# DONKEY BRIDGES
## ON THE CREATIVE AND TECHNICAL PROCESS BEHIND "ESELSBRÜCKE"


## CRISTIAN VOGEL


"Eselsbrücke" is a collection of 10 pieces of computer music, composed and recorded in Berlin over a period of 6 months. This essay aims to document some of the process and challenges which shaped the compositions. The story touches on the responsibility inherent in decision making,  on the complications of additive dimensions and the interfacing between non-sonic forms and musical significance.

As a starting point, let us remind ourselves that the Ancient Greek philosophers, Aristotle especially, acknowledged that a relation between sound and sense, gives music tremendous symbolic force. Music is able to affect the way we feel things and perceive our lives.  This significant power to transform remains undiminished, and brings with it a need for responsibility around the intentions and actions involved in music creation, and listening.

In modern music, especially recorded music, the responsibilities of interest and attention often get reduced to the narrow scope of pleasure-seeking, 'like' or 'don't like'. Because of this tendency, the existential angst of responsibility gets repeatedly zapped over time.  For the listener this can lead to impatience and boredom, triggered by a narrow expectation of musical value. For the composer, such suppression of reasoning can lead to severe frustration, an apparent lack of any deeper significance informing the myriad of choices that have to be made to work in music. If the composer does not begin to realise that there may be more to taking decisions than just habit or 'likes', work will become increasingly more difficult as the options for measuring success taper out. Output could eventually stop. It is not easy to break habits, indeed it is not a good situation for practice, when doubts build around the minutiae of method, especially in an art form where the recombinance of output with its ecology, plays a vital role. Improvisation, indeterminacy, algorithms, repetition and drinking are all methods composers have experimented with for regulating the build-up of pressure coming from the responsibilities inherent in compositional choices, whilst continuing to produce output. For my 15$^{th}$ album "Eselsbrücke", I was drawn away from the pub and towards number theory, in search of new means with which to handle some of the decision procedures involved in the composition.

Of course, this is a well-trodden path and there are many old rabbit holes. Music is so intertwined with numbers and mathematics, that styles have often become stifled by too much formalism -  from Baroque to Serialism to Techno. The power and scope of music becomes weaker, under the rigidity of the system which contains it.  In practice, I believe it is not the formalist approach in itself which lies at the root of the problem. What is debilitating is excessive adherence to prescribed forms, combined with the arbitrariness of decision making at structural foundations. For example, how does one choose the intervals in a tone row or the position of pulses in a loop or the selection of records in a DJ bag? Furthermore, as the composition work evolves, there will be significant decisions involving correspondence and allegory, i.e. mapping. If the starting choices are not taken with some degree of rigour, the holistic result can become overtly problematic, like a rocket mission missing the moon. If they are not flexible enough, things can become intolerably arid. So how should a composer deal with decisions concerning form? Should they be down to intuition or technique, or both? Can there be structural forms underpinning a piece, which connect immediately with the listener? In fact, how do we even go about planning novel musical significance, before any sounds are created?

Looking for answers to these questions, I went back to the theoretical propositions of Iannis Xenakis, a firm believer in the potential of formal systems and algorithms for building complexity into compositional decisions. I began studying his implementation of sieve theory, as described in "Formalized Music" and other Xenakian scholarly papers. Figure 1.0 shows a simple visualiser I developed to observe how Xenakian "modulo sieves" work, and the intervallic patterns they can generate[1].

