Morphological evolution of musical interface: design approach (work in progress)

S.K. Kasich
Computer Music
UC San Diego Department of Music
skasich@ucsd.edu

ABSTRACT
The recent advancements in digital fabrication have led to a wider access to prototyping in all sorts of fields. Beginning of the last decade was marked by the word “revolution” in relation to “maker’s culture” at least in some publications [3, 15]. This has influenced the sphere of physical computing in arts and NIME sphere as well. As currently there are more and more possibilities to create new instruments, we suggest that it can be useful to think about approaches to conceptualize these creations. This paper is an attempt to propose a methodology for NIME prototyping, based on evolutionary metaphor.
First we observe the application of evolutionary concepts to the field of music technology, briefly discussing its appearance in related publications. We then assemble our own operational concept, which can be used for the direct prototyping of interfaces. Mainly by introducing metaphorical “DNA”, inside which the “gene” of “interactive kinematic concept” is of a particular interest, and also by applying the now obsolete but useful “Meckel–Serres recapitulation hypothesis” (embryological parallelism) as a model for rapid prototyping.
Understanding the speculative nature of such an approach we do not offer it as a scientific basis for classification, research or prediction, but as a workable concept for development, which can lead to valuable results.
In the end we describe two case studies of NIMEs, which were prototyped in the discussed fashion, showing illustrations and reflecting on the practicalities.

Author Keywords
electronic musical instrument, musical instrument design, ergonomics, playability, methodology, human computer interface

CCS Concepts
• **Applied computing → Sound and music computing**;

1. INTRODUCTION
Imagine a kind of science, which can be focused mainly on visual and mechanical properties of musical instruments and on physical interactions with them? Shapes, colors, sizes, folding capabilities, haptics etc. Putting aside acoustic, musical and other properties. Something like a “Deaf Organology”. If it does exist, then it does so in an intersection between Ergonomics, Kinematics, Interface Design, Organology, Semiotics, Topology etc. We can use a term, taken from biology, and call it “Morphology of musical interfaces". In this paper we apply a biological metaphor even further and suggest that musical instruments perform their kind of evolution - changing their shapes in time obeying Natural Selection. This means we can try to apply other biological analogies to them, possibly related to the theory of Evolution. Thus we are talking about “Morphological Evolution of Musical Interface” as a subdivision of the aforementioned “science” - observation of changing shapes in time. If not science, then it at least can be regarded as a certain scope on the history of musical instruments. And one reason for us to have it - is that it can be useful for the practice of creation of NIMEs.
About terminology. We will be using terms “musical instrument” and “musical interface” in a lot of cases here as synonyms. We will use the term “class” sometimes when talking about analogies between animals and musical instruments classifications, without very detailed descriptions and distinctions. There might be some other terminological vagueness further in the text, but we tried to be as clear as possible.

2. Biological metaphor and technical objects
We can try to lay some basis for the use of biological terms while talking about anthropogenic objects - e.g. machines - by introducing the Actor-Network theory (ANT) and Morphology.

2.1 ANT
Actor-Network theory (ANT) - a social theory and methodology, which tends to describe all the processes as networks of relationships between so-called “actors”, and which was largely popularized by works of Bruno Latour [12]. The most interesting for us though, is the particular emphasis on the importance of “non-human actors" in these relationships [22].

2.2
2.1.1 Networks
Though the term “network” within the ANT was seen as problematic by Latour himself, it plays the most central part in the whole theory [12]. Networks in ANT are characterized by lack of hierarchy and constant process of performance and

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exchange between the actors, as well by translations happening between different networks. Being in development since the 80s - ANT was very much in line with global domestication of the idea of networks as an influential model for different types of research and development [7, 12, 27]. Network emphasizes the importance of interconnections, and questions the hierarchy between the actors.
Here are the important terms in ANT, which circulate around the network model:
- Actor (actant) - something which instigates the activity and performs the relationship within the network. Can be humans and non-humans.
- Actor-network - the interconnections between the actors.
- Quasi-object - is an entity, which organizes the network and serves as a glue or a common motivation to it.

