Recent work around Modalys and Modal Synthesis

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Abstract

The originality and flexibility of the physical modelling synthesizer Modalys is being continously validated by an ever-growing community of users made up of composers, acousticians and musicologists alike. In this paper we will present the main lines that have oriented recent research around Modalys. These can be summarized: (1) Exploration and tentative classification of the musical possibilities of Modalys. (2) Use of modal synthesis as a meeting point between signal synthesis and physical modelling synthesis. (3) Port of Modalys to a real-time platform.

1 Background

1.1 How Modalys works

Recent work around Modalys has been developed on the hypothesis that sound synthesis design can be considered a fundamental element of musical composition [1]. The operation principle of Modalys is physical modelling by modal synthesis [2] which consists of solving the vibratory equations of the involved physical structures on a modal coordinate basis. A mode of vibration is an eigenvalue (frequency and loss) and an eigenvector (modeshape) of the characteristic equation of a physical system. The user interface of Modalys is a set of primitives extending the Scheme language[3]. The principal data structures handled by the program are: objects (physical structures), connections (interactions between objects), and controllers (time-varying parameters). Two consecutive phases are necessary to synthesize a sound with Modalys: (a) Instrument constuction – instantiating objects and assembling them together via connections, (b) Instrument execution – sending controller information to connections to make the instrument vibrate.

Modalys offers a way to operate on sound which is substantially different from signal sound synthesis methods. The user simultaneously plays the role of luthier, composer and interpreter. It can be argued that these roles exist implicitly in signal synthesis methods, but the fact that in Modalys each role must be clearly defined, implies a new relationship between the composer and the sound material. Furthermore, the complexity that each of the two synthesis phases can have, with the many different levels of abstraction that manifest themselves at the time of sound design, can lead to a situation in which the richness of possibilities may confuse and overwhelm instead exciting the imagination. A tentative definition of a framework which would contain a set of suggestions for musical applications of Modalys, with each suggestion being described with its motivations potential problems, would be more than useful, indeed indispensable. Before proceeding, it is important to remember the particularities of Modalys.

1.2 The issue of synthesis control

Although the first examples of sound synthesis by physical modelling were realized 25 years ago – almost simultaneously with the first experiments of digital FM synthesis! – and some of the equations describing vibratory movement of musical instruments date from many decades, we ascertain that today, physical modelling synthesis is far from being exploted to its full potential and that a substantial reference repertory of compositions using these techniques does not yet exist. The lack of use of physical modelling is explained not only by the heavy algorithms that implement the vibratory equations and the practical difficulty to control them, but also by the fact that, even if progress in hardware technologies has brought high-quality commercial physical modelling synthesizers, market reasons constrain them to be more oriented toward reproducing existing acoustical instruments rather than providing open environments where imaginative instruments can be conceived.

Nevertheless, when compared with signal synthesis techniques, physical modelling offers two precious advantages that cannot be underestimated : (1) causality, or the possibility that human perception associates the synthesized sound with *some* kind of vibrating structure, and (2) expressivity, or the possibility that the control mechanism of the synthesis technique is directly related to the gestural information contained in the sound. In addition, modal synthesis offers the particular advantage of modularity: as the modal representation of physical structures is uniform (a modeshape matrix, a vector of modal frequencies, and a vector of modal losses), the user can indifferently assemble sub-structures and connections to build any imagined instrument. Yet the posibility of building an arbitrary instrument raises inmediately the problem of controlling the synthesis parameters: even if the instrument's construction phase may seem straightforward and intuitive, of the execution phase (finding good values to send to the input parameters of the connections) can often be complex and laborious.

As formal training in sound synthesis has always essentially consisted of the study of signal synthesis techniques, in which spectral operations have a dominant status, composers may at first glance find physical modelling synthesis as a rupture with tradition. Fortunately, modal representation of a physical structure is directly related to the spectral content of the sound produced [4,1]; the user has to benefit the most from this advantageous situation. A principal focus of our research has been the use of Modalys as a place where signal and physical modelling synthesis techniques converge.

2 Composing with Modalys: experiences and suggestions

Now that we understand the particularities of the synthesizer, we can concretize ideas and propose a framework for musical applications of Modalys to the user. We present five possibilities for musical applications of Modalys; note that these are non-exclusive and may therefore be used in conjunction with one another.

(i) Variations on an object. Transforming some physical parameter of an object or changing the way to interact with it may create a family of sounds sharing properties. A beautiful example is the rectangular plate, where slight modifications of its length, width or thickness may result in timbral changes regarding the degree of inharmonicity. Changing the type of interaction will result in even richer genres of sound.

(ii) Virtual lutherie. We distinguish two different approaches to virtual instrument construction: (iia) "Real". This approach encompasses instruments which can be built in Modalys and, at the same time, physically plausible. One could consider this as "computer assisted lutherie". A concrete example in recent work with Modalys is a simulation of the harmonisation of a circular membrane with a disk of masses, to achieve an indian tabla [5]. Changing the mass distribution function around the disk will lead to different kinds of tabla. (iib) "Unreal". This approach encompasses instruments which can be imagined, but cannot be physically buildable. Suppose, for instance, a string piercing through a membrane at a contact point which varies in time [6], or, more interesting, a "recursive bowed string" in which the incoming pressure is function of the current string vibration.

Imaginative users following this direction can fall in the temptation of implementing exotic topological and physical configurations, which are not really recommended. Playing these instruments can be a very difficult task, and the user could easily forget that the purpose of using Modalys in composition should be to stimulate creativity, not to find solutions to artificial problems. It is important to have in mind that a simple string with a bow is already a rich and expressive instrument which takes time and effort to master.

