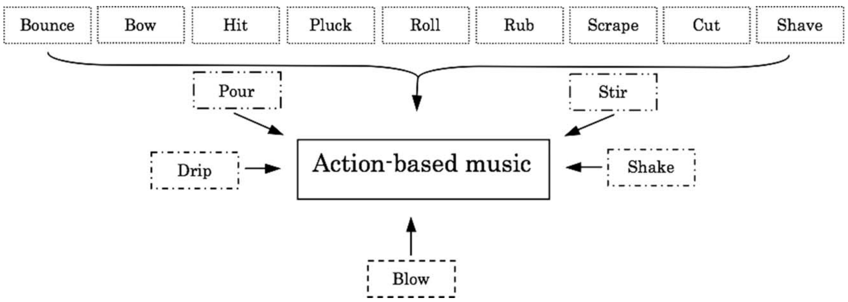

Fig. 3. Action-based music and its lexica.[5]

language: the language of action-based music, the typology of which is displayed in Figure 3.[5]

Establishing, sustaining, and developing actions stimulates creation of the musical content. The syntax of action-based music governs the formulation and order of all-encompassing performance techniques. In the time domain, the focus is on dynamic rhythmical arrangements which result from the inherent motion of physical gestures. In terms of sonic qualities, timbre and temporal developments are the principle music parameters of action-based music. Pitch is often concealed in the coloured noise which highlights actions.

At and Across (2007) for Slovak sheep bells and cyberbell structures rigorously follows the action-based music principles.[6] Physical actions such as shaking, hitting with metal, wooden and plastic beaters (mallet and stick parts), bowing with the violin bow, and blowing inside the bell mark the formal trajectory of the piece. A performer conducts these actions while holding the instrument in the vertical and horizontal positions. Bells hung on a horizontal rod enable controlled performance of multiple instruments. All actions are performed with and without partial or full muting.

Individual actions dominate particular composition's sections with the following arrangement: *Intro*, *A*, *B*, A', x', *C*, B', C', x'', B'', *D*, x''', in which A = hitting, B = bowing, C = shaking and D = combined modes. The performer holds all the bells in his/her hands and shakes them throughout the introduction. Lowercase x parts signify shorter solo electronics sections. Figure 4 shows the map of actions in *At and Across*.

This figure also discloses that *At and Across*, in fact, pairs physical actions with cyberactions. It is this combination that defines the musical terrain of the composition. Cyberactions and cyberbell structures were generated and performed in GENESIS which is a composer-oriented interface designed for building physical models within the CORDIS–ANIMA environment (Castagne & Cadoz, 2002).

3. Cyberactions

Physical modelling synthesis enables the digital simulation of sound production mechanisms and their actions (Cadoz et al., 1993; Adrien, 1991; Smith, 1992). This synthesis facilitates the replication of existing mechanisms and their extensions beyond the limitations of the physical world. The simulation of actions and mechanisms not existing in this physical reality is also possible with physical modelling algorithms. While it is a matter of time before the efficient methods simulate realistically truthful complex instruments in real-time, present research already provides numerous tools for artistic exploration suggesting the powerful potential of this technique.

According to their level of distillation, digitally simulated actions—cyberactions—can be classified as replica extended, hybrid, and abstract (Kojs et al., 2007; Kojs & Serafin, 2008). Specific structure, unique internal functions and possible excitation modes characterize each category. Actions are either congruent or incongruent with the physical world. Table 1 summarizes the three types of cyberactions with their respective structures, functions and driving forces.

3.1 Replica extended cyberactions

Replica extended cyberactions are based on simulations of physical processes as observed in the physical world such as hitting a bell. A beater (the exciter) and a bell (the resonator) are two fixed agents which frame the striking action. The unidirectional nature of the action is established by the fact that it is always the beater which acts on the bell. The structure and direction of such an interaction is thus congruent with the physical world. Once modelled, such action can be quantitatively

[5]This scheme is suggestive, rather than comprehensive. Other actions can be added to this typology.

[6]The composition engages a single performer playing on a set of sheep bells and computer performing on cyberbell structures. Traditionally, all sheep bells of a single herd were tuned to a common tone to ensure that a shepherd recognizes his sheep when mingling with others.