In application to our study, we can translate it like this:

- Actors - humans (musicians in a wider sense), non-humans (musical instruments).
- Actor-network - musicking (as coined by Christopher Small) - music in the form of diverse processes.
- Quasi-object - music.

2.1.2 Non-human actor

It can be said that everything, besides humans and symbols, can be regarded as non-human actors in ANT [22]. The "technical object" - is a large topic in this field itself. It is a non-human actor, but can be represented as a sort of network as well [2]. We will not go there in this text. What is important for us, is that a musical instrument in this view can be defined as a non-human actor, which is involved in non-hierarchical relationships with human actors. And "non-humans have agency, as Latour provocatively puts it" [22]. Let's leave it here so far.

2.3 Morphology in biology and design

Morphology is commonly understood as a study of forms and academically manifested in different fields, but mostly in linguistics. We are more interested in Morphology as a discipline, related to biology, where it is believed to be a "failed science", but nevertheless very influential in historical context, established a path for such areas as: embryology, systematics, functional morphology, comparative physiology, ecology, behavior, evolutionary theory, or histology [17]. Biological morphology was simply speaking - investigation of visible features (shapes) of animals and plants, attempts to compare and classify them, etc. Both fathers of modern theory of Evolution by Natural Selection - Charles Darwin and Alfred Russel Wallace - were doing sort of morphological studies. The important feature of this understanding of the term "morphology" for us - is that it was a study of three-dimensional shapes of non-humans.
The practical field, which is constantly concerned with study of 3d-forms - is design. We can talk about morphology of technical objects (which are designed), the same way, we used to talk about animals and plants [1]. For the same reason - to compare and classify them. But also - to design new ones.

2.4 Evolutionary metaphor

Besides being the most influential theoretical concept in modern biology - Evolution by Natural Selection is also a widely used explanatory model for different processes in frames of other sciences. For example Evolutionary Economics, Evolutionary Psychology, Evolutionary Epistemology, Evolutionary Computation, Molecular Darwinism, etc. All of which are currently stored under the umbrella of so-called "Universal Darwinism". The successful practical application of at least some of these fields can probably prove the explanatory power of what we can call "evolutionary metaphor".
"Morphological evolution" - can be understood as the evolution of shapes, and is currently discussed in both biology and robotics design among other fields [1, 11].

3. Musical instrument as a non-human actor

As stated earlier, in frames of ANT, agency is granted to non-human actants [22].
Presumably even before ANT, there were other examples of putting agency onto some non-human entities, which previously were not supposed to have it. Famous one and related to our exploration - is Richard Dawkins's "Selfish Gene" [6]. The book shows evolution as a process, in which genes keep their shapes, by using living beings as tools (or we can say transportation). Basically it gives agency to gene (a relatively small assemblage of molecules). The name of the book itself is a name of a molecular assemblage ("gene") prepended with a motivational-emotional attribute, previously used for humans only ("selfish").
We won't go so far, to assume that musical instruments may have emotions and motivations (although it may happen they will soon), but at least we can grant them enough agency to have their own evolution. And from this point of view - the change of shapes, which happens in this evolution - is a result of many conditions (relationships within the networks in ANT terms), of which human will is only one of.

4. Evolution of music instruments

The evolutionary metaphor applied to historical music technology development is met in publications on the subject. Usually though it is never augmented with the methodological steps, which we provided in sections 1, 2 and 3 of this paper.

One example is in Michael Spitzer's "The Musical Human": "Musical instruments evolve. They rise and thrive, or fall into extinction like dinosaurs" [23, p.143]. And after that phrase the author provides some detailed examples, also comparing biological taxonomies to Hornbostel-Sachs classification.

Another one is in Thor Magnusson's "Sonic Writing", where he talks about "..the evolutionary mechanics of design" of musical instruments [14, p.10]. And later: "From one perspective the move of musical practice to use electronic and digital technologies might seem like a drastic rupture, while from another it appears to be a natural evolution" [14, p.13].

