

# Raptor: The Random Arpeggiator

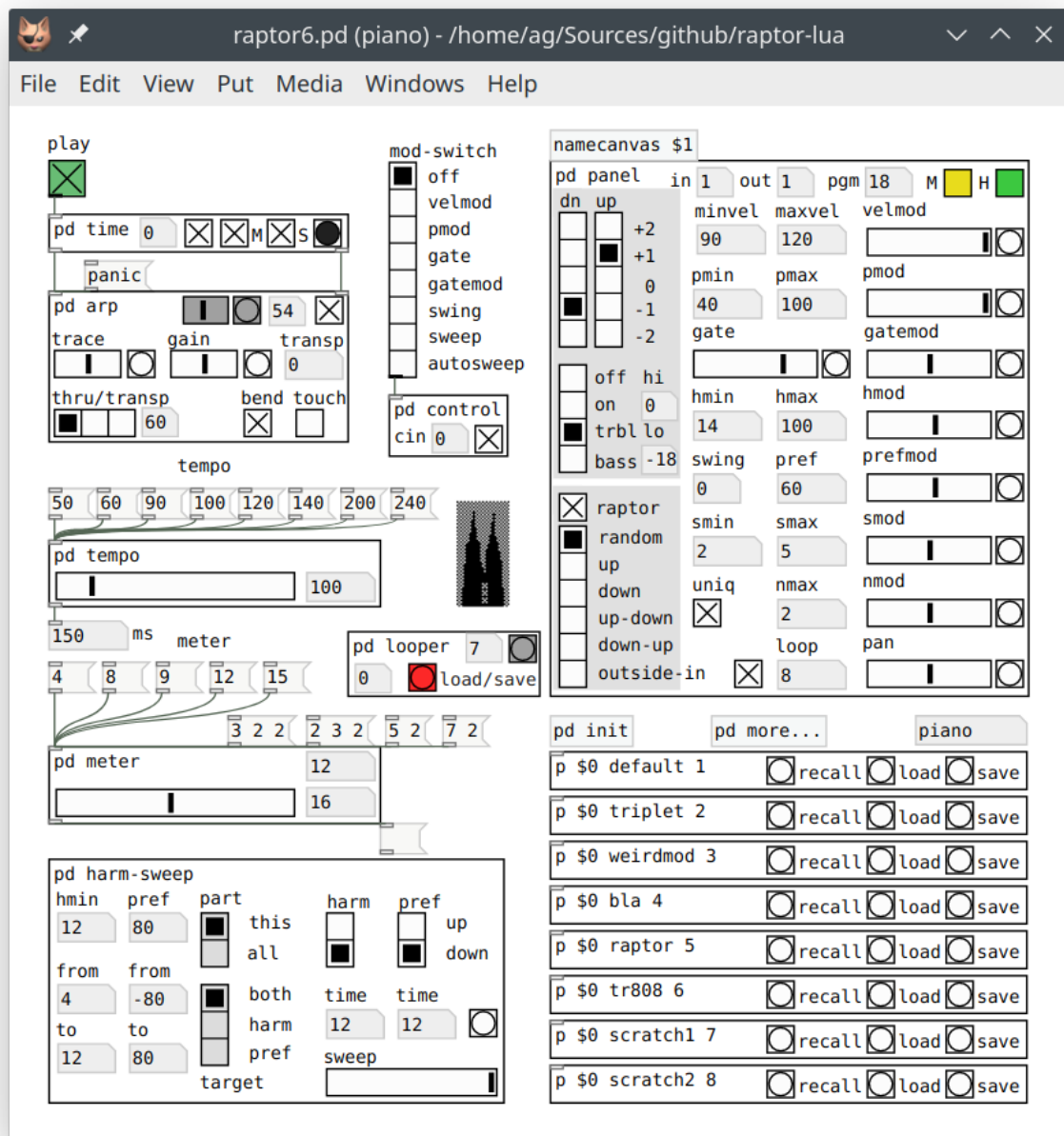
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The raptor6.pd patch implements an experimental arpeggiator program based on the mathematical music theories of the contemporary composer and computer music pioneer Clarence Barlow. This is already the 6th iteration of this program, now ported to Lua so that it can be run easily with any Pd version. Compared to earlier versions, it also features a much cleaner source code and many noticeable improvements, including more robust timing, proper MIDI clock sync, and a built-in looper. Here's Raptor running in [Purr Data](#), Jonathan Wilkes' modern Pd flavor:



Raptor is quite advanced as arpeggiators go, it's really a full-blown algorithmic composition tool, although it offers the usual run-of-the-mill deterministic and random arpeggios as well. But the real magic starts when you turn on raptor mode and start playing around with the parameters in the panel. The algorithm behind Raptor is briefly sketched out in my [ICMC 2006 paper](#) (cf. Section 8), and you'll find some practical information to get you started below. But if you'd like to get a deeper understanding of how the algorithm actually works, you'll have to dive into the source code and read Barlow's article in the [Ratio book](#).