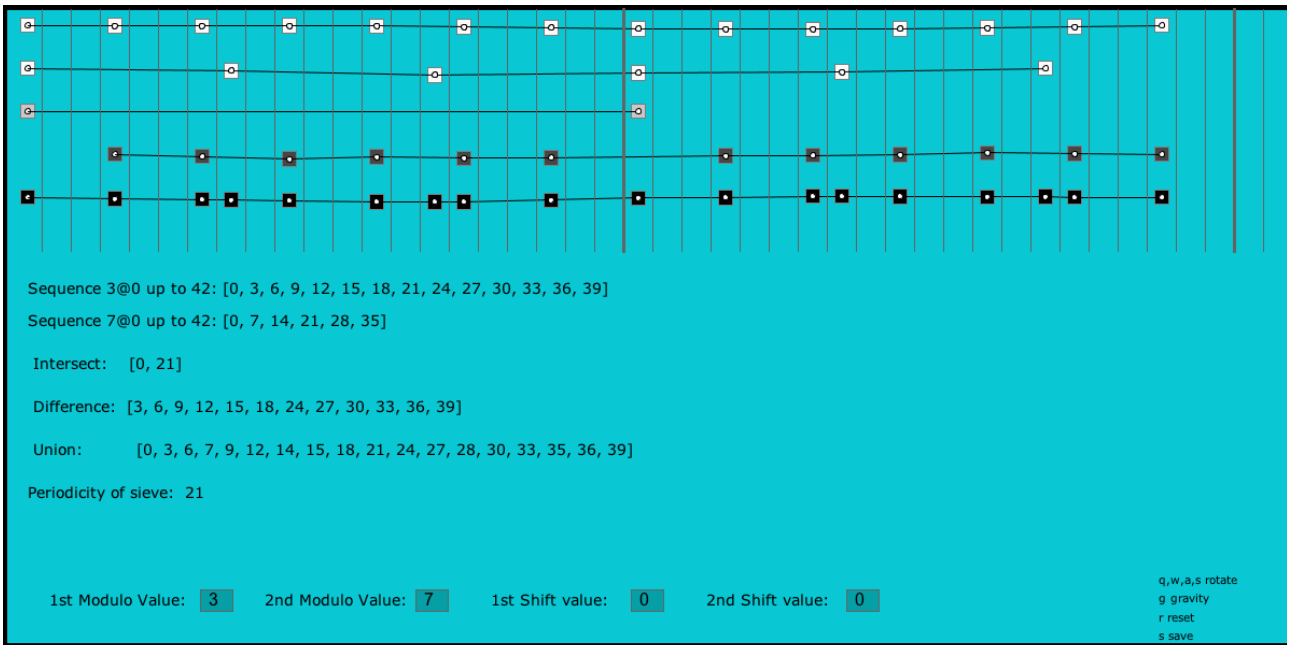

Fig1.0

In a general sense, a "sieve" applies a pattern, could be a sequence of typographical rules or a recursive process, to sift or percolate a finite set of integers from the infinite set of natural numbers. Through the iteration of rules, it frames a fixed set of numbers, effectively choosing them. A sieve is also a combining filter which adds information about itself, to a sifted result. That is to say, the intervallic relations within a sifted set, are an expression of the patterning characteristics of the sieve that created it.

[1] the program can be downloaded at http://tinyurl.com/d8s92ns

The sieve implementation I drew up for “Eselsbrücke” starts with a set of numbers defined by some first-order rules. They are that the set cannot hold the same number more than once, and the elements are ordered in sequence up to a limit. A valid set can then become an input to a combining operation, along with a second set. When combined, a third set of numbers is derived, one with a higher notch of complexity than the inputs. The set operations I use are Union, Intersection or Complementation.  They operate by comparing each element of one set against the corresponding element in the other, and interlacing them to form a new ordered collection. Fig 1.1 demonstrates some example results.

Fig1.1
a Union
(1 3 5 7 9) + (4 7 9 12) = (1 3 4 5 7 9 12)
a Complementation
(1 3 5 7 9) – (4 7 9 12) = (1 3 4 5 12)
an Intersection
(1 3 5 7 9) ∩ (4 7 9 12) = (7 9)

For “Eselsbrücke”, I decided early on not to use the Xenakian “modulo sieves” method for generating the sequences, but instead a prime number sieve. This frames regions of the first prime numbers up to a certain limit, creating sets which express the early prime number intervallic patterns.

As this essay is grappling with the difficulty of taking early decisions with significance, you may well ask “why prime numbers?”