(iii) Simulation of instrumental gesture. The former discussion and the bowed string example serve to introduce another type of utilisation which can be fruitful and efficient only when used with a clear compositional purpose. It is very tempting to try to reproduce exactly a Stradivarius violin with a Perlman-like playing. If we compare the time spent by generations of luthiers to achieve good instrument quality and the years of professional training for performers, with the number of weeks that the realization of the electronic part of a piece takes, we can conclude that this approach can be as metaphorical as erroneous. After all, reproduction of instruments and players is an invaluable tool to get insight into the structure of sound and musical gesture. But, when compositional issues are concerned, care must be taken not to spend too much time on simulation.

(iv) Complement to natural instruments. As we do not want to compete with performers, a logical way to use Modalys is thus to extend acoustical instruments with sounds which could be difficult or impossible to produce otherwise. The success of the result depends on how close the acoustical and the virtual instrument are, the ideal being that our sense of perception does not feel any rupture between the synthetic and the acoustic sounds. As an example, we have obtained satisfactory results with multiphonics, as even skilled performers have difficulty in producing this kind of sounds, and the Modalys simple-reed interaction coupled with tubes can produce a rich range of multiphonics.

(v) Convergence of signal and physical modelling synthesis techniques. As we explain in the next section, new categories of sound can be created by mixing the causality and expresivity of physical models with the precise spectral control of signal synthesis.

From these five possibilities we have experienced that Modalys can be a powerful tool for creating sound specially when the virtual instruments fill three conditions: originality of the timbre, flexibility of the control, and life-like quality of the sound. We have discovered that 3-structure instruments, such as bow-string-membrane or reed-tube-plate, work particularly well because the qualities of the two resonating structures can finely melt to produce an ambiguous timbre that shares the perceptual properties of both structures, but that has, at the same time, an individuality of its own. The same observation can be made about physical structures whose modes have been altered with the data of another structure. Flexible instrumental control is indispensable to allow the user to develop a "feeling" for the instrument; this is one of the motivations for a real-time implementation of Modalys.

It is worthy to mention a repeated experience we have had with professional musicians: when they hear an interesting Modalys sound without knowing that the sound is synthetic, the reaction is always to associate it with some "contemporary" perform technique on this or that acoustic instrument, without initially thinking that the source of the sound is a completely virtual instrument. This kind of experience would be a good test to validate the degree of musical interest that the Modalys instrument may have.These conclusions arise mainly from the attempt to use Modalys in musical production. Today we count at least four pieces using Modalys as the principal synthesizer [7].

3 "Signalic" physics and "physical" signals

Recents extensions of Modalys make static or dynamic changes of frequency, loss and modeshape scaling possible. As it is very difficult to predict how modifications of a modal parameter will be reflected by changes in the physical data of the structure and vice-versa, it might seem contradictory to instantiate a structure from its physical properties for later changing its modal properties. However, practical compositional reasons exist to justify our approach [1]. Smooth changes often keep the complexity of control within tolerable limits (bow pressure and velocity may need to be adapted permanently to a string whose modal data rapidly varies). Another synthesis control problem is raised when dealing with the "modeshape amplitude", which may refer either to the global amplitude, or the amplitude at the contact or excitation points. This is the motivation for the introduction of the "single-point" object in Modalys.

"Single-point" objects are physical structures discretized with one point described solely by its modal characteristics. Thus, for one point, the "modeshape amplitude" corresponds to the amplitude of the spectral component defined by the mode frequency. For the case of one mode, the associated physical structure is the classical mass-spring system, and, for this simple case, the modal properties could be reversed to find the physical properties. For the case of several modes, we could see the single-point as a "modal compilation" of some physical system whose physical properties' information may be impossible to extract from the modal data.

The fundamental difference between signal methods and a physical modelling approach to sound is that the latter takes interactions and spatial properties into account. From the signal point of view, sound is a mere function of time (or a set of functions if several channels are taken into account), representing a measured air pressure, whereas for physical modelling, sound, represented by the instantaneous vibration of one or several points of a physical structure, depends on at least three variables: time, the excitation force (a function of time), and the structure's impedance (which can also be a function of time). The conceptual complication of physical modelling, comes from the fact that if the source of excitation is an interaction, the injected force will be function of the instantaneous vibration. The inherent causal properties of physical models are a consequence of this feedback relationship between the excitation and the vibration.

The musical interest of single-points comes from the fact that a time signal could be represented with spectral information and latter "converted" into a Modalys object via a single-point. Thus, we can indiferently see signals as physical points vibrating in space and, also, vibrating objects as signals with spectral content. Conceptually, this could be seen as *contextualizing* a sound with the relation of causality (suppose for instance a hammer striking a vowel, or a bowed trumpet). New classes of sounds that share the properties of both signal models (precise spectral content) and physical models (causality, expresivity) are thus obtained. The price to pay for this benefit is a higher complexity of control for the instrument.

4 Other axes of interest

A subset of Modalys has ben ported to the FTS real-time environment [8,9] and runs on a Sillicon Graphics with an R4000 processor. Real-time control is important in Modalys to prototype sounds in a simple way and to make direct and live instrumental control possible. Also, "Modalyser", a graphical interface suitable for non-programmers has been written in Macintosh Common Lisp by Richard Polfreman [10]. We are currently testing the musical validity of these tools.

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