Using the patch is easy enough, however. Open the patch in Pd, hook up your MIDI keyboard and synthesizer to Pd's MIDI input and output, respectively, press the green play button, and just play some chords. I'm mostly driving Raptor with a MIDI guitar and a [Nektar PACER](#) foot pedal these days, so the patch is somewhat tailored to that use case, but it also works fine with just a MIDI keyboard and a free software synth such as [Qsynth](#). I've included my modified Nektar PACER setup in case anyone wants to use it, please check the pacer subdirectory in the distribution and the included [description](#) for details.

This project is work in progress. In particular, the included presets need some work, but hey, you get them for free, so feel free to modify and use them for whatever purpose. ;-) Bug reports and contributions are welcome, and I'm curious about uses of my programs, so please send me links to music produced with Raptor!

## Getting Started

We recommend running Raptor with [Purr Data](#), as it includes a recent version of pd-lua and the other required libraries, and the layout of the GUI has been optimized for that version. But the patch should also work fine in Miller Puckette's "vanilla" [Pd](#) if you have the required libraries ([pd-lua](#), [zexy](#), [iemguts](#), and [ggee](#)) installed. **NB:** When using Pd, ggee, iemguts, and zexy can all be installed from [Deken](#). But the pd-lua versions usually distributed with Pd are for Lua 5.2 or even earlier, and Raptor absolutely needs **Lua 5.3 or later** to work; you can find a suitable pd-lua version [here](#).

We assume that you're already familiar with Pd, so you know how to open a Pd patch and use it. There is no real installation process, just download the latest Raptor release or the current git source from [GitHub](#) and unpack it. If Pd has been set up properly, double-clicking the raptor6.pd file (or running something like `purr-data raptor6.pd` from the command line on Linux) should open the patch in Pd. If that gives you a bunch of error messages in the Pd console window, then you probably need to install some Pd add-on libraries first, see above.

The raptor6.pd patch can be invoked by itself, or as a subpatch in another patch. In the latter case, you can also specify the name of an "autostart" preset to be recalled on startup as an argument (see the the-raptors.pd "orchestra" patch included in the distribution for an example). If no autostart preset is given, then all parameters will be set to factory defaults, which can be found in the `init` subpatch. A few sample presets are included in the presets folder, use the `p` abstractions in the lower right corner of the main patch to switch between these, or create your own. As shipped, the first preset labeled `default` is identical to the factory defaults, so that you can quickly restore some sane defaults if needed. More presets can be found in the `more...` subpatch.

The main patch has quite a few controls to change meter, tempo, and the other parameters of the algorithm. The current state of all these parameters is stored in a preset on disk if you hit the save button, so that you can recall it later with the `recall` button. The `load` button lets you reload a preset from disk and immediately recall it, which is useful if you edited the preset outside of Raptor in a text editor. Presets are stored on disk as editable text files in Pd's `qlist` format (which basically just lists parameter names and their corresponding values). The file name is specified in the second argument of the `p` abstraction, and the third argument

indicates the PC (program change) number which can be used to recall the preset using MIDI control. The latter is optional, but the first argument of the `p` abstraction is mandatory and *must* be `$0`, which tells the abstraction which Raptor instance to operate on.

## Customizations

Raptor offers most of the configuration options needed for common uses through its preset system, however we can't and won't cover every use case under the sun. One of the great boons of using Pd instead of a custom-built application is that you can just go into the patch and customize it for your own needs. This might seem like a tough call if you're still new to Pd, especially with a complicated patch like Raptor, but most Pd users start doing this sooner or later, and simple modifications such as changing a few default options here and there don't actually require that much Pd knowledge.

The easiest customization options are those visible in the GUI (graphical user interface). We discuss most of these in the following section. Whenever a GUI control is described as "saved in the patch", you can just change it and save the main patch; et voilà, next time you launch Raptor, it will use the new default that you just set. Generally, most options in Raptor are either of this kind, or they will be saved in the presets. The same is true for the various tempo and meter options in the main patch (the Pd message objects looking like little flags); I've tried to include some common defaults there, but your needs aren't the same as mine, so feel free to edit these as needed and save the patch to make your choices permanent.

