Obiwannabe

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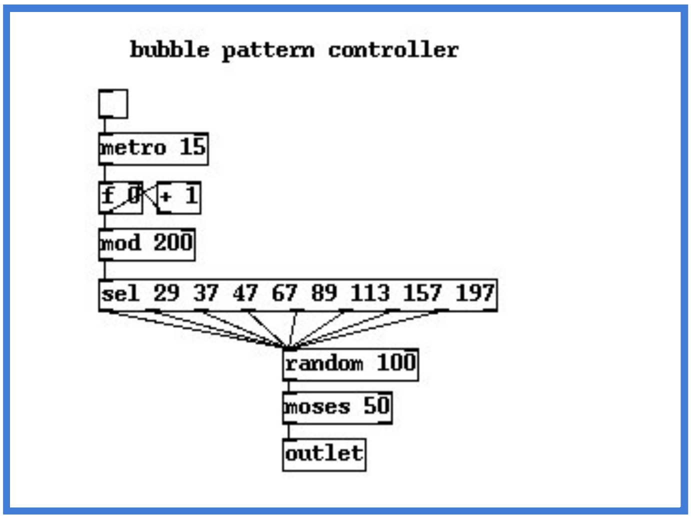
Bubbles

Introduction

One concept I want to introduce is the decoupling of control structures from synthesis structures. If we imagine a piano as a synthesiser then the pianist and her score sheet are the control structure. The same piano can perform any number of musical pieces by replacing the pianist or the score. In the same way lots of sounds we want to design depend as much on the data fed to them as the signal processing programs making the actual waveforms. Often it's hard to see where that line between synthesis and performance should lie. For example when building our second telephone bell remember how we talked about the essence of a message based control method in contrast to the first telephone which had its timing characteristics built into its sound generator as just another modulator? Sometimes having built a synthesiser we have to remove parts of its control structure up to the controlling application or performer when it becomes apparent that they don't belong so tightly coupled to the DSP. Other times we find that the interface is too complex, or there are redundant controls that can be merged back into the DSP. But usually, if we look hard at the problem and think a little beforehand, there will be an obvious line at which to make the break and define a clean interface. In the following example we make a clear distinction between the two parts right from the start.

I also want to introduce the concept of independent and codependent parameters. Sometimes we are lucky or smart enough to find that we have built something where every knob and control has a unique and well defined purpose. Other times we are faced with a set of controls that all seem to effect one another in some way. A good example is the difference between flying a plane and a helicopter. The latter is a far more difficult beast to master because of the way its controls interact. The bubble generator in the next section is a nice example of, unwanted but manageable, codependency. In later exercises there will be time to consider the slightly mathematical process of identifying and factoring out troublesome codependencies, but for now let's merely be mindful of the phenomena. Alright, it's time to get our feet wet with a few aquatic waveforms.

Bubbles and bubbling patterns



The control level consists of a simple metronome and counter combined with a modulo operator. This extremely common combination is found in a great many patches, it give us a circular counter that cycles round a range of numbers, in this case 0 to 199 (200 modulo 200 = 0). In fact it's such a common block of atoms several externals exists that perform this exact function, but we like to use only PureData standard atoms where possible. The time between each increment of the counter is 15ms, which gives us a regular timebase. What we actually want is not a regular series of bangs though.

Bubbles underwater usually come from some source of gas under pressure. What we are trying to simulate is a process of decaying relaxation. In a similar way that a dripping tap behaves, a source of energy must overcome a force that resists its movement. For the tap it is the surface tension of the water drop, which once it become big and heavy enough detaches from the reservoir of water building in the tap and falls under gravity. For our bubbles the opposing force is the pressure of the water, a dripping tap and underwater bubbles are kind of complementary phenomena. Of course a dripping tap and bubbling gas under constant pressure release each drop or bubble at regular intervals. However it is rarely the case that water bubbles form under constant pressure, instead they tend to come in bursts which decay in frequency followed by periods of very few bubbles and then another burst. The reason for this involves some complex dynamics, but let us just say that once some bubbles have started moving other bubbles find it easier to break through for a short while. We will revisit this concept again when we look at electricity, a phenomenon that shares a good deal in common deal with water and fluids in this respect. To simulate a relaxation of flow we use a cheap trick. The select block outputs a bang when the integer on its input matches one of its arguments. Do you recognise the numbers in the select block? They are small primes in a mildly diverging ascendency. Why? Well as humans we are very good at picking out patterns, we tend to notice any periodicity in a sequence if we listen to it long enough, but the primes create the illusion of a non-periodic source. That's not the same as a random source, which is why we haven't duplicated the circuit we used building the fire crackling unit, something slightly different is called for here. In fact having every bang event produce a bubble would still be too much , a way of culling a few events or "decimating" them is required. Removing one in every two events is sufficient for a realistic bubbling pattern, however we don't just want to remove each alternate event, we want to cull them randomly. By doing this the stream of events will sometimes contain longer gaps and sometimes shorter ones while still retaining the overall "feel" of a steady average rate. To do this a number between 0 and 100 is generated for each event, and fed to a stream splitter with a midpoint of 50. Because the random numbers are evenly distributed on average exactly half the events will make it through.