Magnusson's work is particularly interesting for us, because he is concerned with the question of memory, which is embodied in the design of musical instruments. We will touch on it later, but another useful observation from this source - is what the author calls "Epochs or Epistemes". They can be "roughly defined as the instrumental paradigms of the nineteenth, twentieth, and twenty-first centuries, here framed as representations of practices with acoustic, electronic, and digital technologies" [14, p.6].

The Epistemes can be considered as an example of stages of the Evolution:

Acoustic to Electronic to Digital.

5. Morphology, kinematics and ergonomics

Music instruments have shapes. So we can apply Morphology to them. But they are also tools to be used - to interact with. The interaction in most cases happens through physical movements of human (or non-human) actors. Those movements are partly restricted, and partly identified by the shape of the instrument. Kinematics is the subdivision of mechanics, which studies motion of points, bodies and systems of bodies [24, 26]. In application to musical interfaces Kinematics can be used to study movements of the player, or motion of the mechanical parts of the instrument, in case it has ones [4]. Kinematic calculations can be used to research and improve Ergonomics of musical interfaces. And Ergonomics - is an interdisciplinary field and a term, which describes the relation between design of the object and comfort of human operation with it. Ergonomics of musical interfaces is an active research field, especially in NIMEs [9, 16, 25].

We can see the term “morphology” being used in the NIME field sometimes as part of the language of “dynamic or fixed morphology” of sound, taken from works by Trevor Wishart and others [18, 19, 20]. That sound morphology is in constant connection with the design of the interfaces intended for live performance. But as mentioned above - in the context of this paper we use the term “morphology” directly applied to the physical shapes of the instruments.

As morphology of musical interfaces evolves - so does kinematics of interactions with them, so does their ergonomics.

6. Ergodynamics and DNA: the memory question

At some point one class evolves into another one. Lyre becomes harp, harp becomes piano [23]. So not only the shape changes, but also the name. The instrument starts to be differently classified. What is the significant feature which is crucial for the new class to form distinctively from the previous one? If we continue to reflect the evolutionary paradigm, we can say that the drastic change in DNA leads to change in shape, and all of it is determined by some change in the environment. That’s where we need to find the analogy to “DNA” in our construct.

We suggest that in order to keep the name of the class (keep being a version of itself) in the process of this evolution, the instrument has to keep it’s “DNA”. So if we look into the attributes, which stay intact, when the shape evolves - we will identify it.

Lyre evolves into piano, when keys are added. When does the piano stop being a piano?

When it loses keys. Not when it loses the strings inside, because digital piano is still called “Piano”, while technically being an electronic synthesizer with keyboard control.

Guitar probably stops being guitar when it loses its neck. Not strings again, because you could find digital stringless “guitars”. E.g. Yamaha EZ-EG, MI Guitar by Magic Instruments, Z6 by Starr Labs, etc..

Guitar example is particularly helpful, because everyone is aware of the “existence” of the Air Guitar. This type of guitar is so popular that it has its own festivals and awards. And it still keeps the name of the class - guitar. It also can serve to us as the very clear marker of the “DNA”. Until you can perform with it as with guitar - it is a guitar. In other words - as long as the ergonomics of its shape provokes the kinematics associated with the class - we will tend to classify it equal to other members of the class.

We can call it the "interactive kinematic concept". It describes main interactive attributes, which are manifested in the design of the main elements of control.

The “i.k.c.” is an ergographic agent or the carrier for ergogenetic memory in terms, which Thor Magnusson uses in his book [14]. He particularly talks about Ergodynamics - as a name for the experience from the actions with the musical interface, which is related to “Ergogenetic Memory” - as “incorporated memory on how to use the object”. Ergodynamics is also related to “Ergographic analysis” - as a potential way to focus on the evolution of the object, but not the static form of it.

“Ergodynamics is for music technologies (and perhaps any interface) what the concept of “gameplay” is for game developers..” [14, p.11].

In short “i.k.c.” - describes what kind of kinematics are learned to play the instruments called by certain names. The difference between movements of fingers of a pianist playing piano and a clarinetist playing clarinet - is the difference between “i.k.c.”.

