A discussion of multidimensional mapping in Nymophone2

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Abstract

The paper presents *Nymophone2*, an acoustic instrument with a complex relationship between performance actions and emergent sound. A method for describing the multidimensional control actions needed to play the instrument is presented and discussed.

1. Introduction

Nymophone2 is a semi-acoustic string instrument with four strings (see Figure 1). The strings are attached to both sides of a *stressed*, flexible metal plate. A stressed plate means that the strings are tightened to keep the plate in a curved shape, while its natural equilibrium shape would be flat. The plate-string-system is attached to a wooden frame, and the instrument is augmented with a simple electromagnetic system for picking up vibrations from the strings and the plate.

The paper starts by discussing some theoretical considerations on mapping between action and sound, before presenting the physical construction, the sound, and the control actions of Nymophone2. For a more thorough discussion of Nymophone2, please refer to [1].

2. Terminology

Before describing the interaction between the performer and Nymophone2, we will start by looking at the relationships between a performer's actions, mappings in the instrument, and the resultant sound.

2.1. Taxonomies of sound and instrument control

When we are discussing sound from the perspective of interaction with a musical instrument, sound is primarily a perceptual (rather than an acoustical) phenomenon. Hence, in this context one should strive to use terms based on the perceptual (rather than the physical) properties of sound [2]. Pierre Schaeffer's [3] theory on the *sonic object* is a good starting point for describing the perceptual properties of sounds. In his theory, the perceived excitation type, and what he calls *tonal mass* (i.e. pitch stability), are used to describe and classify a sonic object. These descriptors, in addition to a sonic object's *pitch*, *loudness* and *timbre*, is what we will refer to as *sound parameters*.

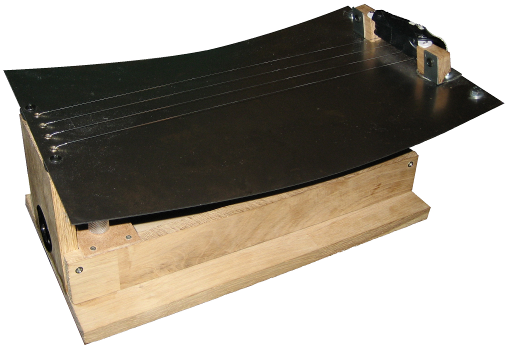

Figure 1: Nymophone2.

Rolf Inge Godøy has introduced the term *gestural-sonic object* to point out that perception is linked to mental imagery of body movement [4]. In other words; the causal coherence of the sonic object presents the perceiver with an idea of the action that produced the sound. Following this idea, it is possible to extend Schaeffer's idea of *reduced listening* [3] to *reduced observation*. Just in the same way as reduced listening allows for studying lower-level features of the sonic object without its everyday connotations, we can study gestural-sonic objects through reduced observation of what we shall call *control parameters*.

The term *control action* denotes an action performed by a musician with the intention of creating or modifying musical sound. Hunt et al. [5] uses the term *control parameters* to denote output data from a musical input device. This is useful in the specific context of musical input devices, but in a more general case, perhaps the term could be applied to all control actions, denoting *features of control actions*, and thus provide a repertoire for describing playing technique.

We prefer to make a distinction between the control action as a *unidimensional* or *multidimensional* object. A multidimensional object has several aspects that are relevant in a certain context. In the context of playing a musical instrument, a control parameter is relevant if it affects the instrument sound. The control action "pressing sustain pedal" on a piano serves as a good example of relevant and irrelevant control parameters. This action can be measured in the relevant dimension of "pedal down"/"pedal up", but a control

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parameter like "how much of the foot touches the pedal" does not affect the sound, and is irrelevant from a technical perspective. Thus this control action is unidimensional.

2.2. Mapping

As this paper discusses an acoustic musical instrument, the term *mapping* is used to passively describe the existing relation between control parameters and sound parameters. This is opposed to construction of mappings in digital musical instruments, where the term usually refers to how the instrument constructor actively chooses to use a certain set of input parameters to make sound. In our sense of the word, the different mappings between control parameters and sound parameters provide an interesting way to compare and classify musical instruments [2].