To answer this question, I can identify two influences. In the Autumn of 2012, I listened to some musical experiments from Pablo Palacio[2], of polyrhythms he had generated using prime number sieves. The interesting way the pulses interacted with each other, caught my attention. Not long after hearing these sounds, another friend, in a discussion about reverb tail algorithms, mentioned that the best sounding ones use prime number delay times, as they never synchronise when super imposed[3].

The notion of the affects of a reverb model being altered by prime number filtering, combined with the curious rhythmic relations of overlaid pulses in Pablo’s experiments, gave rise to enough information for two of the earliest decisions.

a) the music would be based on prime number patterns
b) it would express those patterns in additive dimensions.

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[2] http://pablopalacio.com/Pablo_2.html

[3] For example, 4 delay lines repeating at times of 1 s 2 s 4 s and 8 s will synchronise on the same beats and this sounds ‘unnatural’ in a reverb model.

“Additive” is the term describing replicated instances of similar objects, with different parameters, occurring simultaneously in time. It is polyphony when we are talking about voices or instruments, but when we stack up exotic music objects such as delay lines, filters or noise streams, we are working in the realms of an elaborate additive synthesis.

In additive synthesis, the composer can begin to think about music in terms of increasing dimensionality. The basics are horizontal and vertical, time and frequency, but more dimensions emerge as things get more dense; fractal, spectral, holistic. Essentially, the more music objects you can add up, the more you get when they sound together – the compelling art of signal mixing. Additive composition needs filtering, to reduce information sometimes, and the abstraction of the sieve, fits comfortably with the additive approach.

The "Eselsbrücke" sieve implementation requires given input to start,  an axiom if you like. The composer must decide on one number, **n** , the highest value up to which primes will be calculated. Fig 1.3 shows an example result up to 37.

Fig1.3
**n**= 37.
(2   3   5   7   11  13  17  19  23  29  31  37)

Then a simplified feature from Xenakis' modulo sieve theory is applied to generate a second set.  My humble version takes one set with a fixed periodicity ( the **n** ) and shifts it ‘vertically’ using another number. That is, another number '**i**' is added to each element in the first set, to create the second set, a transposed and shifted version of the first set. Those sets are then combined using set operations, to compose a third, higher order set.

Fig1.4.
**n**= 37.  **i**= 0.
(2   3   5   7   11  13  17  19  23  29  31  37)
**n**= 41.  **i**= 2.
(4   5   7   9   13  15  19  21  25  31  33  39  43)
**UNION**
(2   3   4   5   7   9   11  13  15  17  19  21  23  25  29  31  33  37  39  43)

If we look at Fig 1.4, we can see that the Union results in a set with more information than the input ones. It interlaces the vertical shift of ‘**i**’ and also a horizontal expansion. It is longer than both the inputs and has a more dense intervallic pattern, characteristic of the sieve processes involved.

Once I had researched and explored this method of framing sets of numbers, and generating other sets with sieves, I was ready to begin thinking about the next stage of composition; the transformation of numbers into organised sound, into music.

These days, this stage of composition is often called “mapping” and often reduced to the simplistic situation of a linear interface between some tangible hardware and software. I consider the process differently. For me, it usually has little to do with gestural expression, more with the expression of abstract constructs, such as pattern. In a broad sense, this interfacing process is similar to the creation of analogies, the magic of ancient times.

In the non-linguistic sense, the meaning of analogy can be understood as the transfer and eventual correspondence of information from one domain to another. Composing analogies, deciding on the correspondence between things, relies on some tricky intellectual work. Firstly thinking about domains and coupling, and secondly, about the entities which might exist to connect intangible things. Not only that, one must also consider topology and transformation; the forms of the information which will cross this connecting “path”, and how it might change on the way over. The quality of bridging analogies from non-sonic forms to sonic ones are vitally important in music.

In mathematics, there is something called isomorphism. It is an information-preserving transform which maps, or reflects, one set into another. I have only a very basic understanding of the mathematical language which defines them, but I do see how isomorphism shares concepts of duality, connection and crossing with the process I am describing.

