ASSIGNING ENGLISH CHANGE RINGING PATTERNS (PERMUTATION) IN ACOUSTIC AND EA MUSIC

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ABSTRACT

Change Ringing has been developed in English church towers since the 16th century. The number of towers in England dominates other countries in the British Isles - hence English, rather than British Change Ringing. Strangely, it occurred in few places other than former British colonies.

Bells have provided symbolic and cultural messages for civilisations throughout the centuries. They can provide signals and important information (someone's coming, bring out your dead…). Composers' have used bells for a corresponding amount of time, whether it is to investigate the spectral content (the very sound of a bell) or the envelope or pattern created through a peal of bells (Sir Peter Maxwell-Davies [1], Sir Harrison Birtwistle and Anthony Gilbert most notably in the 20th and 21st Centuries).

Permutations found in English Change Ringing Patterns can be very beautiful as a pure self-contained logical entity. They are not rung to sound a melody but rather create different mathematical patterns using the permutations on the set of available bells. This paper discusses a variety of applications within musical composition.

1. INTRODUCTION

Permutate *v.tr* = PERMUTE
Permutation *n*. 1. an ordered arrangement or grouping of a set of numbers, items, etc. 2. any combination or selection of a specified number of things from a larger group
Permute *v.tr* alter the sequence or arrangement of (from Latin *permutare* 'to change thoroughly')
Algorithm *n.* Math, a set of rules used for calculation or problem-solving

In English Change Ringing, permutations of bells are rung obeying the following simple rules. There are compositional and practical reasons for this, notably concerning the swing of the bell: [2, 3, 5]

1. bells are first rung in order from highest to lowest pitch (treble to tenor)
1. each bell is struck once in each row
1. a bell can move one place from one row to the next or stay in the same position
1. no repetition of the permutation is allowed until the last row returns

A simple four-bell permutation demonstrates these rules - note the movement of numbers (elements), rule 3. [2, 3]

$$1\ 2\ 3\ 4$$
$$2\ 1\ 4\ 3$$
$$2\ 4\ 1\ 3$$
$$4\ 2\ 3\ 1$$
$$4\ 3\ 2\ 1$$

An extract of a twelve-bell peal looks like this. Elements 11 and 12 are shown as E and T (look at the lines showing the path of bells 1 and 2). [4]

Figure 1 - Bristol Surprise [4]

2. TERMINOLOGY

2.1 Change Ringing [5-8]

Rounds - Ringing the bells in descending order of pitch (from treble to tenor – 123412341234 etc.). This is the oldest and simplest method and involves repetitions of all bells without changing order (as a loop).

Treble – highest bell signified as 1 in the score

Tenor – lowest bell (signified as 6 in a six bell score, or 8 in a eight bell score)

Hunt – (plain) ringing a pattern that ultimately reverses the set (and back again, 123456 to 654321).

Bob - to modify the sequence of changes in order to alter the path of the composition.

Dodge - To change direction for one stroke.

Queens – odd numbered bells followed by even (13572468).

Kings – reversed odd numbered bells followed by even (75312468) .

Tittums – high and long bells alternate (15263748).

Peal - the sequential ringing of all possible rows (also known as a *extent*). All permutations are performed without repetition. For an eight-bell peal (8! or 40,320 possibilities) this may take around eighteen hours to complete.

Quarter Peal - like a peal, but a quarter of the length. For a complete eight-bell peal this is still a significant amount of time but becomes more manageable with six and seven bells (less than an hour).

2.2 Maths, Permutation Formula and Set Theory

Permutation - an ordered arrangement of a selection of objects (numbers, variables, colours, notes, durations…) in which the order of the objects *is* of importance. English Change Ringing patterns are examples of permutations without repetition.

Set - a selection of objects (numbers, variables, colours, notes, durations…) in which the order of the objects *is not* important (neither is repetition).