In most musical instruments, several control actions can be performed to affect a single sound parameter, and each control action may affect several features of the sound. This is what is usually referred to as a *many-to-many mapping*, displayed in Figure 2.

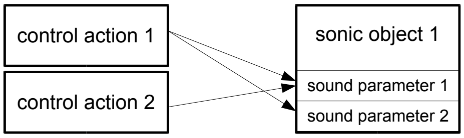

Figure 2: Simple many-to-many mapping between two control actions and one sonic object.

By including a *parameter level* when describing the mapping between control actions and sound, we believe that the description of the mapping will be more detailed and more precise. The separate features of a control action may adjust fine nuances in the sound or have a radical affect on the instrument sound. In most cases, all of these features will be relevant, and thus most control actions in music are multidimensional. For instance, the control action of hitting a drum membrane is multidimensional because it can be measured in terms of the hitting position, the hitting force, the type of mallet used, etc.

A multidimensional control action may have several control parameters that all affect the same sound parameter. This is another type of mapping where there may exist a many-to-many relationship between the parameters of two objects, and can be referred to as *multidimensional mapping*. For example, when using a finger on the left hand to shorten the vibrating length of a guitar string, both the position (fret) and the applied force will affect the pitch. Figure 3 shows the simplest form of a multidimensional mapping, where two parameters of a control action affect a single sound parameter, and one control parameter affects two sound parameters. Note that this multidimensional mapping would often be called a one-to-one mapping on a higher perceptual level (directly from action to sound), but from a parameter level it is clearly a many-to-many mapping.

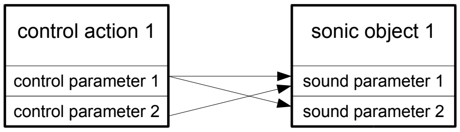

Figure 3: Simple multidimensional mapping between one control action and one sonic object.

Because there may exist multidimensional relationships in the mapping from control action to sound, it is necessary to look at the mapping from action to sound at the parameter level to compare the mappings of different musical instruments. For an even more precise description of the mappings, the parameter mappings should be described in more detail by determining their *range* and *resolution*, i.e. to what extent and with what accuracy a control parameter can influence a sound parameter [2].

3. Nymophone2

Nymophone2 was built with experience from Nymophone1 made in 2006. Both instruments are semi-acoustic, based on amplifying the vibrations of vibrating elements using electromagnetic pickups.

3.1. Physical Construction

Nymophone2 consists of 4 steel strings attached to a metal plate. The steel plate on which the strings are attached is 400 mm long 250 mm broad and 1 mm thick. In one end of the plate there are four holes, approximately 2 cm apart, where the strings are fixed. In the other end, four tuning pegs are mounted on a steel/PVC base. A small piece of plastic (a combination of PVC and polyethylene) works as a nut with indents for keeping the strings in place.

The plate-string-system is mounted on top of a wooden base, resting on the wood in each end, and vibrating freely in between (see Figure 4). In one end the plate is attached with screws, and in the end where the tuning system is located the plate is resting on the base without being physically attached to it. Between the plate and the wood there are small pieces of hard rubber.

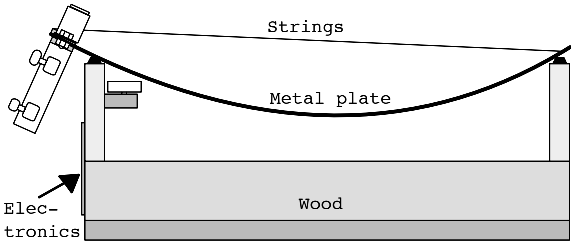

Figure 4: Side-view sketch of Nymophone2.