Mathematical isomorphism preserves information from one domain to the other; like reflection. In the context of language, art and music, mapping into memory, physical and emotional response seemingly generates extra information; it can amplify things.

As an example of this in linguistics, let us look at the word "Eselsbrücke". In modern German, it is understood as “mnemonic”. A mnemonic, aide-memoir, is an isomorphic-like reflection of the thing it is supposed to make you remember. But strangely, "Eselsbrücke" literally means "Donkey Bridge" which for most German speakers makes no literal sense at all. Yet the imagery in the phrase “Donkey Bridge” functions in a way, as example of how to remember something by imagining something else. This is extra, functional information about the meaning of “Eselsbrücke”, contained within itself, neatly recursive[4].

Historically, a bridge for the donkey seems to have been a practical solution to fool the animal into crossing rivers and streams, as it always refuses to enter water willingly. With a little etymological research, we also find out that *Pons Asinorum*, latin for “bridge of asses” or “donkey bridge”, is the name that has stuck for Euclid's fifth proposition in Book one of his Elements. We can read on Wikipedia about *Pons Asinorum* that “whatever its origin, the term is also used as a metaphor for a problem or challenge which will separate the sure of mind from

[4] Similarly in English, the oddball phoneme "mn" in mnemonic has a correspondence to Mnemosyne, the greek goddess of memory, thereby also being a demonstration of how to design a mnemonic for yourself using a phonetic sound, rather than word image.

the simple, the fleet thinker from the slow, the determined from the dallier; to represent a critical test of ability or understanding."

The point I am trying to make here is that in the symbolic worlds of language, music and art we have multidimensional isomorphic interfaces – they adapt, modulate or amplify information as they bridge domains.

Fig1.5.

(2 3 4 5 7 9 11 13 15 17 19 21 23 25 29 31 33 37 39 43)

In Fig1.5, the integers from this sifted set could quite simply be mapped into pitch space using Note Numbers (the mnemonic of which is NN). For example NN=43 is a low G. Unfortunately, NN=2 or 3 are very low notes, inaudible low frequencies, problematic sonically.

Therefore it is apparent that all the numbers need to be transposed up to a "useful" sonic range. At this point, a strategy is needed, decisions need to be taken. These decisions will move away from the patterns in the numbers, or any conceptual framework, towards the technical necessities of sonic music; much as the donkey *will* cross the water if some wood is laid across it. These choices bring with them aesthetic implications, and thats what makes them difficult. The distance to transpose is chosen by the conventions of praxis, technical limitations, subjective aesthetics and/or the ear. In effect, these decision procedures are sieves too and like the number sieves, they add information about themselves to the process.

To proceed with transposition, I settled on a seemingly arbitrary, mathematics-tinged strategy. I would derive a new set of numbers made from the squares of each element of an input set, offset by 60 or 80, and mapped into frequency space as Hertz values.

Once again I will document the reasoning behind these decisions. I chose to square, because no new numbers need to be decided upon, just one number multiplied by itself. The multiplication also happens to give a wider spread in frequency space, a musical bonus.

The 60hz or 80hz offset must be there, because below that are inaudible low frequencies. Essentially, this offset is a cutoff line for sonic meaning, set by ear.

Let us take a look at a sieved set after this transposition is applied.

(2 3 4 5 7 9 11 13 .... 43)

becomes

(64 69 76 85 109 141 181 229 .... 1909)

You could point out here, that we have actually moved some distance away from the initial idea of exploring prime number properties in music. You would be right.

Essentially, by deciding (a) to shift values and (b) to square them, I committed design choices which were against the starting point of the whole thing. In effect, there are no more prime numbers. Of course, these decisions were informed by something. What motivated them? By shifting the prime numbers around, I seem to have been deciding “by eye” that there would be a more interesting pattern when combined. And by eventually squaring and offsetting the numbers to generate a musical spread in frequency space, decisions were taken “by ear”. In effect the ear, the eye, and tacit experience were all making calculations too, some kind of “cellular computer”. And the results caused a rebellion against the formality of the numbers I had set out to explore with music.

