

Processes
and systems
in computer
music; from
meta to matter

DR TONY MYATT

05

QUADERNS
D'AUDIO

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start

'...[there is] no concern for discontinuity [from a musical heritage] – rather a surprising acceptance of even the most banal of continuity devices: ascending or descending passages, crescendi and diminuendi; passaged from tape to orchestra that are made imperceptible. The skills that are required to bring such events about are taught in the academies. However, this scene will change.'

John Cage, 'History of Experimental Music in the United States' (1959)¹

1 John Cage, 'History of Experimental Music in the United States' (1959), *Silence*. Middletown, US: Wesleyan University Press, 1961.

The use of the terms 'system' and 'process' to generate works of music are often applied to the output of composers such as Steve Reich or Philip Glass, and also to Serial composers [🔗]² from Schoenberg to Stockhausen, or to the works of experimentalists like John Cage. This may be where these terms are most clearly expressed, in either the material of the work or in the discourse that surrounds it, but few composers would not claim that systematic processes lie at the root of their work, in the methods they use to generate, manipulate, or control sound.

The grand narrative of twentieth century classical music to move away from the tonal system of harmony has prompted experimental composers to push at the boundaries of music to discover approaches that create original musics. With the advent of the computer age and the use of computers to control and generate sound, it appeared to many that it was inevitable this new technology might take forward the concept of music. Computers, as we will see, were initially employed as tools that sustained traditional concepts of music, but as Cage hinted in 1959, and maybe for the same reason, perhaps this is now changing.

In this essay, I will discuss how these early approaches to systematic process developed a canon of computer music, and in particular algorithmic systems and processes that reflected an underlying vision of what computer technologies were thought to hold in store, from a utopian and rationalist perspective. I will look at the musical forms and outputs of a several composers, consider their writings and propose a distinction between two types of contemporary practice: one that reflects a modernist, rationalist stance, and one a pragmatic approach, also common in contemporary philosophical discussions about the use of technology in many aspects of our lives.

Experimentation with music: some pre-computer music

At beginning of the twentieth century, Charles Seeger, Ruth Crawford and Carl Ruggles, and famously Henry Cowell, established musical experimentation and process as an area of fruitful investigation.

Compositional principles to achieve dissonance were defined by Charles Seeger in his text On Dissonant Counterpoint [🔗],³ developed around 1914. This described a series of rules to establish how prominent harmonic dissonance might be achieved when creating

2 The text includes numbered references to a series of related links included by the editors.

3 Charles Seeger, 'On Dissonant Counterpoint', *Modern Music* 7, no. 4, New York, (June–July 1930), pp. 25–26.

musical counterpoint. Works such as *Psalm 137* (1923) illustrate these rules: melodies should consist primarily of dissonant intervals; no consonant intervals could be used between simultaneous musical lines; pitches could not be repeated until five notes had passed; and so on. Dissonant rhythms, irregular subdivisions of the music's beat, were also promoted.⁴

Ruggle's work *Portals* (1925) employs two sections and an introduction and coda. It exhibits a typically arched shaped formal structure. Similarly, for *Sun-treader* he employed canonic techniques and formal organisation principles similar to those of a sonata (that would have been familiar to Hayden and Mozart), but within this formal framework he applied abstract processes, palindromes of pitch sequences and used multiple lines of music all created within the rules of dissonant counterpoint. He also added parallel pitches to track these lines at a consistent dissonant interval.

Ruth Crawford's *Diaphonic Suite No 2* and *No 3* (1930) used an extension of dissonant interval principles, through the use of note trills to establish a harmonic function. Works like her *2 Ricercare: Chinaman, Laundryman* also illustrate her use of rotations of short sequences of pitches, transpositions of these plus rotations, retrogrades, inversions and permutations of intervallic pitch sequences; abstract manipulations of pitches similar to Schoenberg's Serial pitch permutation techniques.