Other options will be hidden away in the various subpatches (pd objects) of the main patch. You probably won't have much reason to edit these, unless you want to rearrange the GUI controls in a subpatch or change some defaults, but to give you an overview, here's a quick rundown from top to bottom and left to right:

- `time`: Basically, this is a Pd `metro` object generating pulses for the arpeggiator, but it also takes care of synchronizing different Raptor instances and handles MIDI clock sync with external programs.
- `arp`: The arpeggiator itself, including note input and output, looper control logic, and time-related processing. Its core is the `arpeggiator` object which does most of the heavy lifting and is written in Lua, but everything else is just plain Pd code.
- `tempo and meter`: Controls for setting up, you guessed it, tempo and meter.
- `harm-sweep`: Controls and logic for the "harmonicity sweep" effect which leverages Raptor's advanced harmonicity-based processing. As far as I can tell, this kind of effect simply isn't available in other arpeggiators, so you should really check it out (it's explained in the section on harmonicity).
- `control`: Basic MIDI control and PACER support. This is the subpatch that you'll want to customize if my PACER bindings don't suit your needs, or if you're using a different foot controller and would like to replicate at least some of the functionality offered by my PACER setup.
- `Looper`: Some extra controls for the looper which let you load and save loops from/to disk files.
- `panel`: This has all the GUI controls for the parameters of the arpeggiator.
- `init`: Initialization, this is where you go if you want to change any of Raptor's factory defaults.
- `more...`: Some extra factory presets, you can also place your own custom presets there.

In the lower right corner of the main patch you can find all the factory presets. Note that in the current implementation all presets that you're going to use need to exist as `p` abstractions *in the Raptor main patch*, so that they know which Raptor instance to talk to (that's what the `$0` argument of the `p` abstraction is for). The presets can all be edited to your heart's content, but you should *always* keep the first default preset as is, because it also takes care of the MIDI control input for the preset parameters. The MIDI bindings themselves are hard-wired (see the Control section below for details), and that's a good thing because it

makes MIDI CC automation in DAWs portable across different Raptor installations. But if you absolutely need to change them for some reason, you can do so in the source of the p abstraction (see lib/p.pd).

## The GUI

Before we go into Raptor's MIDI controls, let's have a quick look at some important GUI controls in the Raptor patch that you should know about. As indicated below, some of these are saved in the patch itself, so you can just save the patch to change their defaults.

First, in the main patch there's the mod-switch control (saved in the patch) which assigns some PACER controls to various different parameters for hands-free operation. Most related controls can be found in the `panel` subpatch; the most prominent of these are the yellow mute toggle (labeled M) which mutes the arpeggiator (stops all note output), and the green hold toggle (labeled H) which holds all note input in memory, so that the arpeggiator keeps playing the same pattern while this toggle is engaged. These are mostly intended for live control and automation, so they both have MIDI bindings (CC64 and CC67). Of course, you can also operate them in the GUI, but their state is neither saved in the patch nor in presets.

The mod-switch control goes into the `control` subpatch which contains the interface to the PACER and some other basic MIDI control functions. This subpatch also has a numbox (labeled cin) and a toggle (both saved in the patch) which allow you to set Raptor's control input channel, and to enable control input separately for each Raptor instance. By default, the MIDI channel is set to 0 (omni) and control input is enabled. The control input toggle is mostly for interactive usage, if you need to restrict control input to individual instances in a multi-Raptor setup. The MIDI channel can be set (and saved) to accommodate your studio or stage setup. E.g., it often makes sense to have all your control inputs, such as the PACER, a fader box, or MIDI automation from your DAW, go into a separate Pd input port, so that normal MIDI input from other devices doesn't accidentally interfere with Raptor's MIDI control. Pd has a set of 16 MIDI channels for each MIDI input, so you can set the control input channel, e.g., to 17 in order to receive control data on channel 1 of the second MIDI input.

Next, in the `time` subpatch there are the time master and MIDI clock sync toggles (labeled M and S, respectively, both saved in the patch), which will be discussed in the section on tempo and time below. There's another (unlabeled) start/stop toggle (not saved) which enables you to start and stop the sequence manually, and a pulse button to trigger individual pulses in a step-wise fashion, which can be useful for debugging purposes. The pulse button also goes red to indicate MIDI clock sync. The little "anacrusis" numbox on the left will set the pulse offset from the beginning of a bar (counting from zero) when playback starts. This is filled in automatically if your DAW sends song position pointer (SPP) messages, but you can also set it manually (whether using MIDI clock sync or not) if you need to start playback on an upbeat.