$_nP_k$ - the permutation formula for the number of possible permutations of k objects from a set of n expressed as:

$$_nP_k = \frac{n!}{(n-k)!}$$

Group – all available permutations (also known as a *peal* and *extent* in English Change Ringing terminology). For instance, in a four-bell peal, there would be twenty-four listed permutations.

Element – in English Change Ringing patterns the elements of a four-bell peal would be 1, 2, 3 and 4.

Intersection (of sets) - the elements two or more sets have in common. Intersection is indicated by the '∩' symbol.

Union (of sets) - combining the elements of two or more sets. Union is indicated by the '∪' symbol. Intersection and Union are not directly relevant to English Change Ringing patterns where we are dealing with one peal at a time. It becomes relevant when using the elements for assigning in composition and is best-displayed graphically using Venn diagrams.

How many permutations? A greater number of elements gives a greater number of possibilities.

4 bells:	4x 3x2x(1)	4!	= 24
6 bells:	6x5x4x3x2x(1)	6!	= 720
8 bells:	8x7x … …	8!	= 40,320
12 bells:	12x11x10x9x …	12!	= 479,001,600

From this, it is clear that a complete peal with eight bells would take a considerable amount of time to complete. A complete peal with twelve bells would take an enormous amount of time!

3. COMPOSITIONAL TECHNIQUES

Within composition, the numbers (individual *elements*) found in English Change Ringing are *assigned* to various musical parameters.

3.1 Pitch

3.1.1 Fixed Pitches, Equal Density

The most simple and obvious use of change ringing patterns within composition is to assign the elements to specific pitches. It will produce an ostinato that never actually repeats until the permutation has been completed. In figure 2 demonstrates a simple outcome. It may be deduced from Section 2.2, that if this process is carried out to completion with a twelve-bell peal, the total number of possible twelve tone rows is over four hundred and seventy-nine million!

3.1.2. Fixed Pitches, Prioritised Density

In this example (figure 3), an E has been assigned to element 2 *and* 3 (in affect priority has been given to the E). It is arguably possible to produce a hierarchy of pitches (in simple terms, there are more E's; they will be heard more often than the others). These priority pitches will also appear next to each other whereas the other pitches cannot. It is important to realise that it is now no longer possible to distinguish between the individual E's (i.e. which E belongs to element 2 or 3).

3.1.3. Pitches in sets (and sub-sets…)

Pitches are grouped together (in this case in simple triads and single notes). The triads are treated as an individual entity that in turn is treated to the assigned element procedure. Sets may have objects in common. The macro-structure is being transformed to the micro in gradual stages as an evolving system.
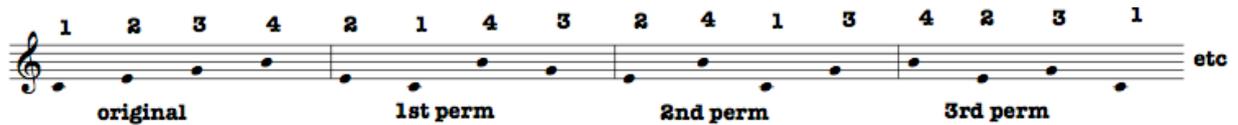
Figure 2 *(all figures until Figure 10 use a 4-bell peal - 'reverse bob')*

Figure 3

Figure 4

As with 3.1.2, the procedure is becoming harder to distinguish, with the composer exerting more creative influence over the simple process.

3.1.4. *Breaking away from fixed-pitches*

Figure 5 shows a simple orthodox inversion/mirror (other serial techniques could be used too) for changing the pitches but maintaining the pattern. The element still applies to the inverted pitch. The process shown in 3.1.3 can also be applied to this.

3.2 Rhythm

3.2.1. *Individual durations*

A separate duration is chosen and each one assigned to an element (figure 6). In this example the total sum of the duration is 3 & half beats. This could be notated in 7/8 bars. It could also be notated in 4/4 bars producing a change of stress on the beat. The final result is a *rhythmic* pattern that will never repeat until the permutation process has run its course.