Seeger's dissonant counterpoint methods were developed further by Henry Cowell, a student of Seeger at Berkeley, to encompass a formalised system to create rhythmic dissonance in his *Concerto for Rhythmicon* [\[1\]\[2\]](#) and *Orchestra* (an instrument that could produce rhythms linked to corresponding harmonics in a spectral series). Nicholls⁵ describes how the principles underlying the *Rhythmicon* were demonstrated to Cowell at Berkeley using a phonograph [disc](#) [\[3\]](#). This had an increasing numbers of clicks in concentric circles from the centre to the outside of the disc, from one click in the centre to sixteen clicks in the outer groove, as demonstrated rhythmic counterpoint. Cowell developed this idea in *Rhythm-Harmony Quartets* where the 4th, 5th and 6th partial of a harmonic could generate 4 against 5 against 6 beats in a bar. Under this system, harmony would automatically generate its own corresponding rhythms. Cowell describes this rhythmic generation process and similar methods in his *New Musical Resources*⁶ text, which contains similar rule-based techniques to developed chords and harmonies derived from harmonic series, along with other formal rules to generate music.

4 David Nicholls, *American Experimental Music: 1890–1940*, Cambridge, UK: Cambridge University Press, 1990, pp. 91–93.

5 Ibid. p. 141.

6 Henry Cowell, *New Musical Resources*, Cambridge, New York, and Melbourne: Cambridge University Press, (1996 [1930]).

Systematic composing to generate musical materials and define a musical language also lay at the heart of the Second Viennese School of composers. This is well documented elsewhere, and of course is most evident in the work of Schoenberg and Webern, their disciples of the avant-garde and those concerned with Total and Advanced Serialism. All these pre-computer systematic approaches had a subsequent impact on the evolution of computer music.

Computer music: three points on a line beginning

Most early computers could only generate simple electronic noises and tones, but had the capability to manipulate data, which controlled these quite easily. Early attempts often applied software to reproduce sequences of pre-programmed notes like a barrel organ or a player piano. Finding ways to operate on these sequences of notes or to create them within the computer become a focus of activity.

Computer music pioneer [Lejaren Hiller](#) [\[4\]](#) discusses these approaches in his 1969 article, 'Some composition techniques involving the use of computers'.⁷ He describes how he and Robert Baker made a music composition programme 'for generating musical scores'.⁸ This MUSICOMP software was used to compose the *Computer Cantata* [\[5\]](#) and the *Illiac Suite for String Quartet* [\[6\]](#), the most cited work of Hiller and his collaborator Isaacson. It was a suite of programs divided into three types: system regulatory routines; composition and analytical subroutines; and sound synthesis routines (these did not perform sound synthesis but prepared data for use in programs which did). In the compositional category the software consisted of: code that would choose values according to several probability distributions, for the purpose of musical parameter generation; a series of processes that performed permutations on data, such as the random shuffling of a sequence of pitches; a series of Markov chains, to make random choices based on previously occurring patterns of data and other subroutines.

Hiller's processes were applied to generate fixed musical scores and then performed by musicians (contemporary computers can use similar compositional rules in real-time, to generate different patterns and music on each performance). From these beginnings the computer was treated as a vehicle for the realisation of compositional ideas, a blank slate on which any musical idea could be realised, if only sufficient software were available.

7 Lejaren Hiller, 'Some composition techniques involving the use of computers', in *Music by Computers*, Foerster and Beauchamp, University of Illinois Press, Wiles and Sons, NY, USA, 1969.

8 Ibid. p. 71.

middle

In *Fractal Mountains* [10] (1988)⁹ Gary Lee Nelson created a work using fractal principles [10]. He applied segmented lines to shape the development of pitch sequences. A line was first drawn and then subdivided by imposing its initial shape at ever decreasing ratios, onto the original – in the manner of a self-similar fractal processes. After four subdivisions this process creates a contoured line, and ‘an image emerges that reminds us of the patterns found in natural landscapes... to arrive at pleasing melodic contours.’¹⁰

To create sound from these shapes, he used a method to convert the lines into discrete steps to control the pitch, loudness and timbral qualities of a synthesiser. The analogies he uses to describe this design are expressed in the same terms as are used to describe fractal images: the processes of composition are ‘...determining whether the beach [the piece] is covered with rocks, pebbles, or fine sand’. The resulting generative process is controlled by a performer depressing the keys of a MIDI wind controller (like the keys of a clarinet). The software plays a synthesiser set to reproduce a microtonal pitch scale (the octave divided into 96 pitch steps).