Last but not least, there's the `arp` subpatch containing the guts of the arpeggiator itself. You can send a panic message to the arpeggiator to kill hanging notes, and switch the metronome tick on and off with the toggle control in the upper-right corner (saved in the patch). The gray slider displays the pulse strengths, and the gray beat indicator next to it briefly flashes at the beginning of each bar (it also goes red if you stop the sequence, until the arpeggiator finishes playing the current bar). We mention in passing that the metronome does a lot more than just clicks. In fact it's a little drum sequencer driven by the same pulse strength data that the arpeggiator itself uses, so it adjusts to the meter and generates output with varying velocities for a GM drumset on channel 10. Its sound can be customized by setting the GM drumkit note number in the little numbox, saved in the patch.

In the second row you find some options affecting note input and output. The `trace` control (saved in the patch) changes the amount of time that incoming note-offs are delayed. This produces a kind of "legato" effect, making notes stick around a little longer while you're changing chords. The slider goes from 0 to 600 ms and should be adjusted to your playing style; the default is 300 ms, and zero means off. The `gain` control ties in with the *velocity tracker*, a function which calculates a kind of envelope from the velocities of the notes that you play and adjusts the velocities of output notes generated by the arpeggiator accordingly. Normally, this value actually controls the mix between preset velocity values (`minvel`, `maxvel`) and the calculated envelope, ranging from 0 (all envelope) to 127 (all preset). However, during loop playback it becomes a real gain control which changes the output velocities by -3 to +3 dB (half to double velocity). The `gain` control is bound to the MIDI volume controller (CC7) and also stored in presets. Both `trace` and `gain` also have buttons to quickly reset them to their default center values. The `transp` control (which also has a MIDI binding and is stored in presets) lets you transpose the note output by a given number of semitones; in loop mode, this can also be controlled more conveniently through note input, see below.

The third row contains some customary processing options for note input and related MIDI data. The `thru/transp` radio button offers three different options for note input: from left to right, the first option ("off") disables pass-through; the second option ("thru") enables it, so that input notes are passed on from MIDI input to output (which is useful if you'd like to hear what you're playing and your MIDI instrument doesn't offer local playback); and the third option ("transp") links note input to the `transp` control. The latter option is only available in loop mode and works in the usual way, i.e., the positive or negative amount of transposition in semitones is given by the offset of your input notes from a center note, usually middle c = 60 (this can be changed in the little numbox next to the radio button). Thus playing the center note resets `transp` to zero, higher notes transpose upwards, lower notes downwards, you get the idea. Finally, two additional toggles, `bend` and `touch` determine whether to pass through pitch bend and monophonic aftertouch (channel pressure) messages to the output. These controls are all saved in the patch; by default, pass-through is enabled for pitch bend and disabled for aftertouch and note input in the factory settings.

## Control

Raptor's parameters have the following generic MIDI bindings, so that they can be operated from a control surface and automatized if you're driving Raptor from a DAW.

### Notes:

- Raptor is controlled using two types of MIDI messages, *PC* (program change) and *CC* (control change). Control input has its own MIDI channel which can be zero to denote "omni" (listen on all channels). This is set in the `control` subpatch and is independent of note input, see the GUI section for details.
- The CC numbers might look a bit random, but at least we gave it the old college try to assign and group them in a logical fashion, while avoiding blocks of special CC numbers (such as bank changes, RPNS etc.) which might actually be emitted by standard gear during normal use, so that these don't accidentally trigger some totally unrelated (and unwanted) response in Raptor.
- For "discrete" controls (0-1 switches: hold, mute, raptor mode, and uniq; 0-n switches: arpeggiator and pitch tracker modes), the control value is taken as is, and any value greater than the number of alternatives is clamped to the given range. In particular, for the 0-1 switches, *any* positive value means "on". For other ("continuous") controls the full 0-127 MIDI range is mapped to the parameter range given in the table, and a CC value of 64 denotes the middle of the range (which means zero for parameters with a bipolar range, such as the "bias" parameters explained below).

- 0-100 ranges generally denote percentages in relation to some measure. These are used for probabilities (pmin, pmax), where 0% and 100% denote zero and one probability, and harmonicities (hmin, hmax), which range from 0% = "anything goes" to 100% = "perfect unison", respectively. The gate parameter, which determines how long generated output notes are sustained, is also specified as a percentage, but its range goes from 0% (extreme staccato) to 200% (extreme legato), with 100% (center value and default) indicating that each note lasts exactly as long as the pulse length.
- Some parameters (pref, swing, as well as all the "mod" parameters) denote *bias values* ranging from -100% to +100% which are used for automatic modulation of other parameters according to pulse strengths in the chosen meter. A *positive* bias means that the value of the dependent parameter increases for *stronger* and decreases for *weaker* pulses; conversely, a *negative* bias indicates that the parameter increases for *weaker* and decreases for *stronger* pulses; and a *zero* bias means that the parameter does *not* vary with pulse strength at all.