The Nymophone2 electronics are similar to that of an ordinary electric guitar. It consists of two home-made elec-

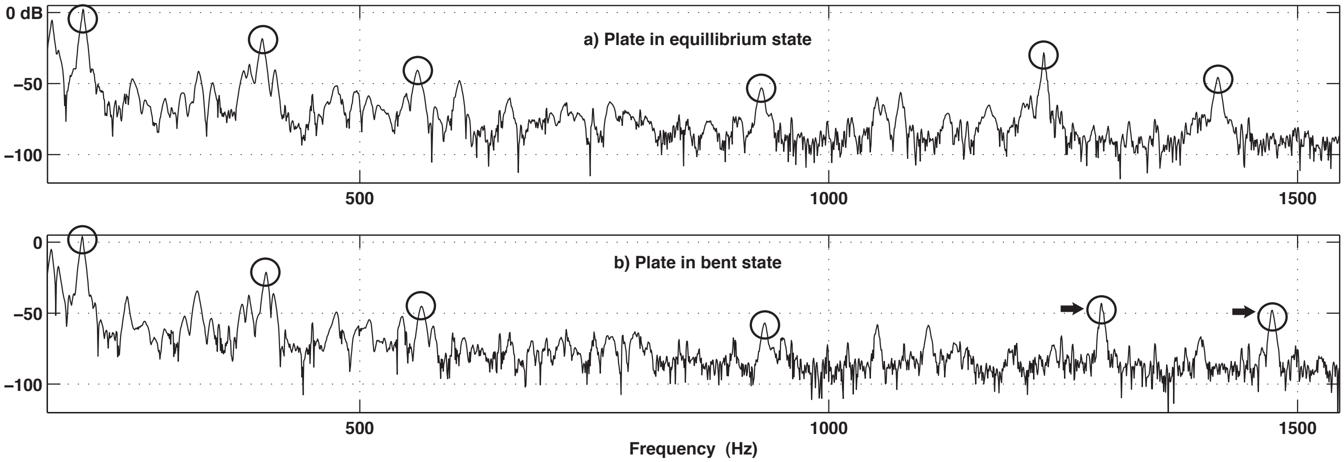

Figure 5: Two spectra showing the differences in plate resonances in equilibrium state (top), and when it is lightly bent in one dimension (bottom). The attack-part of the sound is not included in the spectra.

tromagnetic pickups, a simple capacitor/resistor-based lowpass filter, two volume knobs, and a jack cable output for connecting the instrument to a guitar amplifier. One of the pickups has four magnets matching the distance between the strings. This pickup is placed above the strings in the end where the tuning mechanism is placed. The other pickup has a single magnet, and is placed underneath the plate to pick up the alternations in magnetic flux due to the plate vibrations. The volume of the two pickups may be controlled individually with the two volume knobs.

3.2. Instrument sound

The four strings are tuned to an open A major 7 chord (A, C#, E, G#), with fundamental frequencies of approximately 220 Hz, 277 Hz, 330 Hz and 415 Hz. When the instrument is tuned like this, and the plate-string-system is in its equilibrium state, 12 prominent resonances of the metal plate are found between approximately 100 Hz and 4500 Hz. The spectrum of the sound from hitting the plate lightly with a semi-soft mallet is displayed in Figure 5a.

When external force is applied to pull the strings, causing the plate to bend more, the resonances are altered. Figure 5b shows the most prominent plate resonances when the plate is bent in one dimension (along the strings). Notice how the two resonance frequencies between 1200 Hz and 1500 Hz are affected by this control action.

Because the strings are attached directly to the plate, the vibrating elements of Nymophone2 are all connected. This means that exciting one of the elements will make all of the other elements function as resonators, and thus shape the sound. Both the strings and the plate work as resonators and as primary vibrating elements, by plucking, bowing, or hitting either one of the strings or the plate.

It is possible to get an idea of the interplay between the strings and the plate by looking at the spectrogram (Figure 6) of a guitar slide used to play a glissando on all the strings simultaneously. The plot shows how each time a component of the sound from one of the strings passes a plate resonance, the plate starts vibrating at this frequency.