Time	0—2'	2—3'30"	3'—5'	4'—5'30"	5'15"—5'30"	5'30"—6'30"	6'30"—8'	8'—9'	8'30"—9'	9'—10'10"	10'10"—12'	11'—12'
Part	intro	A	B	A'	X'	C	B'	C'	X"	B"	D	X"'
Genesis		Hit single cyberbell	Bow	Hit cyberbell network	Poly-phony1	Hit multiple plate-like cyberbells	Bow, Blow cyberbell series	Hit single plate-like closed cyberbells	Poly-phony 2	Blow, Pluck cyberbells	'Cyberbell' multiple cyberplates and cyberbells	Polyphony3
Performer	Shake	Hand held (HH) + outside beaters	HH + Bow top	HH + inside beaters		HH + shake	HH + bow + bottom	HH + muted shake		HH + bow all and blow	HH + shake + suspended polyphony with beaters →	

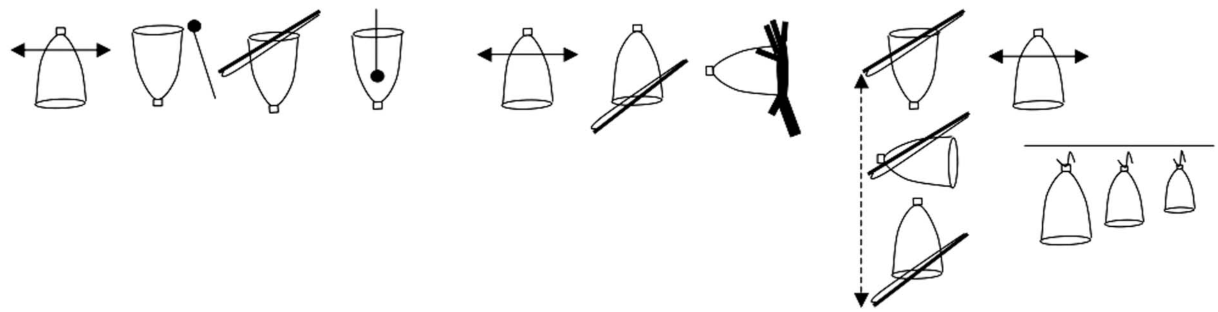

Fig. 4. Actions govern the formal design of *At and Across*.

Table 1. Typology of cyberactions.

Action type	Example	Structure	Internal function and direction	Forces
Replica extended	Hitting the bell	Fixed pair: exciter-resonator	Exciter acting on resonator	Applied as in the physical world and quantitatively extended
		Congruent with physical world	Unidirectional	Example: prolongation of the contact between the exciter and resonator, unrealistic forces and velocities
Hybrid	Plucking the bell; Belling the pluck; Plucking in parallel or serial the pluck and the bell	Reconfigurable pairs or groups of exciters and resonators Incongruent with physical world	E.g. exciter acting on exciter or resonator an exciter Multidirectional	Qualitative alterations such as changes in energy flow and type
Abstract	Plucking the performer; Belling the formal structure of the composition	Potentially vibrating structures, particles, phenomena Supra-congruent with the physical world	Formalizing principles, ideas and causes Vibrating or still	Transduction of energy to create behaviours and temporally organized sequences

augmented, meaning that the process and forces applied to it can cross beyond the limitations of the physical world, as in the case of striking the bell with unrealistic velocity and in extreme dynamics.

Replica extended actions such as hitting, blowing, and bowing the cyberbells are engaged in *At and Across*. Figure 5 exemplifies a cyberbell structure constructed of eleven masses which are connected with the viscoelastic links in GENESIS. The bottom two masses are ground to a fixed point. The square icon signifies a cybermicrophone module which enables us to hear the instrument. The beater consists of a fixed point connected to a mass. The nature of the cyberaction between the beater and instrument (blowing, bowing, and hitting) is defined by the connecting link, hitting in this case.