Control	Range	Meaning
PC	0..127	selects preset 1-128
CC1	0..127	harmonicity sweep (also bound to CC11 in the PACER configuration)
CC7	0..127	velocity tracker level (0 = tracker, 127 = preset) and loop gain (-3..+3 dB)
CC8	0..127	pan (0 = hard left, 127 = hard right, 64 = center)
CC13	0..3	pitch tracker mode (controls voicing, 0 = off, 1 = on, 2 = treble, 3 = bass)
CC14, CC15	-64..63	pitch lo and hi (low and high offsets for the pitch tracker in semitones)
CC16, CC17	-64..63	octave range (number of octaves down, up, meaningful range is -2..2)
CC18	-64..63	transpose (transposes output by the given number of semitones)
CC19	0..5	arp mode (0: random, 1: up, 2: down, 3: up-down, 4: down-up, 5: outside-in)
CC20	0..1	raptor mode (on/off)
CC21, CC22	0..127	minvel, maxvel (range of velocity values)
CC23	-100..100	velmod (velocity bias, modulates velocity)
CC24, CC25	0..100	pmin, pmax (range of note probabilities)
CC26	-100..100	pmod (note probability bias)
CC27, CC28	0..100	hmin, hmax (harmonicity range)
CC29	-100..100	hmod (harmonicity bias)
CC30	-100..100	pref (harmonic preference)
CC31	-100..100	prefmod (harmonic preference bias)
CC64	0..1	hold (keep current chord in memory while "on")
CC67	0..1	mute (suppress note output while "on")
CC75	0..200	gate (as percentage of pulse length)
CC76	-100..100	gatemod (gate bias)
CC77	-100..100	swing bias (note delays modulated by pulse strength)
CC78	0..127	meter (number of pulses, always uses normal stratification; e.g., 12 = 2-2-3)
CC79	0..127	meter base pulse (this is usually a power of 2, i.e., 1, 2, 4, 8, 16, 32, 64)
CC84, CC85	-64..63	smin, smax (min and max step size)
CC86	-100..100	smod (step size bias)
CC87	0..127	nmax (maximum chord size a.k.a. number of notes per step)
CC88	-100..100	nmod (chord size bias)
CC89	0..1	uniq (don't repeat notes in consecutive steps)

# The Arpeggiator

Raptor's note generation process is quite involved, but at the heart of it there are just two basic "[musiquantical](#)" notions and corresponding measures from Barlow's theories: *meter* (which determines a kind of one-to-one pulse weights called *indispensabilities*) and *harmonicity* (a measure for the consonance of intervals calculated from so-called *indigestibilities*). In fact, there are a lot of similarities between Raptor and Barlow's famous [Autobusk](#) program which is based on the same concepts. Both programs can operate in real-time, but Autobusk is driven exclusively by parameter input and will happily produce a constant stream of notes as soon as you turn it on. In contrast, Raptor never becomes "creative" on its own, it *always* requires note input, otherwise it will just sit there twiddling its thumbs. In a way, Raptor is the illegitimate child of Autobusk and an arpeggiator. ;-)

Thus, in Raptor harmonicities are used to *filter* candidate notes in relation to its note input (the notes you play). In other words, they determine *what* to play. On the other hand, the pulse weights are used to *assign* various parameters to each step in the pattern, such as note velocities and probabilities, swing and gate values. That is, they determine *how* to play the notes picked by the filter. The arpeggiator orchestrates the entire process, by taking note input from the musician, feeding the required data to the various parts of the algorithm in each step, and playing back the resulting stream of notes.

One rather unusual feature of Raptor's algorithm is the way that the Barlow indispensabilities drive the entire process by modulating various other parameters. Like in Autobusk, the pulse strengths affect note velocity and probability, but in Raptor they also modulate harmonicity and thereby change the note selection process itself. Another unique feature of the algorithm is the harmonic preference parameter, which lets you prioritize notes by harmonicity, and can also be modulated by pulse strength in an automatic fashion.

In the following we discuss the various building blocks of the arpeggiator in a little more depth, concluding with a quick tour of the looper which is a new feature in Raptor 6.

