ALGORITHM-BENDING AS TACTICAL MUSICKING: DSP DEVIANCE AND AUGMENTED SAXOPHONES IN THE *ERRO.* PROJECT

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ABSTRACT

The *ERRO.* project [1] follows a practice-based approach to explore and develop algorithm-bending strategies—forms of critical creative coding expressed through instrumental augmentation and mixed-music performance. We introduce algorithm-bending as a practice of deliberate deviance applied to DSP algorithms, generating a multilayered interplay between digital objects, augmented instrumental performance, and critical media theory. Algorithm-bending is intended as a form of artistic contestation: a tactical musicking praxis within the computational systems that increasingly mediate social and cultural life. Following the lineage of misuse and hacking practices, and informed by glitch aesthetics, *ERRO.* treats intentional algorithmic errors as strategies of artistic interventionism. Errors signal here a deviation from technical, moral, or semantic systems prescribing normative functionality. In *ERRO.*, these deviances are introduced at the algorithmic level and enacted through augmented saxophone performance, which serves as an embodied vehicle for contesting the increasing autonomy of computational processes. Within this framework, algorithms are not approached ontologically as neutral rule-inscription and execution mechanisms, but rather as actionable, and thus epistemologically situated, socio-technical structures that exceed their formal specification. It is precisely within this exceedance that *ERRO.* finds a threshold for intervention.

1. INTRODUCTION

Subsection 1.1 situates the project within a broader historical context of misuse practices, while subsection 1.2 outlines the authors' intention to develop the algorithm-bending practice for critique. Sections 2 and 3 detail the practice of algorithm-bending and its inseparable augmented performance dimension. More specifically, section 2 defines the algorithm from the project's perspective (2.1), presents the algorithm-bending methodology (2.2) through two case studies—*erro.convolution*~ (2.2.1) and *erro.psola*~ (2.2.2)—and explains its use as a compositional tool (2.3). Section 3 addresses performance practice. Section 4 situates the project within the lineage of tactical media practices (4.1) and articulates the critical framework that underpins it (4.2), while the concluding section presents preliminary findings and future directions.

1.1 Situating *ERRO.* within misuse practices and their paradoxes

Algorithm-bending is inscribed within the legacy of technological misuse practices [1], in particularly circuit-bending [2, 3] and hardware hacking [4, 5], and resonates with the post-digital aesthetics and theories of failure and glitch [6–8], such as data-bending [2] and hacking art [3], alongside more recent forms of algorithmic misuse such as neural network bending [9] and prompt injection [10]. These practices, which repurpose technologies beyond their intended scope, have the potential to contest the mainstream techno-culture, generating new expressive vocabularies and alternative modes of practice [11]. Nevertheless, as with other forms of counterculture, artistic dissidence and contestation remain susceptible to co-optation and instrumentalization. The deliberate disruption of technologies risks becoming a new canon [7, 8] legitimised by the normative system that adopts and reifies errors, deviances and glitches. Furthermore, digital alteration often operates on a highly symbolic level, generating fully functional new technologies that can easily be assimilated into the very system they purport to challenge. As Cascone [12] states unequivocally, "failure itself failed" because "capitalism has gotten very efficient at quickly appropriating critiques." These paradoxes, which resonate with certain philosophies of noise [13, 14] surface the tension inherent to misuse practice—a tension that, rather than resolving, opens spaces of critical reflection.

1.2 Algorithm-bending for critique

Algorithm-bending is grounded in a critical engagement with the social, political and cultural consequences of algorithmic mediation—in particular, the regimes of technological optimisation [15] and hyper-rationalisation [16] and their impact on human agency [17]. This research responds to the increasing autonomy of computational systems within technocratic governance, systems whose ca-

[1] https://www.erro.zone

[2] https://mtchl.net/tag/sonification/

[3] https://hacking.art/

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pacity for prediction, automation, and behavioural regulation increasingly operates beyond meaningful human oversight or contestation, the planetary scale of computational layers defined by Bratton as "the stack" [18]. Within this context, the error is posited as the operative concept for an experimental practice of tactical musicking. Across philosophical, semantic, moral or technical domains alike, an error signals a manifest or latent deviation from the normative functionality prescribed by any system. As such, the error is closely related to the act of erring, an active refusal of expected outcomes that embraces instead the unknown or the divergent [7]. Where error is a state, erring is a practice—one that may be embodied as artistic contestation and resistance.