While hitting, bowing, and blowing the bell are actions which replicate behaviour observed in physical reality, augmenting the bell's size and changing its material properties stretch beyond the limitation of the physical world. GENESIS enables a simulation of bells larger than the world's most massive 300 ton Great Bell of Dhammazedi as well as microscopically scaled bell structures. Cyberbells and beaters with metal, glass, and wood characteristics were simulated and combined with ease. Simulating performative actions of extreme velocities and volumes signify the type of actions which expand physical reality.

3.2 Hybrid cyberactions

Hybrid cyberactions such as plucking a bell are incongruent with the physical world. Additionally, the exciter and resonator elements can become modular in hybrid actions (Essl, 2003; Burns et al., 2006). For example, we can imagine connecting a multiplicity of exciters to other exciters and resonators. Such free order reconfiguration of these components is typical. 'Belling' the beater suggests a single action in reverse order. Networks of actions linked via serial, parallel, and variable connections such as beating-the-beater-the-bell-the-string suggest how malleable hybrid cyberactions can be.

Figure 6 shows some morphologies of hybrid cyberactions.

While replica extended cyberactions operate with quantitative expansions in temporal and energetic areas, hybrid actions imply the restructuring and partitioning of the energy flow. Such change of focus may result in a diversity of unpredictable behaviours such as feedback loops and even gradually decelerating or accelerating quasi-perpetual motions.

In *At and Across*, multiple exciters of varying kinds acting on the same place of a single bell and single beaters and bows performing on multiple instruments exemplify hybrid cyberactions. Figure 7 shows a single exciter bowing the bell at eleven different places. Each bowing-link varies slightly in its parametrical design. The four cybermicrophones scan the bell at four distinct locations, suggesting a 4-channel 'ear'.

At and Across further presents hybrid cyberactions such as bell-plucking and interaction of bells connected in a variety of serial, parallel, and enclosed networks. Figure 8 shows five bell structures connected in a serial network. The hitting exciter initiates action on the first instrument. The vibration propagates around the resonating bell and reaches its final component mass, where the energy is transferred to the neighbouring bell via a non-linear bowing-like link. Quality of component links between the individual bells varies in order to sustain the vibration of the complete network.

Figure 9 exemplifies a closed variable-connection network of bells excited by four beaters. The network

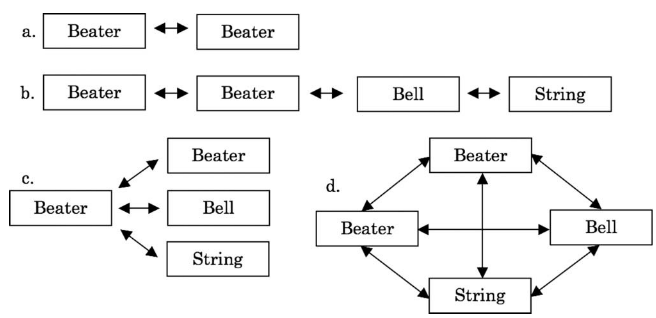

Fig. 6. Morphologies of hybrid cyberactions: (a) two-member action, multi-member actions linked via serial (b), parallel (c), and variable connections (d).

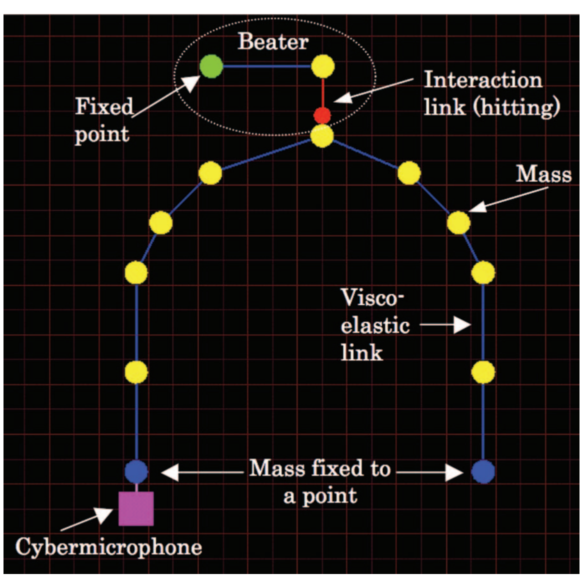

Fig. 5. A simple cyberbell structure facilitating the replica extended cyberactions.