Despite this distance from actual primes, the collections of numbers I was eventually working with were, nevertheless, still being derived from a lower-order “DNA” of prime numbers, which of course, do have special universal properties – these number sets are not completely arbitrary – they are not improvised or “invented” chewing on a pencil. Here we have an important point, and a small revelation.

In the process of “Eselsbrücke”, there is a formal mathematical aspect to the composition of the numbers, and this became inexorably fused with a visceral element – the inbuilt, bounce back necessities of nature, of music, of life. The eventual music is not about prime numbers, it is not a linear mathematical sonification. It is a music which symbolically narrates the way choices gain significance.

Let us return finally to some technical details, those of the additive synthesis, the characteristic sound of the final music.

I used the same sifted and shifted sets from which the frequencies were derived, to compose rhythm. For the generation of rhythmic pulses, I took each successive element of a set of primes, and mapped the number to the “Beats Per Minute” variable of a “clock” instance.

A “clock” has two states, an ON and OFF, which succeed each other in time, at a certain rate. This defines beat, the ‘tic-toc’ characteristic. The length of the ON state is called a Duty Cycle. A clock doesn’t have to be 50% ON, 50% OFF. It could be 99% ON and 1% OFF. If it were to have a Duty Cycle of 100%, it would no longer be a clock. It would be a continuous ON with no contrast, all figure no background. By varying the Duty Cycle, it is possible to shape the perceived 'figure-ness' of a clock. With a short duty cycle, a clock can have a more ‘pointillist’ feeling, and a longer one, more sostenato.

I worked with as many instances of “clock” , as there were elements in an input set.

When started simultaneously, one on top of another, each clock divides up a global duration (usually one minute) into ON and OFF states. All the ON OFF *states* are isomorphic with certain sound *events*. The time at which they occur, and the pitch they reveal, correspond to the same numbers. In this way, the intervallic pattern within a sifted set gets expressed simultaneously in time and frequency space, gaining dimensions of duration, timbre and dynamics which transform it into sonic music.

I was able to calculate and hear the results of all this process in realtime, using the Kyma music environment. The sounds from different input sets could be synthesised right away resulting in much deep listening. To finish the arrangements and narratives, I handed over entirely to “cellular computer” for picking input values which sounded most interesting, those which caused psychoacoustic ripples in the ears after listening, or those that caused an unexpected emotional response on their own, or juxtaposed with other material.

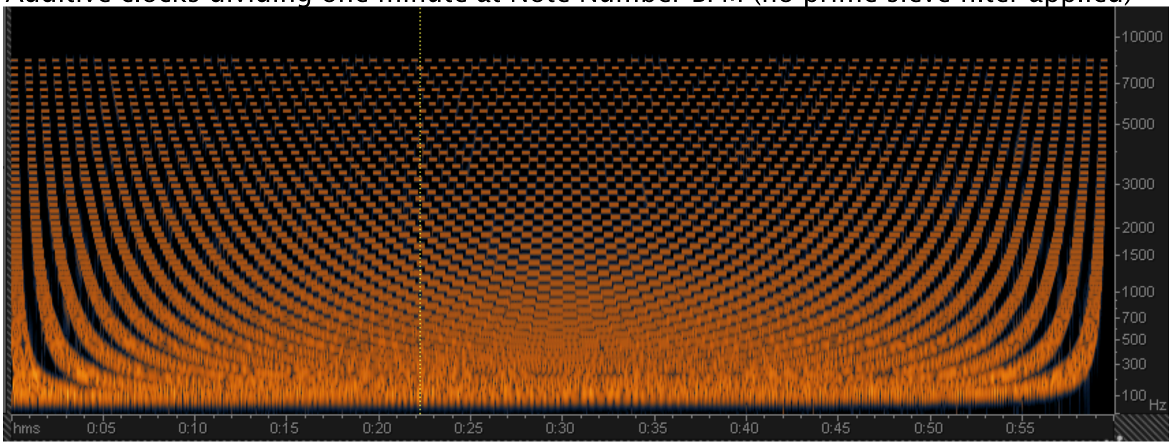
The entire method generated complicated music according to different input values, yet to the ear, it all seems quite coherent.  Listening to the final master recordings, I can hear quite characteristic structures. There’s reflections and elements which climb up and down, architectonic like brickwork, or steps, or mosaic. Narratives emerge.  A sifted set, when synthesised from its sequentially ordered form, could often be interesting enough as sound. Nevertheless, I might 'shuffle' the order of a set before recording, like a pack of cards. Perhaps a set might also get reversed or transposed again. Decisions like this, became more about whether to regulate something, less about arbitrary expressivity.