3.2.2. *Durations as sets (cells)*

Figure 7 shows groups of durations. Here the total sum of beats is four. It includes one group of irrationals. Notice that this now contains notes and rests. It is possible to alter the density of the pattern by changing the value of the rests (from something totally continuous as in this example to something that is much more sparse). If grace notes were included in the same permutation it would become possible to have the grace note preceding a rest (possibly 'against the rules' in traditional western notation).

As with 3.1.2 it is possible to prioritise a certain rhythmic idea (several elements in the change ringing patterns could be all semi-quavers with a result of there being semi-quavers back to back). Again, it would not be possible to tell which semi-quaver belongs to which element.

3.3 Rhythm and pitch in combination

3.3.1. *Rhythm and pitch together*

In Figure 8, durations have been given pitches of their own. All aspects are fixed with the only change occurring in the order of the cells. This brings to attention the issues of play-ability and musicality. Not all of these would be natural or playable on many instruments (an issue that applies to many algorithmic techniques). A change of emphasis on the beat can be created as a result of cells with odd-numbered duration values.

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

3.3.2. Quasi iso-rhythms
(pitches from 3.1 combined with rhythm from 3.2)

Permutated pitches are placed upon permutated rhythms. This is always more interesting when the number of elements in the change ringing patterns is different for rhythm and pitch. For instance, a peal with six elements for pitch and seven for rhythm would produce an iso-rhythm undergoing permutation.

3.4 Dynamics

3.4.1. Changing Dynamic

Figure 10 shows how dynamics can be applied to this process too. As with the other parameters, not all of the dynamics need to be different. If the required underlying feel is to be quiet with the occasional interjection of an attack then most of the values listed in the change ringing patterns can be quiet with perhaps one being loud. As with the other parameters it is no longer possible to distinguish which value applies to which element.

3.4.2. Dynamics in Combination

When placed in combination with the rhythm and pitch example (figure 9) a very complex result can occur. It need not be this complex. All issues of play-ability and musicality are raised again.

3.5 Timbre
(References are to be found in Halo – for piano and responsive electronics, Duel – for piano and sound projection and Abigail's Party for String Quartet) [9-11]

3.5.1. Timbre and Structure

Section 3.1.3 gave an indication as to how the micro and macro structure of music can be controlled. Extending this idea, entire sections of pre-composed material can be isolated and placed into the change ringing patterns. If these sections become suitably lengthy in the context of the piece then the entire structure is then being influenced. Figure 11 shows an example from Halo – for piano and responsive electronics (2005). [10]

Sampling, as an electro-acoustic term, means taking recordings (normally quite short), storing them in isolation and using them as a sound source often via a MIDI sampling keyboard. When a sample is of a live event (a microphone recording of a real happening - someone talking, a trumpet sounding etc.), all aspects of this recording can be played back. This will include the sound source, but it also include the sound sources acoustic, any characteristics of the microphone being used - everything!

The previous examples shown here have demonstrated how a musical pattern can be built up and controlled. When the final result has been achieved it is possible to look back and see what you've got. Quasi sampling is a technique whereby musical quotations (from the piece itself or from others) are sampled and de-contextualised.