Many elements might be at the foreground of the work’s reception: the microtonal scale system, the material sound generated by the synthesiser, the concept that segmented lines can control melodic trajectories or that these could develop a fractal based musical language.

Nelson’s work with chaotic algorithms *Bifurcate Me, Baby!* [11] (1995)¹¹ was composed in response to a request for a short piece to be included in a concert of the Yamaha Disklavier. His notes on the work describe how the mathematical parameters of the logistic difference equation affect the output of the algorithm, and also the algorithm’s bifurcation process. The work¹² is a player piano piece featuring oscillating pitches and an increasing density of notes. It translates a selected proportion of the algorithm onto the notes of the piano. Fig. 1 describes the work, and can be compared with Fig. 2 to show how the piece embodies the algorithm’s behaviour, how the algorithm is interpreted in discrete note steps, and how the musical implementation of the algorithm in the work is subject to a palindromic permutation. ‘I used the golden section [10] to determine the proportion between the rising and falling gestures.’¹³

9 <http://www.timara.oberlin.edu/~gnelson/mp3s/FullLengthMP3/Mountains.mp3>, as 23/12/10.

10 Gary Lee Nelson, <http://timara.con.oberlin.edu/~gnelson/mp3s/ProgramNotes/FractalMountains.html>, as 23/12/10.

11 <http://www.timara.oberlin.edu/~gnelson/mp3s/ProgramNotes/BifurcateMe.html>, as 23/12/10.

12 <http://www.timara.oberlin.edu/~gnelson/mp3s/FullLengthMP3/Bifurcate.mp3>, as 23/12/10.

13 <http://www.timara.oberlin.edu/~gnelson/mp3s/ProgramNotes/BifurcateMe.html>, as 23/12/10.

The notes of a piano conform to an equally tempered scale. This is the division of a continuous pitch range into equal steps. The method for this division was first introduced in the late sixteenth century so that music could be transposed to different pitch registers and retain the same interval structure between notes. This facilitated key changes in tonal music.

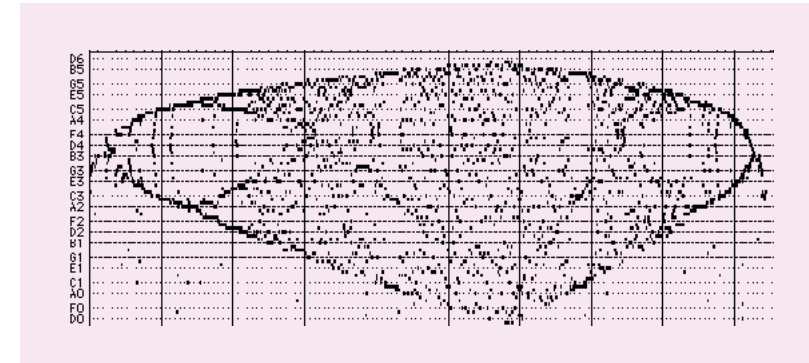


Fig. 1. Score of *Bifurcate Me, Baby!*, by Gary Lee Nelson (1995). Courtesy of UC San Diego.