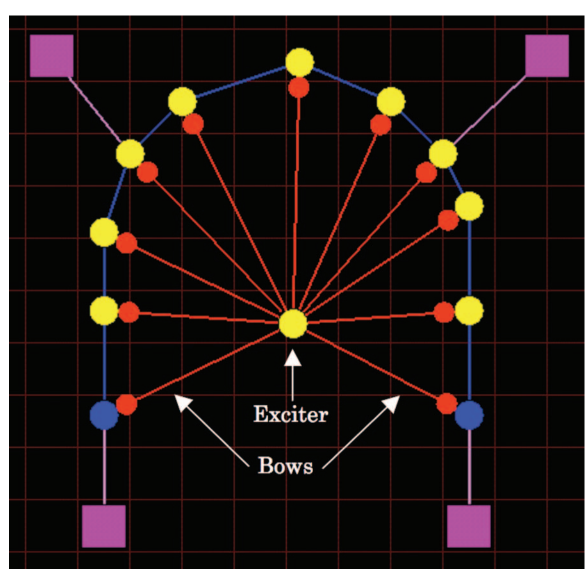

Fig. 7. Single force bowing the cyberbell at eleven spots.

shows how individual masses within individual bells can be connected to introduce disturbances to the natural bell resonating behaviour, thus producing complex timbres and rhythms. Note that directionality of flowing energy between the connected masses (marked by the point at the end of the link) varies to initiate diverse feedback paths.

3.3 Abstract cyberactions

Abstract cyberactions are the hierarchically most conceptual distillations of physical activities. Plucking the performer and using a bell to form a compositional structure (or 'belling' the composition) exemplify actions in which a potentially vibrating structure initiates and performs fundamental music-making choices. Abstract cyberactions are thus principles, ideas, and causes which formalize music creation whether that part of the creation process be composition, performance, or listening. Any possibly vibrating structure, particle, and phenomenon in its latent and active forms can be a source of action. Abstract cyberactions are supra-congruent with the physical world in the sense that they show both the world's multiplicity and its unity.

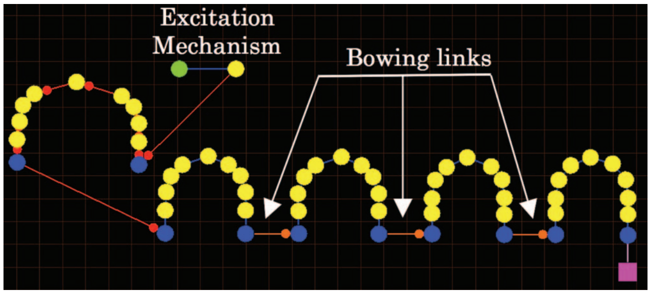

Fig. 8. A serial network of five cyberbells excited by a single beater.

The behaviour of a vibrating structure exemplifies an abstract cyberaction. The pattern propagation along the medium, with its characteristic energy dissipation, gain, and transformation, can give rise to temporal structure of a composition. Patterned force, velocity, shape, size, and other parameters may inform other compositional choices. In its totality, such action can be both composition and performance. Activating other sounding structures with the parameters of the original instrument may also enable a performance. Figure 10 exemplifies how 'belling', i.e. using a vibrating cyberbell, can foster a complex formalization of the compositional, performative and listening attributes in a music creation.

The cyberbell instrument forms the micro, mezzo, and macro levels of the composition, a classification previously proposed by Cadoz (2002, 2007). Energy and behaviour extracted from the initial bell, whether it is still or set in motion defines the overall compositional form, conducting patterns, performance behaviours, and listening-like responsiveness. The composition remains in an unexhibited state while all the bells are latent. Set in motion, the cyberbells exchange their ecological information such as vibrating patterns, forces, and velocities. Such exchange can be facilitated by a conductive pick-up similar to the