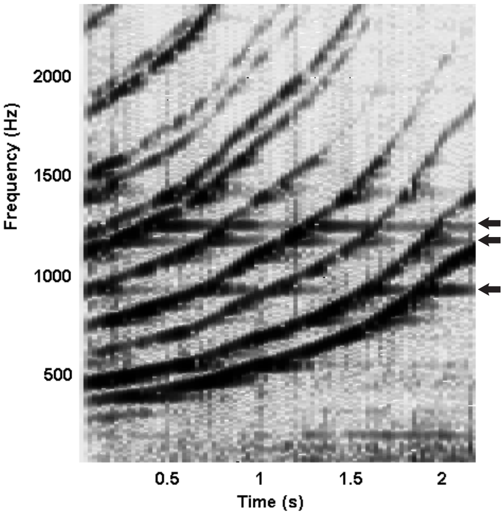

Figure 6: Spectrogram of the plate response when the four strings are excited and adjusted upwards in pitch by using a guitar slide. Note how the plate resonates when one of the string partials matches one of its resonance frequencies. The three most prominent resonances are marked with arrows.

3.3. Instrument control

The performer may play Nymophone2 by plucking, bowing or hitting either the strings or the plate. The pitch of the vibrating strings and the frequency of the modes of the vibrating plate may be adjusted by alternating the tension of the vibrating elements. The tension of each of the strings and the tension of the plate are mutually dependent on each other, and thus any control action performed on a single element will affect the other elements as well. The pitch of the vibrating strings may also be adjusted by using a slide object for shortening the vibrating part of the string.

Let us look at the complexity of the control parameters and sound parameters related to the control action "plucking string" (summarized in Table 1). This action, which would often be regarded primarily as a sound-producing action, is in itself more complex than just being sound-producing. First, the choice of plucking one or several strings, and which string(s) to pluck influences the *sound execution type* (*impulsive* for one string and *iterative* for several strings), as well as the pitch and timbre of the sound. For a string plucked with a large force, the pitch will decrease while the sound decays. Thus plucking force will affect tonal mass, pitch, timbre and loudness. Choice of plucking medium will affect timbre and loudness, and the plucking position will affect timbre.

Table 1: Parameter mapping for "plucking string"

	Plucking position	Plucking strength	Plucking medium	Choice of string(s)
Timbre	●	●	●	●
Loudness		●	●	
Pitch		●		●
Tonal mass		●		
Execution type				●

If we consider the control actions "bending the plate", "shortening the vibrating parts of the strings", and "pulling any of the strings", the mapping between control action and sound becomes quite complex. Even though each of these control actions has less parameters than the action "plucking a string", they are all interleaved. This type of complexity can be shown in an example where a guitar slide is used to pull down the string which is currently being played (Figure 7). Here the slide touches the string, and thus shortens the vibrating part of the string, which again causes the pitch to rise. The tension of the string is increased when the string is pulled, and so the pitch goes further up. Pulling the string also causes the plate to bend, and the tension of the other strings will decrease. This lowers the resonance frequency of the other strings and alters the plate resonances as discussed in Section 3.2.

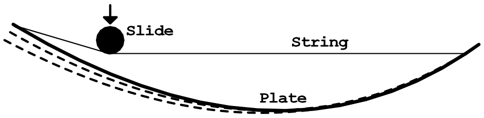

Figure 7: Illustration of pulling string with slide object.

3.4. Classification of Nymophone2

In Hornbostel and Sachs' system [6] for classification of musical instruments, Nymophone2 would be classified among both chordophones and idiophones, since both the plate and the strings are its primary vibrating materials. Within these categories, the steel guitar and the musical saw are perhaps its closest relatives. However, by classifying the instrument after its playing technique, Nymophone2 could rather be compared to pitched membranophones or other instruments where both timbre and pitch may be controlled individually by performing a single control action.

4. Final Words

The paper has presented Nymophone2, and discussed some considerations on the complexity of mapping between, and classification of, control actions and musical sound in the instrument. The diversity and complexity in control actions for Nymophone2 presents the musician with a great repertoire of musical expressions, but also with a great challenge when it comes to mastering the instrument.

As we have seen in the development of a taxonomy for Nymophone2, there is a need for a detailed way of describing the relationship between control actions and sound features in musical instruments. A study of lower-level features of control actions seem to be profitable to achieve this. Better knowledge about mappings in acoustic musical instruments may also be beneficial when constructing new digital musical instruments. Properly defined control parameters will most likely help instrument constructors when selecting the technology and design for digital musical instruments. Hopefully this can lead to the creation of new digital instruments that are both intuitive to play, while opening for more complex interaction.

5. Acknowledgments

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