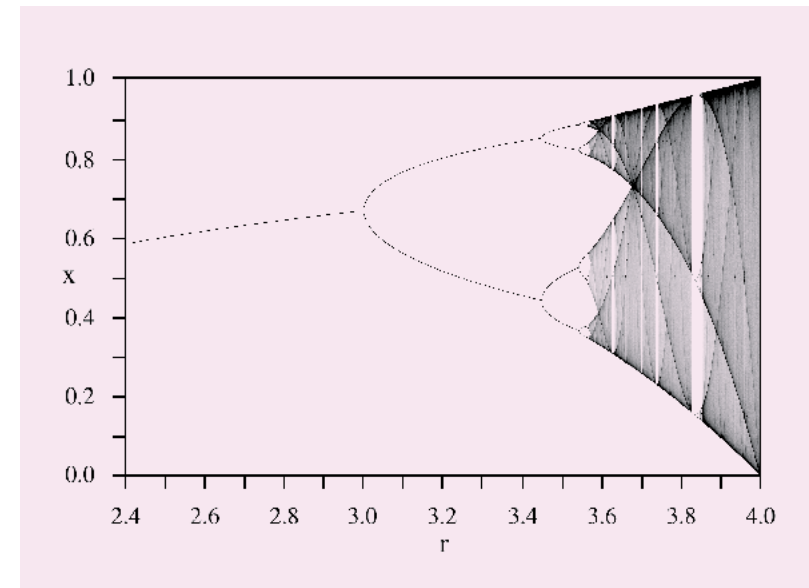


Fig. 2. Iteration of the Logistic Map Equation [11] (Wikimedia Commons).

The essential components of this work are: the algorithm, its interpretation, the palindromic exposition to shape the piece and the introduction of the 'golden section' to organise the structure of the work.

end

Eduardo Reck Miranda's [\[1\]](#) book *Composing Music With Computers*¹⁴ is a guide to computer composition. It describes 'music as generally [being] associated with the artistic expression of emotions' and goes on '...but it is clear that reason plays an important role in music making'. The primacy of reason and the consequent themes in the historical context of the text could not be clearer. This rationalist position is reiterated on several occasions: 'At the writing stage, the composer then materialises his conceptualisations into music';¹⁵ 'music may be regarded as invoking cognitive phenomena at one of the most deep and sophisticated levels of human intelligence: ...*metaphorical associations*' (emphasis in the original).¹⁶ This description of music is rejected by radical contemporary composers of computer music.

The text builds to a description of Miranda's propositions for organising musical components, Evolutionary Music. This technique translates the time varying patterns produced by cellular automata algorithms, artificial life algorithms and genetic algorithms into sequences and patterns of notes. He describes how computer algorithms function and can be applied to 'play melodies', 'perform retrograde inversions of pitch sequences', but differs from Hiller and Cowell through the inclusions of iterative algorithms, fractals and chaotic algorithms. Each is described in relation to their conception in realms outside of music, their mathematical behaviour, and an identification of similar patterns of behaviour within established music. Miranda introduces neural computing models in a similar way, and includes a 'hypothetical example where one wants to train a neural network to produce a particular style [of music]'.¹⁷ Here, style is only manifested as a melodic sequence of pitches.

In its final case study, and in an echo of Cowell's *Rhythmicon*, the book describes a further hypothetical example, to generate a sequence of notes derived from the spectral harmonic content of vocal sounds. The case studies are all presented as propositions about how various pattern generation processes can be used or combined to generate music.

The similarity between this description and that of Seeger or Cowell is clear, but Miranda's rarely references practice as they do. This is a highly theoretical model based

14 Eduardo Reck Miranda, *Composing Music With Computers*, Oxford, UK: Focal Press, 2002.

15 Ibid. p. 11.

16 Ibid. p. 14.

17 Ibid. pp. 113–14.

in the domain of computer tools. Software tools also accompany the book and include harmony generators, fractal music programs, and 'an affordable brain wave analyser' (demo version). These are described without reference to works of music; process is consistently described without reference to sound or musical works.

coda

The common thread running through these systematic rules is the quest for a new language of music; the definition of systematic rules that could be followed by others to organise their musical materials – that material is primarily reduced to the pitches of notes, their rhythms, durations or loudness.

Significantly in this context, many of these rules were seen to be manipulations of data sets, permutations and modifications of, say, numbers that might represent each note on the piano. The process of inversion, retrograde, expansion or contraction of a sequence of parameters is seen to be no different from the permutation of any number. Following this assumption, any mathematical technique can generate note sequences or rhythms.