## Meter

Barlow's method requires the meter (or more precisely the number of beats) to be specified in *stratified* form as a list of prime subdivisions, such as, e.g., 3-2-2 (3/4 subdivided into 16th notes), 2-3-2 (6/8 in 16ths), or 2-2-3 (12/16). Therefore, if you to specify the meter as a single composite number, Raptor assumes a partition of the number into its prime factors in ascending order, e.g.: 6 = 2-3, 12 = 2-2-3, 15 = 3-5, etc. This is usually in line with musical tradition (at least in the simple cases), but if you want a different stratification, you can also specify it explicitly as a Pd list such as 3 2, 2 3 2, 5 3, etc.

Raptor also suggests a base pulse when you specify a meter. This isn't really part of Barlow's method, but needed for the tempo calculation which is always done in relation to a base pulse. Traditionally, these are powers of 2, so Raptor calculates the base pulse by rounding up the number of beats to the next power of 2 (e.g., 4 becomes 4/4, 6 becomes 6/8, 15 becomes 15/16, etc.). If the suggested default isn't what you want, you can change it manually after setting the number of beats. E.g., to get a 9/8 meter, you'd enter 9 using the big slider or the numbox at the top, then change the default 16 pulse to 8 in the numbox at the bottom of the meter subpatch.



## Tempo and Time

*Tempo* may be specified using the traditional quarter beats per minute (bpm) value. The corresponding pulse period in ms is calculated automatically and displayed in the numbox labeled ms. You can also enter the period and have the corresponding bpm value calculated instead. Note that the pulse period depends on the base pulse of the meter. E.g., at a tempo of 120 bpm, quarters run at 500 ms per step, 8ths at double speed (250 ms/step), 16ths at quadruple speed (125 ms/step), etc.

Transport starts rolling as soon as you turn on the big green play toggle at the top of the Raptor patch, and stops when turning it off again, *after* the arpeggiator finishes playing the current bar (the beat indicator in the arp subpatch changes to red until the arpeggiator really stops; if needed, you can also start and stop transport instantly with the leftmost, unlabeled toggle in the time subpatch). Playback usually starts at the beginning of a bar, but you can also have an *anacrusis* (an upbeat) if you enter the pulse offset (counting from zero) into the little numbox in the time subpatch. This value can also be negative, to indicate a position relative to the *end* of a bar (e.g., -1 tells Raptor to start on the *last* beat of a bar).

When transport is rolling, Raptor generates pulses according to the current meter and tempo settings, and the arpeggiator creates note output at each pulse from the calculated pulse strengths and the notes that you're currently playing. At any point in time, you can change *any* of the arpeggiator's parameters, including arpeggiation mode, meter and tempo, and (of course) the notes you play, and Raptor will respond immediately by changing the sequenced pattern accordingly. You can also change presets on the fly.

You can even have a whole band of Raptors accompanying you, by running multiple instances of the main patch in the same Pd instance, either as separate toplevel patches or as subpatches of an "orchestra" patch (check the-raptors.pd included in the distribution which shows how to do this). In that case, *exactly one* of the Raptor instances must be selected as the "time master" which takes care of the transport, as indicated by the M toggle in the time subpatch. This will normally be the first launched instance by default, but you can make any instance the master if you launch the arpeggiator by engaging the big green play toggle in that instance.

Raptor can also sync to an external time source via MIDI clock messages, in which case that time source takes over Raptor's transport and determines tempo and pulse period. Most DAWs support this, you just need to enable MIDI clock output in the DAW, connect it to any of Pd's MIDI inputs, and make sure that clock sync is enabled in the time master by engaging the S toggle in the time subpatch (which is on by default using factory settings). As soon as Raptor starts receiving MIDI clocks, the pulse button in the time patch turns red, playback starts automatically, and the current tempo and pulse period are displayed in the tempo section. Playback stops as soon as Raptor receives a MIDI stop message, or hasn't received MIDI clocks for a short while (3 seconds in the current implementation, but this value can be changed in the midiclock abstraction).

## Harmonicity

Normally, an arpeggiator sequences exactly the notes you play, over a range of different octaves. Raptor can do that, too, but things get way more interesting when you engage raptor mode which selects notes at random based on the *average harmonicities* with respect to the current input chord (the notes you play).

Raptor mode works on a set of *candidate notes* from which the output notes are selected. This is a full range of semitones which is determined from your input notes and the octave range. The octave range is often too coarse in raptor mode, so it can be further adjusted with the lo and hi values in the panel (typically, lo will be negative or zero, hi positive or zero, to extend the range as needed). The corresponding section of the panel also contains a radio button which gives you a choice between different voicings: off just ignores lo and hi which gives a voicing consistent with non-raptor mode; on also applies the lo and hi values to give a



full range of notes; treble and bass do the same, but restrict the voicing to the treble and bass register by computing a range based on only the highest and the lowest input note, respectively.