2. ALGORITHM-BENDING

2.1 Algorithm: a definition

This section specifies the working definition of algorithm that underpins the bending practice and distinguishes it from standard computational accounts. While recent research, such as Primiero's [19] layered algorithm ontology—abstract, procedural, and physical—has introduced expansive technical accounts, most definitions still constrain algorithms to self-contained goal-oriented computational procedures implemented via software. We embrace a broader conceptual framing of algorithms as Cellardian "figures" [20], a definition that binds the abstract, implementational, technical, semiotic, and institutional dimensions of algorithmic systems into a single configuring structure. By doing so, algorithms serve to describe current socio-technical assemblages [21] as the *épistémè*—the dominant knowledge-ordering framework—of our age, inseparable from the processes of subjectification and individuation proposed by Simondon [22] and Stiegler [23][4]. In this sense, the "figure" of an algorithm functions as a canvas for exploration and critical interventionism—that is, as both tool and target.

In *ERRO.*, algorithms are selected to the extent that they can be interpreted not only as mathematical and functional objects, but also as textualities [24]: signs embedded within algorithmic architectures. Our search for extra-functional meanings in algorithmic ontologies, which follows an approach related to digital ethnography [20] and Critical Code Studies [25], supports the bending practice: re-interpreting optimally designed algorithms through a semiotic lens opens up a space for their critical alteration.

2.2 Bending Methodology

Unlike certain bending practices that proceed without a thorough understanding of the technologies underlying the manipulated medium—such as circuit-bending, where practitioners do not necessarily know the function of every point in the circuit—algorithm-bending demands a more rigorous methodology, requiring sufficient knowledge of both the abstract, logical, and mathematical structure of an algorithm and its specific implementation through code and hardware. Hence, in algorithm-bending, deviances and errors are intentionally and consciously designed, yet likely without the practitioner fully grasping the implications of the alteration introduced. Furthermore, this praxis leads to the paradox of creating perfectly functioning algorithms, which yet appear deviant and capable of producing the "post-optimal" [26] sounds characterising this tactical musicking practice.

The algorithm-bending methodology here proposed follows five steps: (1) an audio DSP algorithm is selected and analyzed both as a digital object and as a cultural and hermeneutic object capable of unfolding and motivating broader significances[5]; (2) the algorithm is implemented in C/C++ within the Max[6] SDK framework; (3) intentional deviances (functional, logical, procedural, performance-related, aleatoric, etc.) are subsequently introduced, altering the algorithm's prescribed behaviour; and ultimately, the bent algorithm is used as a (4) sound design tool for fixed-media composition and (5) as a real-time processing tool in augmented instrumental performance, where autoregressive mechanisms between performers, instruments, and algorithms shape the sonic result.

Following the methodology described above, four algorithms were developed[7] and subsequently applied in off-line sound design, real-time processing, and as a source of conceptual and narrative inspiration for macro-formal compositional processes. The following subsections present two illustrative case studies.

2.2.1 Algorithm-bending case study I: erro.convolution∼

The *erro.convolution∼* is a Max object for real-time audio processing, which implements a deviant, consciously "hijacked" [27], version of a time-domain convolution algorithm, a generic signal processing operation typically employed, in the realm of audio processing, to multiply spectra [28]. The convolution operation can be performed through several methods. The one selected for *erro.convolution∼* directly implements the straightforward FIR filter structure of the equation (1).

$$y(n) = \sum_{k=-\infty}^{\infty} x(k) \cdot h(n-k) = x(n) * h(n) \quad (1)$$

This method is usually avoided in optimally engineered scenarios, being inefficient—especially with long impulse responses [28]. The *erro.convolution∼* implements a deliberately inefficient method, which can bring CPU over-

[4] In their studies on human memory as inseparable from the technological development, Stiegler, based on Simondon's environmental definition of "associated milieu", affirms that within the reticular influence of psychotechnologies and technologies of spirits, the individuals are dissociated from their physic and collective individuation. The algorithmic realm, "intervene in our perceptions of opportunities" and as a consequence "influence our decision-making processes."

[5] This approach follows and expands upon that of Critical Code Studies [25] which treats source code as a cultural text—like an artifact in archaeology—to uncover the social, ideological, and human meanings embedded within it, beyond just its technical function.

[6] The choice of Max, `https://cycling74.com/`, as diffusion platform is strategic: its broad adoption and commercial predominance within the creative industries make it an exemplary site for tactical media and critical coding practices.

[7] *erro.convolution∼*, *erro.psola∼*, *erro.wiener∼*, *erro.circular∼*

load glitches, while further intervening in the implementation of the formula through a set of bending strategies:

- The actual kernel $h(n)$ is derived from an impulse response (IR) loaded into a Max *buffer~*, truncated to a percentage of its full length via the *bend_IR_percentage* parameter, ranging 1% to 100%. The sonic result is a fragmentation of the original IR: as the percentage decreases, the later portion of the IR is progressively reduced. This parameter additionally functions as a control mechanism of CPU overload, given that the deployment of extended impulse responses, in conjunction with an elevated *bend_IR_percentage*, is liable to stress the computational capacity on the audio thread due to the inefficient FIR filter structure.