The numeric permutation or generation techniques applied above adopted the hi-tech signifiers of their age, defining the new, the modern, the latest theoretic discoveries – logic systems, heuristic and stochastic processes, iterative mathematics, chaotic systems, fractals, artificial intelligence and neural computing, evolutionary models and genetic engineering. These signifiers appear to be intentionally associated with the composition work, but we might ask what these have to do with the realm of music per se, the social experience, the function of music or why these methods are likely to result in new musics rather than permutations of traditional musical parameters? How are these complex permutations to be heard and understood within music? Does the experience of the resulting music result from these metaphorical origins?

Although it is a belief that the world can be described completely by unified theories, and widespread practice will automatically follow theoretical discoveries, can we identify evidence in the history of computer music that this is truly the case, or are we witnessing an endless repetition of Cowell's project to instigate a metaphysical system of rules, based on traditional musical assumptions – notations, scales and parametric thinking?

Some pragmatic situations

Haswell and Hecker's *Blackest Ever Black* [1][2][3] (Warner Classics, 2007) used Xenakis' UPIC machine exclusively for sound generation. The UPIC is a computer system for creating sound where the user draws on a blank computer interface or 'page'. A number of lines or arcs, up to around 3,000, can be drawn onto the page. Each page represents a defined period of time. As each arc ascends the screen, so the frequency gets higher. When a line terminates, the sound component it represents stops sounding. Multiple lines create sound textures.

The UPIC was designed following Xenakis' concept that anyone should be able to make sound with the machine. Its pedagogic applications were central to his motivation but he also used it to create electronic music. Xenakis' UPIC drawings consisted of sweeps, curves, graphs, gestures and lines, or appear to be drawn with the intention to produce the types of complex timbre featured in his previous compositions. He also used drawings inspired by natural, organic forms, although it seems clear that these were drawings infused and directed by a knowledge of additive synthesis techniques and preconceived musical sound trajectories, musical forms and audio textures.

In preparation for the *Blackest Ever Black* project, Haswell suggested to Hecker that they take the idea of drawing more literally, and adopt an approach to sound generation that used images in a way that if one were to produce a frequency analysis spectrum of the resulting work, it might recreate a series of pictures, a sequence of transformed drawings. Under this approach he also sought to eliminate issues about how one might move between successive pages in a UPIC composition. Many composers had meticulously tried to match the end of one page with the beginning of the subsequent page, to create a continuity of sound.

The process used by Haswell and Hecker was to constantly engage in a dialogue with the technology, try a range of drawings, listen, form judgements about the resulting sound then either modify it (primarily by making multiple copies of, or shifting an image) or rejecting the output and trying another drawing.

In fact, the final UPIC sound outputs were edited together, so the reverse-engineered sonogram of the piece might reveal '...half a leg and the end of a kebab...'¹⁸ This approach reveals an application of technology without predetermined concepts of the final work's material form. Here, the process of operating with the audio technology is not to force it to realise a pre-conceived idea, but to establish a working method, to evaluate the outcome then act to shape it to reveal and expose the sound of the UPIC

¹⁸ Russell Haswell, interview with the author 1 December 2010.

itself. Seeking these models of practice is also prompted by discovering something new about a well established technology: '...other people tried to do more "musical" things or produced material intended to accompany instrumental performers, but the sound the UPIC could make wasn't being explored'.¹⁹

As Gary Lee Nelson, Roc Jiménez de Cisneros was also drawn to work with the logistic map through his audio projects in the *Punani* [1] series of CD and vinyl releases.²⁰ His approach is not to confront, describe or attempt to understand the behaviour of this algorithm. He emphasises experimentation with the algorithm over theoretical understanding it. He is drawn to specific types of behaviour found in mathematical systems, and in discussions with the New Aesthetic in Computer Music research group,²¹ he refers to Robert May's investigation of dynamical non-linear systems,²² which led to his frequent use of equations such as the logistic map [1].

Roc identifies a tension between chaotic processes and an interplay between stable states and chaos [1]. 'It's something I try to find... in the algorithms to make these patterns... tiny structures like instances of constant iteration of different functions.' Roc also sees this play between unpredictable and predictable states as a way of generating sound materials that exhibit 'aggressive' characteristics. His works, such as *Punani Xerrameca* (ALKU, 2009), create a direct connection between a mathematical function and a sonic parameter, treating the algorithms as they are, without attempting to make a connection with 'musical' process such as a scale or musical form, e.g., without adding a formalised approach to frequency, in the form of an equally tempered scale.