Raptor then filters the candidate notes, getting rid of notes which don't satisfy the harmonicity and various other constraints. To these ends, you specify a range of harmonicities (*hmin*, *hmax*), as well as a corresponding bias (*hmod*) which is used to vary the actual harmonicities with the pulse strengths. Eligible step sizes for the generated pattern (i.e., intervals measured in semitones between the notes in successive steps) can be specified with the *smin* and *smax* parameters, and you can also tell Raptor how many notes to generate in each step with the *nmax* parameter. As with all the other note generation parameters, these values can be modulated according to the current pulse strength using the corresponding bias values (*smod*, *nmod*).

Last but not least, there is the parameter of harmonic *preference* (*pref*) which determines how much harmonious notes are to be preferred among all the eligible candidate notes which remain after the filtering process. The preference value can also be negative which lets you prefer *low* harmonicities in order to produce anti-tonal patterns. Again, the parameter can also be modulated through the corresponding bias value (*prefmod*), so that the preference changes with pulse strength (for instance, this lets you produce patterns with less harmonious notes only on the weak pulses). This parameter can be *very* effective when used with the right choice of *hmin* and *hmax* values.

By these means, patterns contain a lot more variation compared to traditional arpeggiators. With the right choice of parameters, Raptor can go from plain tonal to a more jazz-like feel to completely atonal (or even anti-tonal) in a continuous fashion. Such "harmonicity sweeps" are a hallmark feature of many of Barlow's compositions. To mimic this kind of effect in live performances, the *harm-sweep* subpatch lets you do sweeps of minimum harmonicity and/or harmonic preference either manually or in a fully automatic fashion. So you can "go Barlow" on a whim and quickly return to the safe harbor of tonality, or play an entire piece in (an approximation of) "Barlow style" with varying degrees of tonality.

Here is a fun little experiment concerning harmonicities to try for yourself. Some interesting harmonicity thresholds are at about 21% (the 5th), 17% (the 4th), 10% (major 2nd and 3rd), and 9% (minor 7th and 3rd). To listen to these, make sure that raptor mode is enabled, set *hmin* = *hmax* = 100% and *pref* = 0%, then launch the arpeggiator and play just a single note. Continue to hold that note while successively lowering *hmin* to the various thresholds. You should then hear that Raptor gradually brings in more notes (first only unison and octave, then at 21% the 5th, etc.), and finally descends into complete anarchy (producing random notes) at *hmin* = 0. Next play any chord (still at *hmin* = 0) and bring up the *pref* value until it reaches 100%. Observe how your chord gradually emerges from the sea of atonality. This should give you a good initial idea about what you can achieve with these parameters. When playing live, the same kind of harmonicity and preference sweeps can be performed in a (semi-)automatic fashion with the *harm-sweep* subpatch.

**NOTE:** Inquiring readers may have noticed that our harmonicity measure, although derived from the same indigestibility metric, isn't quite the same as the one from the Ratio book. Raptor uses a slightly modified definition from my ICMC 2006 paper which avoids the unison infinity in Barlow's definition, and also redefines the octave to be equivalent to the unison. Thus the specific threshold values mentioned above are slightly different from the corresponding Barlow harmonicities.

# Loops

Version 6 of Raptor now finally has an integrated looper facility. There are two related GUI controls at the bottom of the panel subpatch, a numbox-toggle pair labeled `loop`. The numbox tells Raptor the number of bars to record. Engaging the toggle saves whatever you just played to an internal buffer (up to the given number of bars, but the looper will also be happy with less if input runs short) and immediately starts looping it. Disengaging the toggle instantly clears the loop and resumes normal arpeggiator operation.

While the loop is playing, note input to the arpeggiator is suspended, so you can use your input controller to play along. Control input works normally, though, so you can also start twiddling the knobs, change presets, etc. Since the looper records the arpeggiator's *output*, not its input, most of the preset options won't affect loop playback, but changing output options such as gain, transposition, as well as MIDI channel and program will work.

You can check the current state of the looper at a glance by looking at the `Looper` subpatch. If a loop is playing, the numbox at the top of the subpatch counts off the bars in the loop, and the pulse indicator flashes at the beginning of each loop iteration. Moreover, the `load/save` button changes color if there is a loop that can be loaded from or saved to disk. There are 100 slots (numbered 0..99) for each preset where loops may be stored, which can be selected using the numbox next to the `load/save` button. The button color indicates if a loop is currently playing and if something has been stored in the current slot:

- If the *arpeggiator* is active, *white* indicates a free slot. This turns to a *light gray* once a loop has been stored there, indicating that you can press the button to load that loop and start playing it back immediately.
- If the *looper* is active, *orange* indicates a free slot to which the current loop can be saved by pushing the button. This turns to *red* once a loop has already been stored there, indicating that pressing the button will overwrite that slot (after creating a backup copy, so you won't actually lose any data).