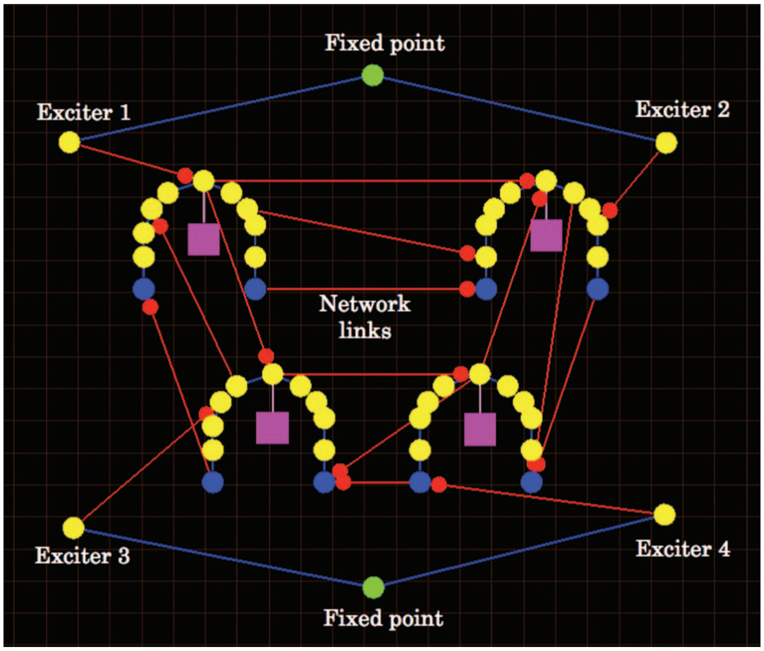

Fig. 9. An enclosed variable-connection network of four cyberbells hit by four exciters at various places.

temperature transfer between molecules, or more traditional links expressed as single actions of hitting, bowing, etc.

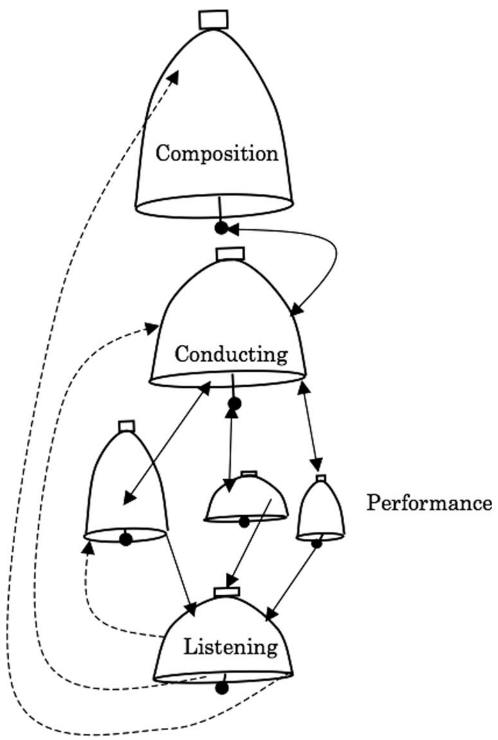

Fig. 10. Complex structurally consistent abstract cyberaction of 'belling' a music creation.

The unit Composition 'bells' another vibration structure—the Conducting unit via a deliberately placed link. The link location and type will define the possible energy transfer between the two structures. The Conducting adapts the vibrating patterns from the Composition according to its own internal order. Absorbed as such, information and energy is further transferred to a set of Performances. Listening absorbs the complex information from the Performances. The process may stop here, or the energy and information can be injected in any place in the loop.

All aspects of the action share the same sounding structure in this example. The composition, conducting, performance and listening certainly can be of the same type, state of matter (e.g. solid, fluid or gas), shape, size, and material as in the case of a structurally *consistent* action; however, they may also parametrically differ as in a case of *variable* action. The cyberaction may be initiated at any stage thus abandoning the traditional energy flow between composition, performance, and listening. For example, it may be Listening which initiates the vibration and sets the other components of the action in motion. Continuous interaction between the constituent substructures results in feedback and perhaps eventual energy dissipation.