In the end, it is the symbolism of the bridge as forward progress, as interface, which emerges strongly from the “Eselsbrücke” compositions, more so than number patterns or sieve theory. For me, this symbolism represents the challenges we face as free agents, as we interface with everything through old analogies and uncertain decisions, like so many wobbly bridges. I hope the music inspires further crossings into unfamiliar territories.

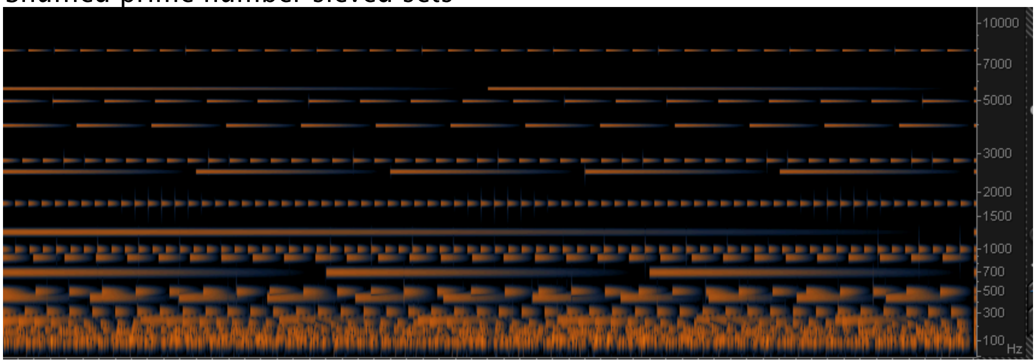
*Cristian Vogel “Eselsbrücke” will be released in May 2013 by Sub Rosa Records, Brussels*

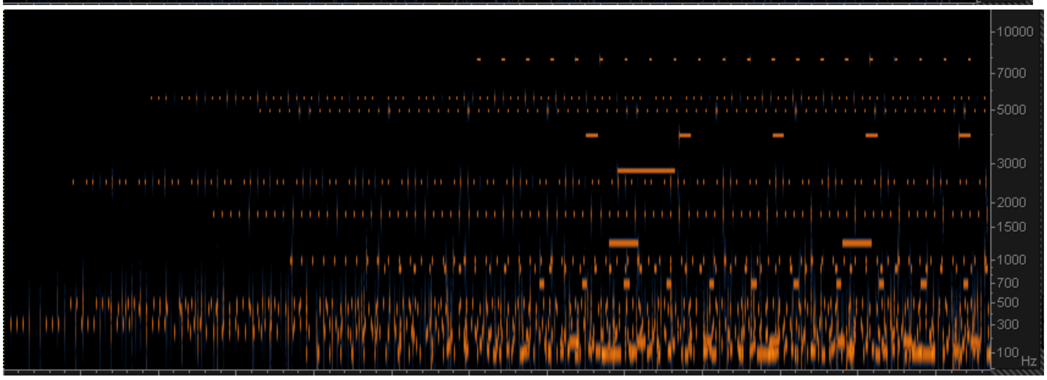
# SPECTROGRAMS

Additive clocks dividing one minute at Note Number BPM (no prime sieve filter applied)




Shuffled prime number sieved sets




Characteristic spectral structures