All aspects of the extract to be sampled are taken - as a block. As with electro-acoustic sampling, the sample can be 'processed' at a later time. Figure 11 demonstrates a simple 'quasi-sample'. The individual cells (samples) have been taken from elsewhere in the piece. Figure 12 shows four independent layers of quasi-sampling. Note the convergence point, 2nd beat of bar 60. [12]
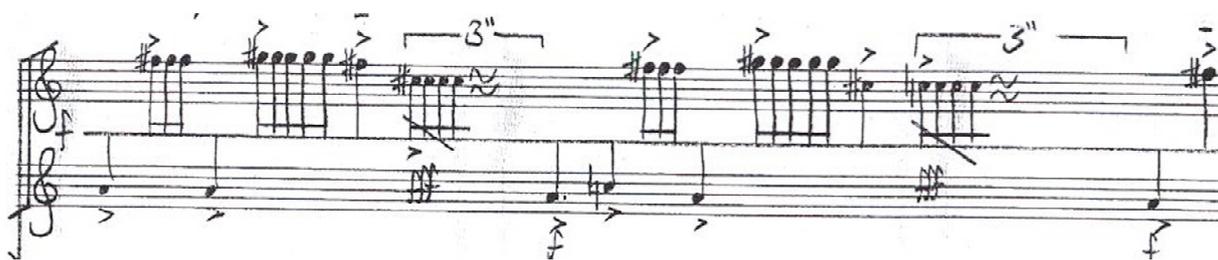
Figure 11 – *Halo* for piano and responsive electronics (2005) [10]

Figure 12 – *Abigail's Party* for String Quartet (1992) [9]

4. AN AUTOMATED ALGORITHMIC APPROACH FOR ACOUSTIC MUSIC

A series of six acoustic pieces originating from the authors fascination of Mike Leigh's play 'Abigail's Party' (the String Quartet shown in Figure 12 being the first) deals with the interaction between live performer and process. Change ringing patterns are used in an analogous way to transform pseudo dialogue. [9]

In 1992 all methods of assigning elements to musical parameters were manually produced. Clearly, this is a time intensive, error ridden method! An automated technique was required.

4.1 Automation

Section 3.1.3 demonstrated a means of generating quite complex material through sub-grouping. A computer will carry out these quire complex operations with consummate ease. However, permutations by their very nature change the internal order of given material. Computers are most happy when allowed to simply repeat material. [Godman Trigger Permutator] is a programme written in Max/MSP and is based upon an eight bell peal (the contents, or permutation numbers being found in the objects [p duff8-selector1].
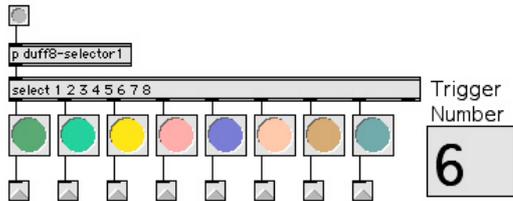
4.2 Max/MSP Realization

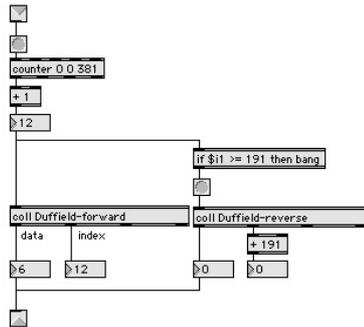Figure 13 - [Godman Trigger Permutator]

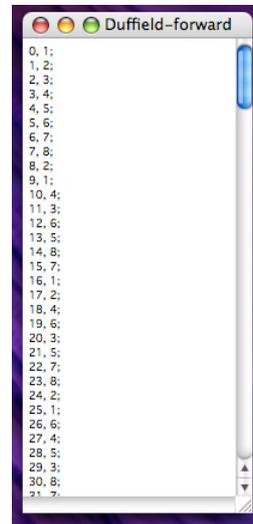Figure 14 - [p duff8-selector1] subpatch

Figure 15 – notated MIDI capture

Figure 16 – contents of [coll Duffield-forward] (index on the left; elements on the right)

Figure 17 – two extracts using captured data; *Duel* - for Piano and Sound Projection (2007) [11]

Figure 13 shows the [p duff8-selector1] subpatch connected to eight buttons. The numbers listed in Figure 16 are an extract of the contents of the [coll]. The outputted numbers are triggered via a counter (see Figure 14, the permutation 1 2 3 4 5 6 7 8 being the first group of eight numbers, 2 1 4 3 6 5 8 7 being the second).