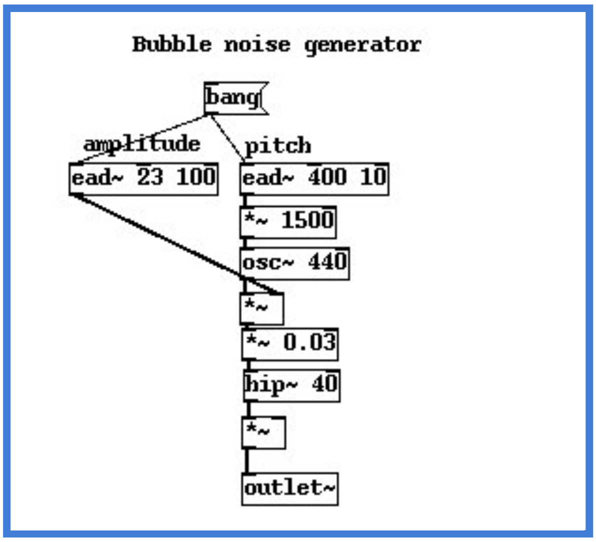
What are bubbles?

Great, now we have a way of making a half decent pattern generator for the bubbles, that's our control structure, but we don't yet have a bubble sound. Now we need to ask Dr Lecters revealing question once more, "What is it's nature? What does it do?"
A bubble is little piece of something that is where it doesn't belong. It doesn't belong there because it's in conflict with its environment and doesn't mix with it. Were this not the case bubbles would either float happily about underwater or the air would redissolve back into the water. In reality the bubble wants out of the water as soon as possible to rejoin its air molecule friends on the surface where the pressure is more agreeable. On all sides are water molecules pressing inwards trying to crush the bubble. Lets consider the complementary phenomena, a balloon filled with water. You've all made water bombs right? So you know where I'm coming from when I talk about how they wobble like a jelly. Well, underwater the bubble wobbles like a jelly too, albeit under a slightly different balance of forces. A bubble rising through water experiences forces of fluid friction and turbulence in an odd way, another way of thinking about the bubble is as a place where there isn't any water, it's not the bubble moving up so much as the water falling down. During this process some energy is exchanged, the skin of the bubble starts to sing.* There are four reasons a bubble can make a noise. When the bubble comes from an underwater source of gas the shock of separation from the larger body imparts an impulse to the bubble. Picture the bubble just the moment before it separates by watching the bubbles in a fishtank aeration pipe, it is elongated, but the moment the bubble "pinches" it snaps backwards and oscillates. A similar process happens when raindrops or stones hit water, a column of air protrudes momentarily into the water but as the fluid collapses behind it the same "pinching" occurs. Another kind of impulse is imparted to a bubble during "cavitation". This is when a bubble simply pops into existence during a pressure or temperature change in a liquid. The mode of this oscillation is slightly different from pinched bubbles since it involves a uniform explosive formation. Finally there is the singing bubble which obtains its acoustic energy through frictional excitation when rising, these bubbles tend to rise in a spiral or zigzag because of their oscillating exteriors. The pitch of a bubble depends on a few things. Like a bell it has modes or eigenstates it prefers to vibrate in and the fundamental is determined by its diameter, but that is a very simple view. The bubbles pitch also depends on the ratio of the gasses elasticity to the surrounding liquids elasticity, the so called restoring force, and that in turn

depends on pressure, which in turn depends on height in the water. I won't even begin to speculate on the full equation for a bubbles pitch as a function of height, temperature, and size, but experiments give us a value of 3kHz for a 1mm bubble. The bubble is actually strongly damped so it sings an almost perfect sinewave, certainly by the time it hits the surface it is a pure fundamental only. When the bubble is larger any deviations in shape will have larger variation of perceived pitch, so big bubbles sometimes sound a bit wobbly while smaller ones sound quite fixed. The larger the bubble the lower the sound, in an inverse square relationship (I thought it should be cubic but I am told otherwise) Also, the perception of the bubbles pitch depends on the observer, hearing it in air where the speed of sound is slower alters the pitch we hear it at. Now for the tricky part. What we are actually creating in this patch is the sound of a surfacing bubble. The sound that the bubble makes as it breaks on the surface is the loud sound that most people think of when they imagine bubbles, not the ringing sound you hear beforehand. Because a bubble is a sphere, and we assume it's oscillating at a steady frequency as the sphere emerges at a constant rate the cavity diminishes in an exponential fashion, but because the same energy is squashed into an ever smaller space the amplitude diminishes at a different rate, in fact it remains almost constant. To compensate for the Fletcher Munsen effect though we need to doctor our bubble amplitude a little to stop it sounding too loud at high frequencies, this fudge is a deviation from the actual physics, but it's one of those things that just works. Wow! Well now we are almost experts on the physics of bubbles, we need to make some exponentially rising sinewaves in the 1-4KHz range, fortunately we have PureData so the rest should be easy. If I had just said at the beginning, bubbles are exponentially rising sinewaves in the 1-4kHz range you would have spent the rest of your life wondering why, now you know. OK, lets go to work....