In *At and Across*, GENESIS facilitated design of abstract cyberactions. The structure shown in Figure 11 is based on the nesting of two cyberbells. While the bell comprising the instrument's outer layer (*Composer*) is made of denser materials, the middle structure

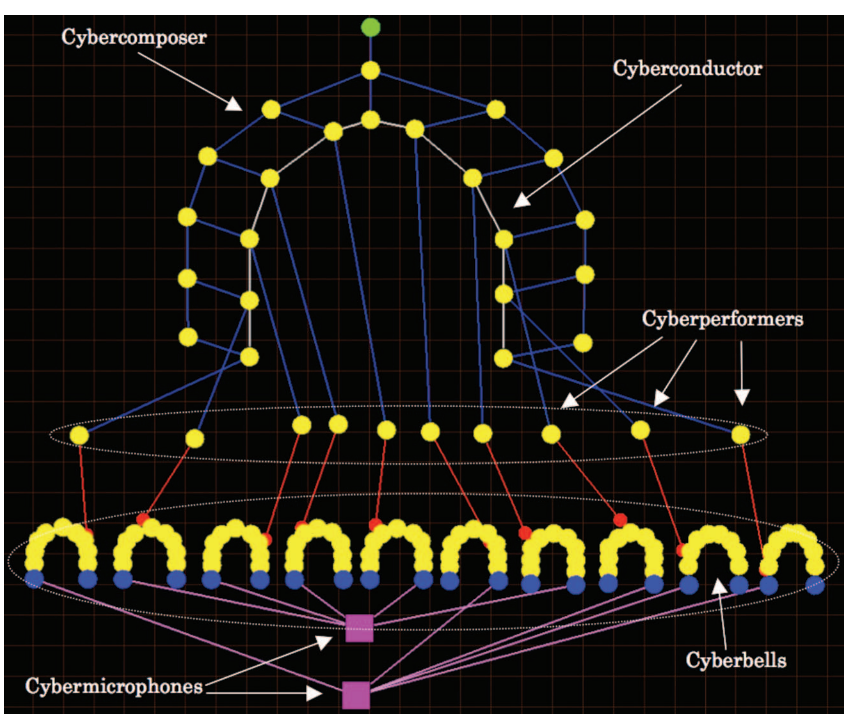

Fig. 11. Abstract cyberstructure consisting of a *Composer* and *Conductor* which movements direct eleven 'performers' to act on eleven sounding bell structures.

(*Conductor*) is created from thin springs with low stiffness. Particular stiffness and viscosity settings of the links connecting the two layers introduce feedback loop which defines the total behaviour of this abstract cyberstructure.

Conductor mechanism is further equipped with eleven arms which can excite eleven sounding cyberbells in the bottom row. Note that although the abstract cyberstructure (*Composer* and *Conductor*) is set in motion, it never sounds. Its vibrational patterns are instead delivered to the beaters which excite eleven cyberbells.

4. Conclusion

Performative actions can become tools for constructing a musical language. Driven by the subtleties of the tactile contact between the performer and an instrument, actions can be abundantly expressive and can stimulate multifaceted compositional interplay. Physical actions have inspired music making in the cyberspace in which cyberactions extend, hybridize, and abstract the principles of physical sound production mechanisms.

All cyberactions are inherently 'actual'. As Gaver pointed out about perceiving a digital sound source simulated by the physics-based approaches, 'listeners comment that they have a strong impression of an actual event causing them, rather than hearing them as synthesized' (Gaver, 1993a). As long as the event bears distinct characteristics of a certain action, the observer will not focus on distinguishing whether a physical cause or a computer generated the sound. As described in the introduction, a scratch tone facilitates recognition of the source, but we may be unaware whether a physical or synthetic instrument produced it.

Actuality in sonic cyberspace is, as in the physical world, dependent on the perception of action itself. It is perceptually unproblematic to validate the actuality of synthetic sources (and, thus, their actions) of replica type and, to some degree, the extended type as well. Hybrid and abstract cyberactions are derived from the same physical principles, however, their perceptual recognition is troublesome, as they often do not refer to any previous aural experience. Ecological perception suggests that we are unable to perceive events and phenomena beyond our limits. That is to say, our perception is limited to our temporal scale, spatial range, and hierarchical order (Gibson, 1966). Extended, hybrid, and abstract cyberactions, however, do expand beyond such boundaries and orders. Action-based music thus offers us a novel 'lens' through which we can re-view, re-hear, and re-enact music as we know it in both the physical world and cyberspace.

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