At this point, it becomes clear that these buttons are capable of being connected to any Max/MSP/Jitter event. Needless to say, the event need not necessarily be musical. Lighting control, switching for other controllers etc. could all be permutated. An additional advantage of such a system is that it is fast and doesn't make mistakes! The level of complexity can also be increased if desired and assigned elements changed on the fly.

The simplest scenario is that the buttons are connected to MIDI pitches (as detailed in 3.1.1). The material can be notated, if required, by routing the MIDI information through to a notation package (Figure 14). In this case, two differing permutations (eight elements each) are employed simultaneously, offset by one semi-quaver.

5. INSTALLATION AND NON-LINEAR EA COMPOSITIONS

Up until this point, this paper has demonstrated techniques within an acoustic framework. The Max/MSP patches have also been used in installation works with the purpose of creating constantly changing and evolving sound worlds – the change taking place over days and months.

Solid/*Ephemeral Cube* is a collaborative work between the author and glassmaker Colin Reid (UK). The installation has run over a period of months with all aspects of the audio being subject to permutation over this time. The work explored the idea of creating alternative acoustic spaces, some real and some imaginary. The listener experienced these spaces as a series of overlapping and shifting montages. Partly, the intention was for audience members have a different experience each time they visited the site. It should be noted that *Solid*/*Ephemeral Cube* is still a linear composition, all be it, a composition without an end.

Figure 18 shows the Max/MSP patch (a series of control strips) each having a separate [coll].

5.1 Analysis - *Solid*

Audio is pre-rendered although spatialization takes place controlled through a 4 element permutation series (Solid runs in quad).

There are seven control strips. A maximum of seven sounds (spaces) can play at any one time.

Each control strip will trigger once every 70", 110", 130" (twice with offset), 170", 190" and 230" (i.e. each [coll] is triggered at a different rate - specified as a multiple of a prime number in seconds). This means that the fastest rate an element can change is 70". Each has a separate permutation group. The numbers were chosen for interesting (and avoidance of) convergence points. [12]

Each control strip can play back between four and eight sounds in its 'bank' (but only one at once). It chooses which sound to play through a permutation series of between four and eight elements. The control strip will not play each time it receives a trigger (from [metro]) as a linear sequence of on/off commands is contained in each series allowing increasing amounts of silence into the work.
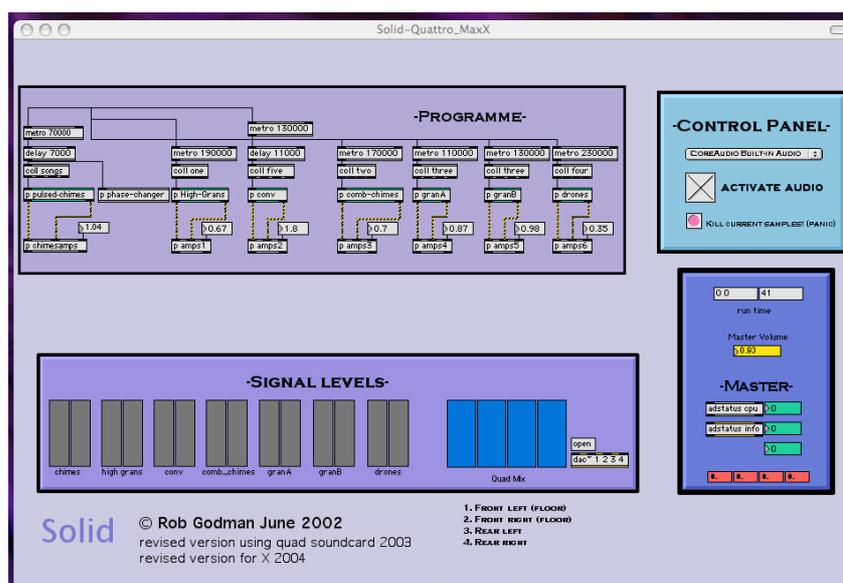