- The parameter *bend_index_offset* adds an offset to the writing index increment in the delay line's circular buffer needed to implement the convolution. Advancing the write index by a non-unit offset corrupts the alignment between the input signal and the kernel, producing spectral artifacts in the convolution output.

- The increment used to step through the kernel $h(n)$ during the convolution loop is made variable via *bend_loop_stride*. Instead of reading consecutive kernel samples at a fixed step of 1, the kernel is sampled at a larger custom stride, skipping coefficients and producing a coarser, stepped approximation of the original IR.

Digital convolution was selected not only for its technical affordances but also for its semiotic potential: as an operation that merges two signals into a composite output, it can be read, in the current algorithmically mediated realm, as a symbol of the prevailing state of hybridisation among digitised subjects. In performance, the concurrent modulation of *erro.convolution~*'s three bending parameters—controlled through the saxophone's sensor-based augmentation—establishes a techno-human feedback loop that explores and questions this symbiotic state by rendering convolution deviances audible and embodied.

2.2.2 Algorithm-bending case study II: erro.psola~

The second case study, *erro.psola~*, is a Max object for real-time pitch shifting and time stretching which implements a deviant version of a time domain Pitch-synchronous overlap and add (TD-PSOLA) algorithm. This algorithm was selected because it epitomises—alongside allied processes such as compression and noise reduction [29]—the manipulative apparatus of speech processing technologies, whose influence extends to the temporal and tonal regulation of digitised human communication.

A TD-PSOLA algorithm, which assumes the processed sounds have a defined pitch, can be described in two main phases [28]. The first phase implements a pitch tracking analysis, which finds the pitch period P—centred on a time pitch mark t_i—and extracts a windowed grain centered at every pitch mark t_i. In the second phase, for each synthesis step, the algorithm finds the nearest pitch mark t_i, extracts from the input buffer an audio segment, windows it, and overlap-adds into a separate output buffer at an interval of $P/pitch_ratio$ [8], producing pitch shift. Time stretching is obtained by re-sampling the output buffer. Here, the pitch tracking phase uses a Fast Lifting Wavelet Transform (FLWT), following Terry Kong's approach [9]. The latter implements a robust and low-latency pitch tracking which low-passes the input signal multiple times until it is smoothed enough to detect the period.

The architecture of a TD-PSOLA algorithm with FLWT pitch tracking encompasses several areas of bending:

- *erro.psola~* allows a real-time low level control over some parameters of the FLWT, such as the number of filtering stages, via the *bend_levels* parameter [10], a robustness control, via the *bend_mode* parameter [11], and the pitch detection resolution, via *bend_detection_hop*. These parameters distort the behaviour of the pitch tracking algorithm, inducing flawed analyses that subsequently condition (and corrupt) the pitch shift and time stretch operations.

- Another level is applied to the extraction and storing procedures of pitch marks t_i. *bend_mark_update_hop* controls how often new pitch marks are placed—very high values starve the synthesizer of fresh marks, producing pitch smearing or frozen artifacts. *bend_mark_update_hop* sets how many marks are added per update—low values cause the synthesizer to hunt through outdated marks, producing stuttering, wrong-pitch grains, or silence.

- *erro.psola~* makes audible pitch tracking failures. When the pitch is not stable enough, no pitch mark t_i is extracted and therefore the synthesis phase fails, producing sonic gaps. The stability threshold is controlled by the performer via the *bend_stability* parameter.

- Time stretch inherits the pitch shifting bendings and at the same time adds other artifacts derived from the real-time re-sampling procedure—at slower playback rates, audio discontinuities emerge; at faster rates, gaps arise.

The *erro.psola~* algorithm is used primarily in real-time and in polyphonic mode to generate fragmented and disrupted chord-like textures. During performance, different bending parameters can be modified using sensors. Moreover, the timbral modulation created by the performer—using techniques such as growl and *bisbigliando*,

[8] The *pitch_ratio* parameter defines the ratio between the desired output frequency and the original pitch-tracked frequency, controlling the degree of pitch transposition.

[9] `https://github.com/terrykong/Phase-Vocoder`

[10] The *bend_levels* parameter influences the frequency range of pitch detection: if set too high, it may filter out the very frequencies it is intended to track.

[11] The *bend_mode* governs the robustness of the pitch tracking algorithm as implemented by Terry Kong.

as well as breaking the harmonic spectrum through voicing—becomes central in the bending process. Indeed, creating unstable spectra further destabilizes the pitch tracking, generating a hyper-reactive digitally distorted sonic shadow of the saxophonist. This shadow becomes the roasted voice of algorithmic failure in interplay with the performer's voice and the instrument's timbre.