Loop files are saved in the preset folder under the name of the preset that is currently selected, with the slot number and the ".loop" extension tacked onto it. If the file already exists, a numbered backup copy will be created automatically, so that you can recover the previous loop or rename it later. The saved loop can be reloaded by pressing the `load/save` button again when no loop is playing. The `loop` and `load/save` buttons also have PACER bindings, so they can be operated hands-free.

Loops are always quantized to whole bars, so you *must* keep playing for at least one bar to have anything recorded. This kind of "launch quantization" should be well familiar to Ableton Live users, although it works a bit differently here. First, there's no overdubbing (since the arpeggiator is suspended during loop playback, there's nothing to record anyway). Second, Raptor's looper always records "after the fact", so no separate button press is needed to initiate the recording. The looper is *always* listening, so once transport is rolling, you can just push the `loop` button *once* at any time to save and loop whatever you just played. If you mess up, pushing the button *twice* will quickly get rid of any pending input and clear the loop buffer, so that you can start over. This kind of workflow may need some getting used to, but it's very effective and works better with Raptor's probabilistic nature than more traditional approaches. You never know when that killer pattern will come around and when it does, you don't want to miss it because you forgot to push the "record" button. ;-)

So not having to first arm the looper is nice, but you pay for that by having to specify the target loop size beforehand, which can be a nuisance. As a remedy, the loop size can still be changed at any time while the loop is already playing. If you don't know the size of the loop beforehand, just set it to a fairly large number, start playing, and push the `loop` button when you're done. Listen to the loop and shorten it to the number of bars you want to keep. If you then push the `load/save` button, only the specified number of bars will be saved to disk. (You can also increase the loop size again, but not past the length that was initially recorded.)

# Bugs and Limitations

Here are some notes about compatibility issues, known pitfalls, and how to avoid them. Anything else that seems to be missing or not working properly? File a [bug report](#), or (better yet) submit a [pull request](#)!

## Compatibility

The present release has been tested and is known to work with Purr Data 2.15.2 and vanilla Pd 0.51.4 on Linux, Mac (OSX 10.14), and Windows 10. We don't support older Pd versions, so please make sure that your Pd version is up-to-date, or be prepared to fiddle with the sources. **Vanilla Pd users:** Depending on the Pd version and OS, the GUI might look a bit wonky, but Raptor should work without any problems if you have all the required libraries installed (ggee, iemguts, zexy, and [pd-lua 0.8+](#); pd-lua versions 0.7.3 and earlier are *not* supported). These are all included in Purr Data, so getting up and running is much easier.

## Time Sync

While MIDI sync should just work out of the box if your DAW can spit out a coherent stream of MIDI clocks, pulses may occasionally appear to be "shifted" (out of phase) if the meter settings don't match up, or if your DAW lacks support for song position pointer (SPP) messages and you start playback in the middle of a bar.

There's not really much that can be done about this on the Raptor side, as the limitations are in the protocol (or due to bugs in the DAW). We might add more comprehensive protocols such as MTC or MMC some time, and [Ableton Link](#) seems to be the way to go for networked jam sessions. But MIDI clocks are so much simpler and they work with pretty much any music application and recording gear, so they will do for now. Just make sure that you have Raptor's meter (and anacrusis) set correctly, then you should be fine.

## Looper Features

Raptor's looper is (by design) quite basic. Its main purpose is to give you a simple way of putting a generated musical phrase on repeat while you have your hands free for soloing, diffusion (knob-twiddling), or capturing that precious pattern before it vanishes forever. Moreover, those .loop files are just Lua tables, so they can easily be edited in a text editor or processed in Lua. If you need more features, then I'd recommend running Raptor alongside a DAW tailored to live usage, such as Ableton Live or Bitwig Studio, or even just a standard DAW like Ardour or Reaper. In particular, this gives you the ability to also record the *input* to the arpeggiator, which makes it much easier to tweak the results later.

Overdubbing and more advanced loop editing capabilities would be nice to have; but then again, if you want Ableton Live, you know where to get it. Other limitations in the current implementation are that at most 256 steps can be recorded, and loops are always quantized to whole bars. The former hopefully isn't a big deal in practice and can easily be changed in the source if needed, and the latter can always be solved by recording directly into a DAW instead.