As a complement to this treatment of the algorithm EVOL compositions often employ sawtooth oscillators without modification, avoiding obfuscation by musical conventions, and to develop a simplicity and immediacy of sound. It appears that he also has no interest in creating sound that reveals its mathematical source. Instead he is primarily concerned with the characteristics of the sound in itself. 'What I want in the end is something that sounds appealing to me. The sound is not intended to point to, or embody, something beyond itself, but to be engaged with phenomenologically'.

The metaphorical processes, described earlier, can be contrasted with methods used to define computer algorithms as a result of practical experience with music technologies or computer software.

¹⁹ Ibid.

²⁰ *The series contains: Super Punani*, 2003 (Fals.ch); *Punani Shell*, 2004 (Scarelight Recordings); *Punani Quatre*, 2006 (ALKU); *Punani Rubber-ist*, 2008 (Entr'acte); *Punani Xerrameca*, 2009 (ALKU).

²¹ New Aesthetics in Computer Music Project, discussion with researchers 19–27 November 2008.

²² Robert M. May, 'Simple mathematical models with very complicated dynamics', *Nature*, 261, June 1976, pp. 459–67.

Sean Booth²³ describes Autechre's [10] (Sean Booth and Rob Brown) use of software and other musical technologies commenting: 'There's a lot of maths and generated beats on [the album] *Confield* (Warp Records, 2001)... They're based on sets of rules and we have a good handle on them.' The musical processes he describes in the article [10] are derived from experimentation with sequencers and a variety of other music technologies to develop rhythmic or sound manipulation processes.

In many instances, these processes are realised on computer (or with some other technology) but rarely as autonomous generators, incarnations of a fully formed musical idea per se, but as materials to be manipulated as music is being generated by them: 'When we do generative stuff we work with real-time manipulation of MIDI faders that determines what the rhythms sound like... we're using our ears and the faders to make the music.'

Outcomes from these processes develop distinctive music or methods derived from practice and experimentations with technology. The musical methods that result, e.g., beat patterns that skip or slide out of synchronisation, are also applied in some instances without the use of computer algorithms, e.g., *Draft 7.30* (Warp Records, 2003), which with the exception of the track *Reniform Puls* was created with 'straight-up normal sequencers and samplers. It's written note by note.'

quit

By creating sound works that are contrary to many musical traditions, these artists can be seen to question previous methodologies and descriptions of computer music. The new points of emphasis promoted by these works, and the descriptions of practice and process they offer, both reveal and reject underlying assumptions about meaning, expression and emotion that inhabit many critical encounters with computer music.

Acknowledgements

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²³ Paul Tingen, 'Autechre, Recording Electronica', *Sound on Sound* magazine, Cambridge, UK, April 2004.

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05

Dr Tony Myatt is the Director of the Music Research Centre at the University of York, UK. He is the principle investigator of the UK Arts and Humanities Research Council's New Aesthetics in Computer Music Project. He is an author, software programmer and academic working in the field of computer music, surround sound and electronic music composition, and was a founding editor of CUP's journal *Organised Sound*. He works closely with Thyssen-Bornemisza Art Contemporary (T-B A21) on the development, implementation and curation of *The Morning Line*, a large scale public sculpture and surround sound installation. He has collaborated on the creation of new multi-spatial works with artists including Yasunao Tone, Bruce Gilbert, Carl Michael von Hausswolff, Florian Hecker, Peter Zinovieff, Lee Renaldo, Jana Winderen and Chris Watson.

In this essay Dr Tony Myatt describes how processes and systems were applied in early experimental music, and contrasts two approaches to the use of systematic and algorithmic processes in experimental computer music. He distinguishes two practices, one based on the evolution of historical models which emphasise a rationalist position, and another more radical contemporary approach based on the material substance of computer sound and technological processes.

