Physical Modeling for Pure Data (pmpd) and real time interaction with an audio synthesis

Cyrille Henry
cyrille.henry@la-kitchen.fr

Abstract

This article describes an application of physical modeling tools for pure data (pd) for real time interaction between a musician and an audio synthesis. pmpd is a collection of objects for pd providing a very flexible way to particle physical modeling simulation and other kind of comportment-based modeling. pmpd is used for data generation. That is to say that, although they can easily be used to *control* audio engines, they do not generate audio signals directly. Virtual physical structure can act as a black box between the musician and the audio synthesis. Using pmpd within the pd programming environment allows real-time interactions with this simulation, as well as natural control of a sound. A musician can play with the movement of a virtual structure, which produces sound.

Keywords

physical modeling, pure data, real time, interaction

I- Presentation of the environment

The system is mainly composed of software environment, mostly based on pd, GEM and pmpd. pd is a real-time generic programming environment dedicated to real time audio synthesis (Puckette 1996). GEM adds Open-GL based 3D Graphics to pd. A visualization of the simulation can be created throught GEM, as in pmpd examples, but other video software could also be used. pmpd is a collection of “objects” for pd which make physical modeling possible. pmpd is an approach to models made of particles, which are only one of many options for dynamics systems. This approach is widely used for video animation and interactive simulation (Castagne and Cadoz 2002). It provides a very flexible way to particle physical modeling simulation and other kinds of comportment-based modeling. Using pmpd allows real-time interactions with this simulation as pd is a powerful programming language in which all kinds of interaction with the user can be made. Moreover, pd programing environment can customize or enhance pmpd possibilities.

II- pmpd description

pmpd is designed to provide low level comportment objects allowing particle-base physical modeling (Cadoz, Luciani and Florens 1993). Assembling these objects can generate complex behavior due to the interaction among the basic objects. A good knowledge of the global equation of the movement is not necessary to simulate very complex behaviors. The cause of the movement and the structure only are needed for the simulation. pmpd can then easily be used for the simulation of a very large variety of comportments.

All the pmpd objects work with control data (as opposed to audio signals). For instance, one cannot hear the sound of a vibrating string because it will not move fast enough; but one can use the movement of these particles along a string to perform additive synthesis.

Complex simulations are basically made from two kinds of elementary objects: “mass” and “link”.
“Mass” objects send position and receive force from “link” objects. “Link” objects receive the position of two masses and output forces for both of them.

pmpd does not use specific units.

1- Mass

“Mass” objects react like a point mass. “Mass” objects have inertia, but they have no volume (they cannot rotate). They take forces at their input, and output their positions.
For each time increment, position of a mass changes accordingly to the mass velocity, while velocity depends on its acceleration. The value of the acceleration is given by Newtonian dynamics:

$$\sum \vec{F} = m\vec{\gamma}$$

When told, masses make the sum of the forces applied to them in order to compute their acceleration, and then deduce their new position.

2- Link

"Link" objects take two mass positions and output two opposite forces depending on the relative position and speed of the masses. Links are visco-elastic connections between two masses. The force generated by a link is :

$$\vec{F} = K\,\vec{X} + D\,\vec{V}$$

where "K" is the rigidity , "D" is the dampening, "X" is the elongation of the link, and "V" is the relative velocity of two masses.

3- Forces and displacement

To allow real-time interaction, "mass" objects accept force and displacement messages from the user. pd can then be used to provide interaction between the user and the simulation. The extreme modularity of pd can offer a very large variety of interaction with the simulation thanks to sensors, haptic transducers, or classical computers inputs (mouse, keyboard).

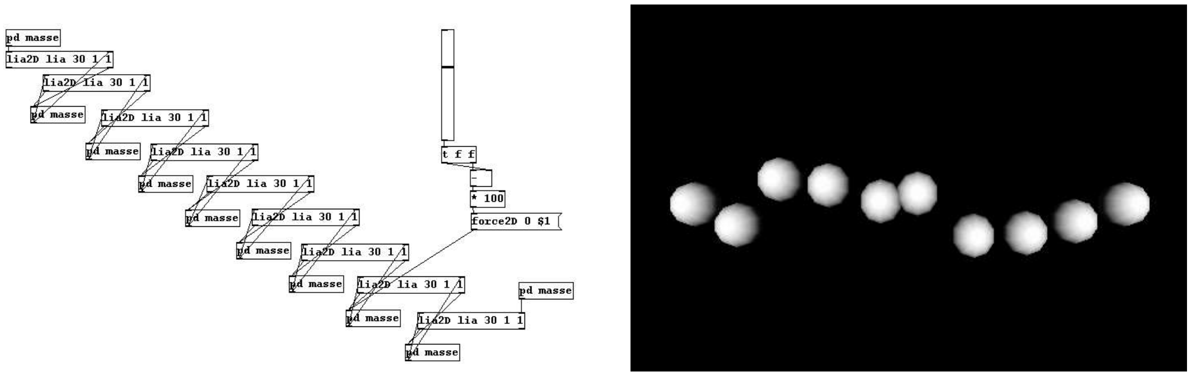

Figure 1. String example

The figure 1 shows an example of a pd patch modeling a simple string made with 2D masses, and a graphical representation of this vibrating string.

III- application for real time interaction with an audio synthesis

One of the applications of this kind of simulation is to create a dynamic structure that can be modified, moved, distorted by the user. This structure can then be used to "control" an audio synthesis. With the help of sensors, a user can create a virtual structure, linked to his or her own movement, to the real. The user can then play with a virtual, but "physical" instrument, allowing a natural comportment of a digital audio synthesis.