It is a good time to remind, that we are doing generalizations here, and totally aware of instruments like “steel guitar” or “keyboard gusli” (Clavichord Gusli), which can be left for now as a peculiar mutations.

We can suggest that “i.k.c.” in most cases is crucial for the instrument to sustain it’s name and attribution to class in the process of evolution of shape. It is the way the interface keeps memory about itself.

But “DNA” in most cases is probably wider. It may consist of different units (genes), but mainly: expected timbres, functional purpose of the instrument, etc. The “interactive kinematic concept” (“i.k.c.”) might be just part of it.

7. Recapitulation

Recapitulation (Meckel–Serres law) - was an influential evolutionary hypothesis, which is currently considered debunct. It can be summarized in its founder Ernst Haeckel's phrase "ontogeny recapitulates phylogeny" [8].

Besides the literary formulation of this theory was refuted with time, some elements of its logic were adapted in modern biology”[13].

If we can say that music instruments have phylogenesis (historical evolution) and they certainly have ontogenesis (each of them gets produced and degrades individually), - then we can speculate further and try to apply recapitulation analogy onto our object.

We suggest taking it as a model to approach the design of musical interface. In other words: ontogenesis of the instrument can follow the phylogenesis. This is especially useful, if we would like to develop a new class of instruments.

Following Richard Dawkins’s reflections on genes having agency and being non-human actors, we can start the design process with assembling the “DNA”, and then follow some evolutionary stages of prototyping [6].

For example, Magnusson’s epistemes:

- Acoustic - Electronic - Digital

Another example of phylogenetic stages can be - eras of production of electronic synthesizers. They started historically as kludge assemblage from existing objects, used for other purposes - like oscillators from physics labs at WDR. They evolved into schematics built individually from scratch or with

use of pre-assembled parts by individuals. And they further evolved into repeatable industrial designs.

- Kludge - D.i.y. - Industrial production

Perhaps the stages can be combined, and other stages can be observed in the historical evolution of music interfaces.

This can be the outline for this recapitulative design method:

1) create the DNA - a description, which would include: "i.k.c.", expected timbres, functional purpose of the instrument, and maybe something else.
2) take or imagine some evolutionary stages.
3) prototype through those stages.

8. Design case study N1 : Dlld

Dlld (a.k.a. "dillidee" with all letters doubled) - one-hand-held expressive electro-acoustic instrument.

1) "DNA": solo instrument to be played with one hand, can be used to accompany singing, can have diatonic or chromatic scales

2) "i.k.c.": one hand operation, maximum expressivity with limited controls, using second hand optionally to manipulate the acoustic features of sound propagation, shaking of the hand creates natural vibrato acoustically (but not via digital sensing)

3) Stages of ontogenesis: (based on Epistemes example)
– Acoustic stage - assembled using repurposed existing objects (see Figure 1)

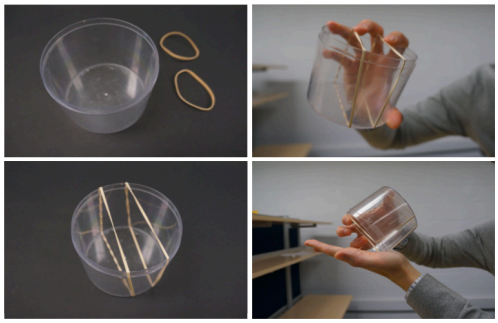

Figure 1

– Electronic stage - combining pre-assembled parts of electric and acoustic nature (see Figure 2)

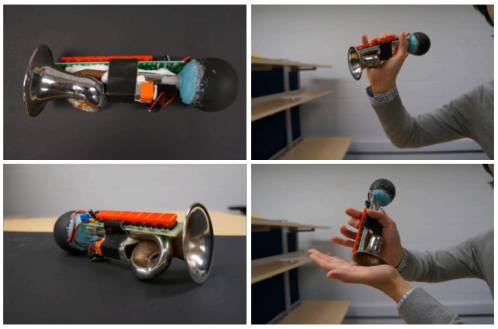

Figure 2

– Digital stage - using DSP board and DAC programming with plaster corpus (see Figure 3)