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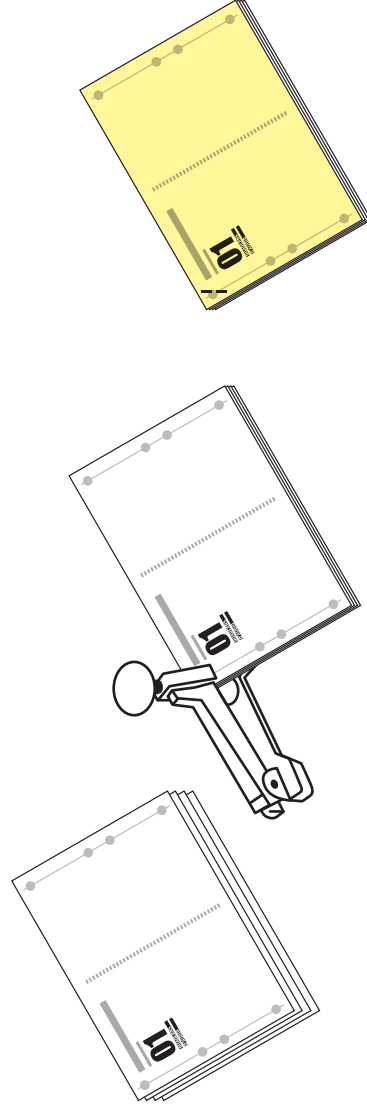
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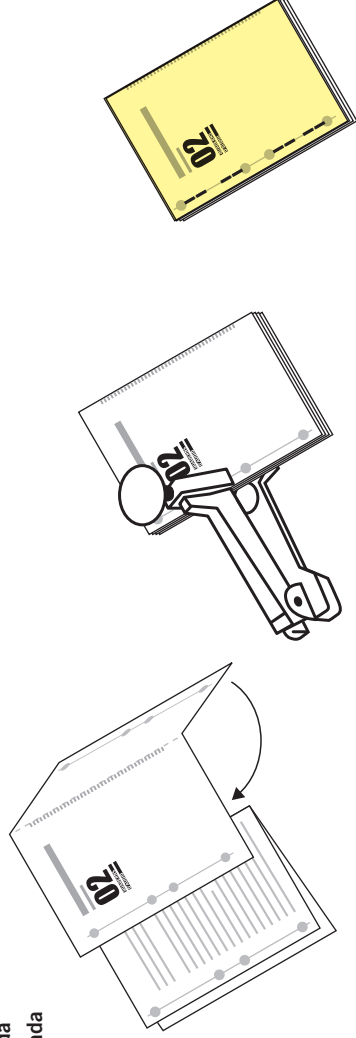
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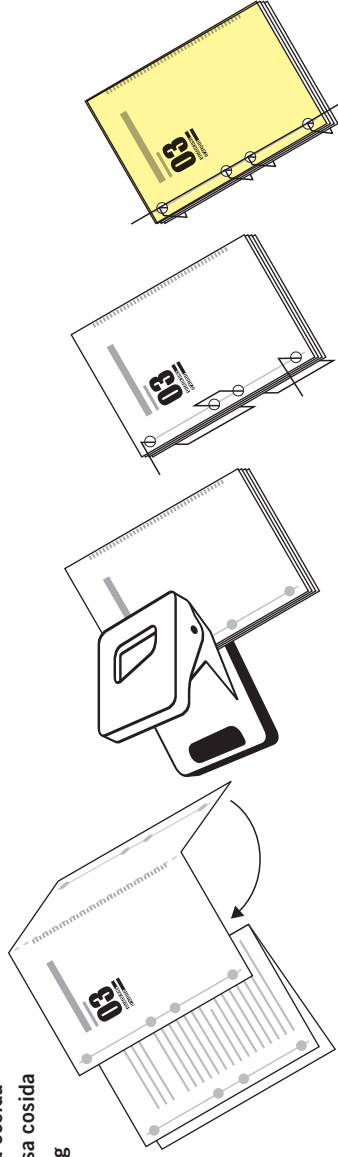
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