Figure 18 – code for *Solid*/*Ephemeral Cube*, in collaboration with glassmaker Colin Reid (2002)

6. THE WORK OF OTHER ARTISTS AND PROGRAMMERS

The programme note for Sir Peter Maxwell-Davies' *Stedman Doubles* [1] states - *'the work has as its basic 'set', pitches and note-values based on the bell-peals of the title'*. Somewhat alluringly, exactly how Maxwell-Davies has used these permutations is well hidden and far from obvious in the score.

Examples of change ringing can be found in literature, most notably *The Nine Tailors* [13] by Dorothy L. Sayers (ringing a church bell nine times signals the death of a man in a parish). The Sayers novel, part of the Lord Peter Wimsey series, uses English Change Ringing patterns as an intrinsic part of the structure, with all chapter headings making thinly veiled references to the terminology. Wimsey finds riddles and codes hidden within the permutations themselves, helping him solve the mystery.
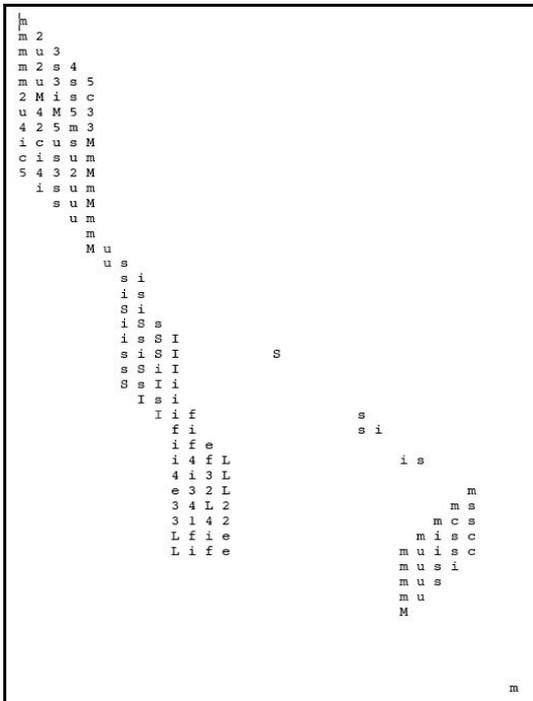
Assign a letter, a number; to a pitch, a rhythm, a dynamic, a sample, a MIDI value, a . . . ;

Figure 19 - *Music is Life* (score, 2006) [14]

Music is Life was written by the author at the request of Andrew Hugill (de Montfort University, UK) for his book 'The Digital Musician', published by Routledge in 2008. Here, elements are assigned to letters and numbers and used spatially.

Nick Collins produced a series of experiments using English Change Ringing for Breakbeat Cutting with SuperCollider. He makes a number of illuminating points in relation to aural discrimination and perception. [16]

"The effect of differentiation [of different change ringing compositions]… For breakbeats, where a similar kick sound might be presented later in the sample, the position states are not so discrete. Because permutations may not take account say of the difference between different positions in a measure (strong, weak pulses) output breakbeat patterns can be very distorted in their feel. However, the sequence of permutations as applied to breakbeats gives a good sense of continuous variation,… without sounding like total randomness; there is method here."

7. CONCLUSION

The examples, for the purpose of this paper, have demonstrated clear use of the procedure of assigning musical parameters to elements. Systems can become complex very quickly making them difficult to analyse. English Change Ringing Patterns are regarded by Campanologists as compositions in their own right (*Snowdon, Diagrams*) [4] with new works being written and performed. Technology has greatly aided the creation and mathematical proof of such systems and it is likely these will be worthy of investigation for the algorithmic composer. However, there is clearly more to the creative process than simply replicating patterns.

8. REFERENCES

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