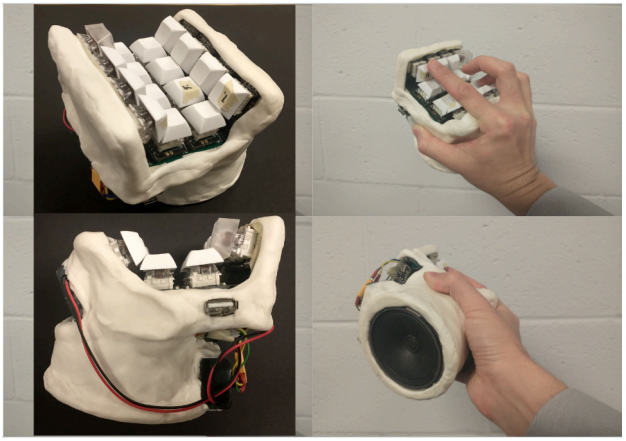

Figure 3

9. Design case study N2 : FrR

FrR (a.k.a. "fingerring" with double "R") - simple and cheap interface for live performance with spatial sound.

1) "DNA": simple intuitive control for multichannel sound, using two hands, timbre independant, as cheap and affordable as possible, not necessarily has tempered scales

2) "i.k.c.": two hand operation, take sounds with one hand, direct them in space with the second hand, using the control panel which can be isomorphic to the positioning of acoustic outputs in the space.

3) Stages of ontogenesis: (based on "Synthesizer" example)

- Kludge stage - basic electronic assembly using found objects - not specifically designed for the interface (see Figure 4)

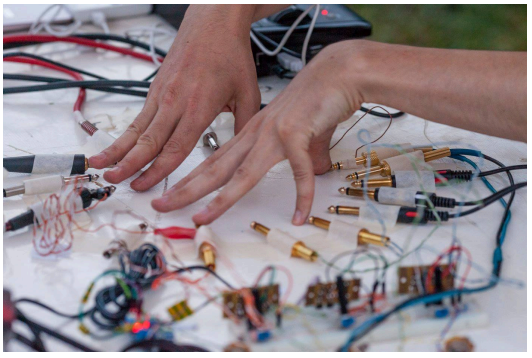

Figure 4

- D.i.y. stage - basic self-made design, using all sorts of available maker sources and tinkerings (see Figure 5)

Figure 5

- Industrial production - (see Figure 6)

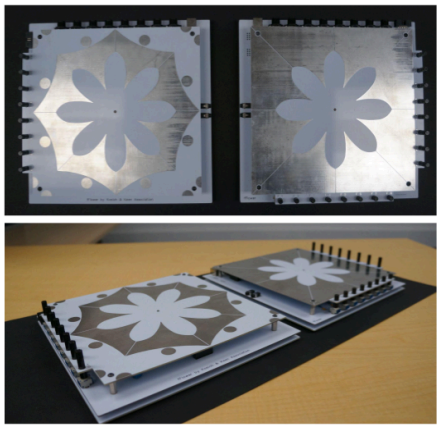

Figure 6

And why won't we add a stage from another phylogeny ?
- Digital version based on touchscreens (in concept) (see Fig.7)

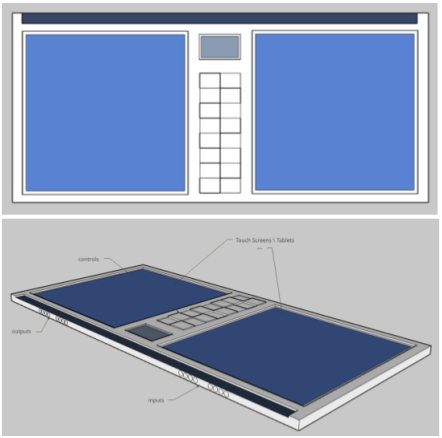

Figure 7

10. Conclusion

Morphological Evolution of Musical Interface - is not a science (yet). But as we showed in this paper - it is a perspective, which can be helpful in structuring the design, and maybe provoking some curious questions for further hypothesis and explorations.

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