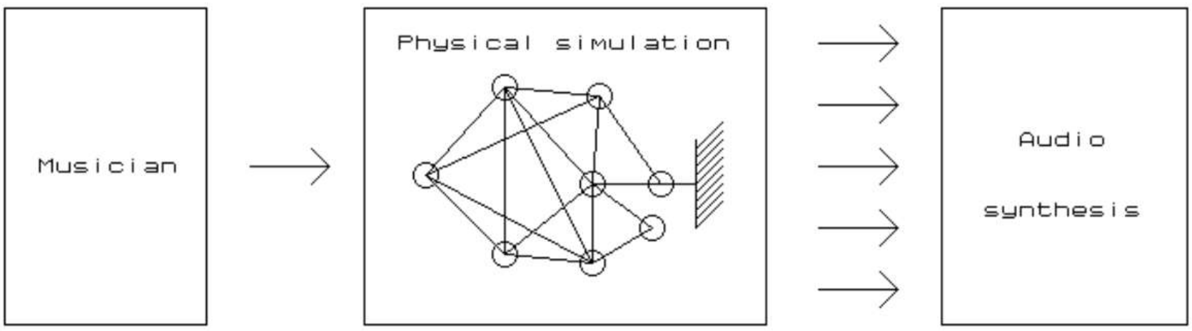

Figure 2. using physical modeling between musician and audio synthesis

The figure 2 shows a virtual structure used as a black box between user action and audio synthesis. This black box has interesting specifications. Only few input parameters can generate lots of different data flows (a musician can play with only few control parameters on the whole structure, and then generate lots of data to control any audio synthesis). Moreover, the control parameters are intuitive because they correspond to physical values. Playing with such a system can be very intuitive for the performer as the system reacts in a instinctive way. Some control parameters can change the way the structure evolves within a time period. Another important specification is that all data coming out of the physical model are not independent. The relation between them can be adjusted regarding the topology of the structure.

The most commonly encountered problem while using physical modeling is the instability. To reduce the risk of instability, one's model should be slowed down (increasing the metronome speed can be necessary to keep the desired speed of the simulation). This is not a problem due to the relatively low frequency needed for the simulation. In this case, the structure needn't be computed at audio rate unlike physical modeling based audio synthesis, but at only a few hundreds hertz. So, this simulation can be calculated by low-cost computer or personal laptop for live application.

1- Bouncing ball

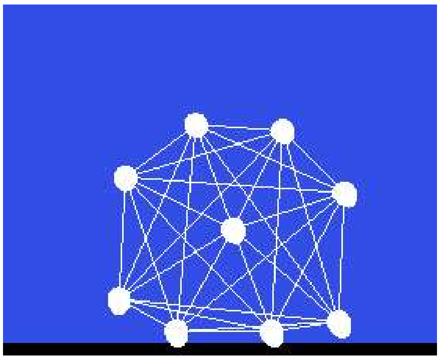

Figure 3. Bouncing ball used for additive synthesis

On Figure 3, forces applied to each masses control the amplitude of sinusoid which performs additive synthesis. The sound produced by the structure can be controlled while moving the structure, making it bounce, etc. The temporal evolution of the sound can be run with few parameters describing the global behavior of the structure such as rigidity or dampening of link.

2- Rhythmic pattern

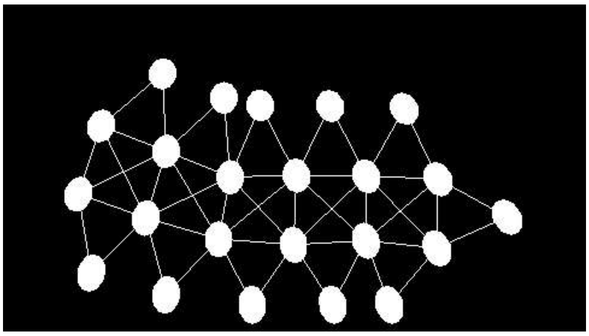

Figure 4. Moving structure used to generate rhythm

The figure 4 shows a self-moving structure that can be used to trigger sound. Whenever a mass hits the floor, a sound is produced.

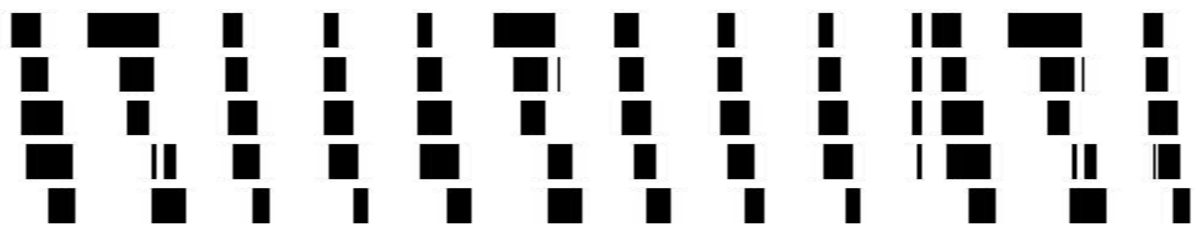

Figure 5. Rhythm generated by this structure

The figure 5 is a time representation of the generated rhythm. The main rhythm corresponds to the structure moving by itself while the internal deformations of the structure create the small rhythm variations.

IV- Perspectives

pmpd can be used for audio or video movement simulation. It can also be used for non real time audio data generation. It can be extended for real time audio synthesis. However, limitations will come from the CPU speed of the computer. pmpd can currently only be run with pd, but it should be ported to Max/MSP soon.

pmpd is released as free software under the GPL, and has been compiled on most common platforms (Linux, Windows, and Mac osX). Binaries, sources, examples and documentation can be downloaded from : http://drpichon.free.fr/pmpd

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