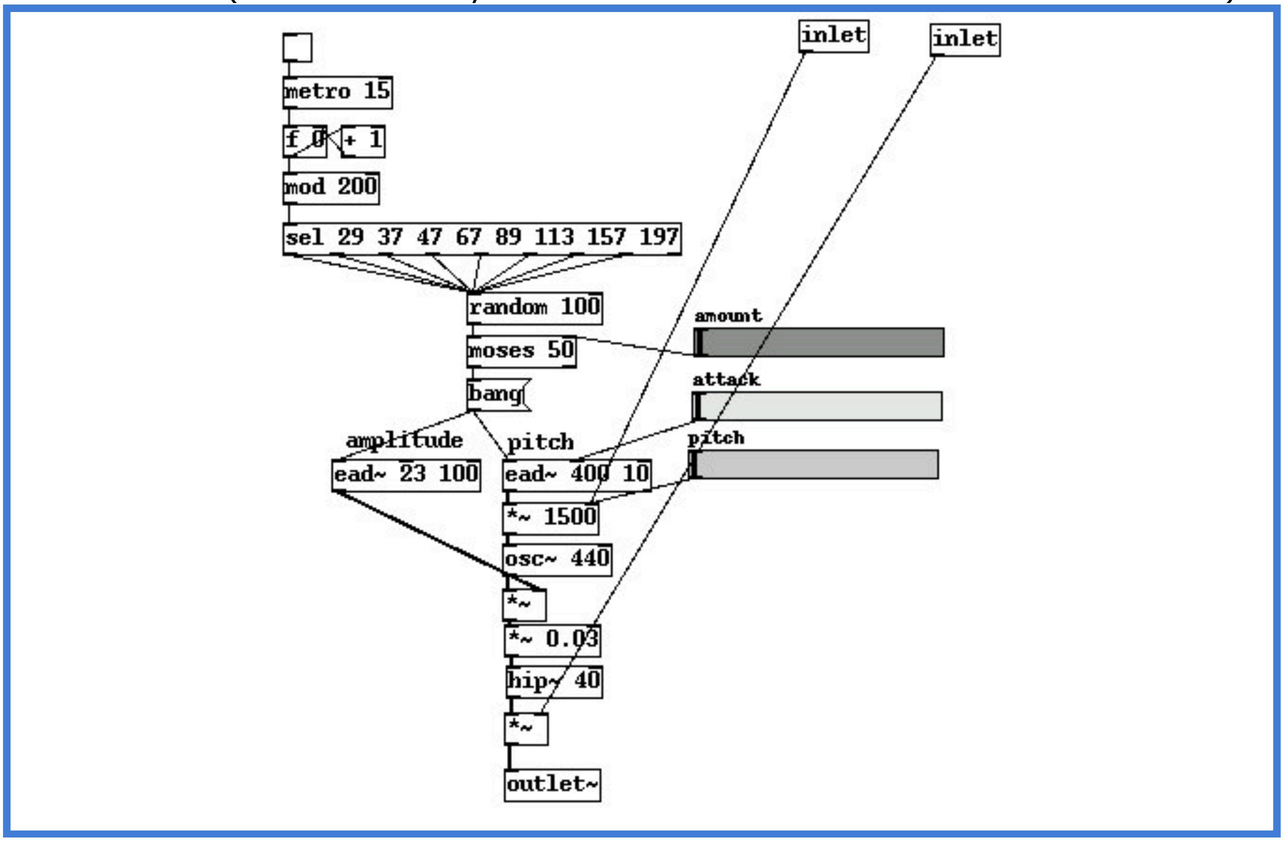
Making a bubble

The atom [ead~] should be available in your puredata distro. EAD stands for exponential attack decay, just the ticket for our patch. It takes a control rate bang message and rises exponentially according to a rate set by its first argument. Somewhat misleadingly the decay phase, given by the second argument is a linear one, but that suits us just fine. To complete the patch we use two envelope generators, one multiply operator to scale the pitch and a little hipass filtering to knock off the unfeasibly low frequencies. The patch below should be self explanatory. The trick is to give a soft attack to the amplitude, but leave the decay just long enough for the pitch envelope to do its magic and no more.



Putting it together

This one is easy, all we have to do is connect the bang event generator from the first part to the bubble generator we just made and voila! some very cartoonish bubble effects (which work very well mixed back in an ensemble of other sounds)



Puredata file .pd Audio .mp3

One last thing. If you tweak the parameter sliders given the above example you will notice that attack and pitch are linked, moving the attack also alters the apparent pitch of the bubble. This codependency is a feature of the very simple model we created, moving the attack changes the point at which the amplitude peaks during the pitch rise.

Links

bubble physics http://www.aip.org/pt/vol-56/iss-2/p36.html

*** GG STokes [1851] Turbulence of a sphere in newtonian fluid**

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