2.2.3 Algorithm-bending as a composition tool

Three bent algorithms were deployed as compositional tools in the realisation of a 40-minute-long multimedia [12] performance, also titled *ERRO.*, integrating both fixed media and real-time processing. The classification, selection, and organisation of sonic materials, together with compositional processes, followed a multi-stage non-sequential structure, repeated in feedback.

- One stage involved feeding the algorithms with various types of sounds (recorded or synthesised), while systematically varying the bending parameters to explore the sound design possibilities afforded by the algorithms. The selection of sounds from this phase led to the composition of several fixed-media tracks.
- Another stage pursued two improvisational approaches with augmented saxophones (alto and baritone). In the first one, the performer spontaneously interacted with the algorithms, generating several sounds, gestures and timbres that were non-reproducible *a posteriori*, given the fluidity and reactive nature of the live processing mechanism. In the second one, the interaction was systematised as a sequence of actions (various gestures, contrasting dynamics, and extended techniques) designed to facilitate the understanding of the resulting algorithmic responses.
- A third stage involved the interaction between the performer, the previously created fixed-media tracks, and the real-time bending process, in order to generate a specific grammar based on the mutual interplay between these elements.
- The sonic results collected during the other stages were composed and formally organized into a narrative [13] and a score with closed and open sections.

3. AUGMENTED SAXOPHONE PERFORMANCE

The *ERRO.* performance employs two augmented saxophones, each interacting with various bent algorithms through two Bela [14] Trill sensors and four button switchers mapped to bending parameters and controlled through the performer's gestures and actions. These controllers were chosen and placed strategically to exploit the performer's technical skill while expanding the overall range of expressive interaction: the switchers buttons are attached on the surface of both right and left hands index's keys (fingering 1 for the left and 4 for the right), the trills flex sensors are sticked to the saxophone tube, behind the key's mechanism, allowing both thumbs to slide within the range and deploy pressure.

Similar projects have largely focused on unifying gestural performance within the figure of the hybrid musician. As an example, the *Meta-Saxophone project* [30], led by Burtner, has inspired both scholars and the constantly evolving role of the performer in hybrid instrumental symbioses by pioneering a hybrid instrument that "while maintaining full acoustic functionality, is also a versatile MIDI controller and an electric instrument." Subsequent work by Portovedo et al. [31] and Schiesser and Traube [32] further explored the performer's role in hybrid symbiosis, analyzing how augmentation alters the performer's gestural vocabulary and public perception. While these studies address the performers' experience with new devices or exploit them to collect technical data, *ERRO.*, mainly investigates the interaction between human gestures and algorithm-bending strategies. The main purpose of the instrument's augmentation is to directly manipulate parameters related to the real-time bending of sound processing algorithms, creating a mixed sonic material with which the performer interacts, simultaneously and in a feedback loop. (See Fig. 1). This approach facilitates the development of new timbrical and gestural possibilities that constitute the basis of an ad-hoc musical grammar, one that is neither generative nor predetermined, but emergent from a recursive exchange between the agents involved—the performer with the augmented saxophone, and the bent algorithms. Following Magnusson [33], this approach, characterised by "epistemic objects with agency", could be analyzed under the methodology of *musical organics* [15] —an organology of digital instruments situated within Stiegler's broader framework which encompasses "bodily organs (brain, hand, eyes, touch, tongue, genital organs, viscera, neuro-vegetative system, etc.), artificial organs (tools, instruments and technical supports of grammatization) and social organs (human groupings… and social systems in general)" [34]. In this framework, *ERRO.*'s augmentation would be defined by Baird as created by "function smiths", an instrument that embodies knowledge "as a material mode of effective action that synthesises representation and action (encapsulated knowledge)" [35].

4. FROM BENDING TO CRITICAL PRACTICE

4.1 Algorithm-bending as tactical musicking

In *ERRO.*, both the experimental coding practice and sonic exploration methodology are based on the deliberate low-level deviance and hijacking of audio DSP algorithms,

[12] The *ERRO.* multimedia performance expands its conceptual horizon through the design of an interactive light sculpture that accompanies the performance.

[13] This narrative explored the core themes and underlying rationale of the project, as evidenced by some titles: *Post-corale*, *La folla*, *The stack*, *Dividuo*, *Bending-war*, *Proto-linguaggio*.

[14] From the Augmented Instruments Lab at Queen Mary University of London, `https://learn.bela.io`

[15] "The epistemic nature of our digital instruments has amplified the grammatisation of music and its production, it has changed our bodily relations to our instruments, and employed new sections to the totality of techno-social structure. A musical organics organology therefore relates to the technologies of the body, of our prosthetic tools and instruments, and what kind of social functions these are inscribed into." [33]

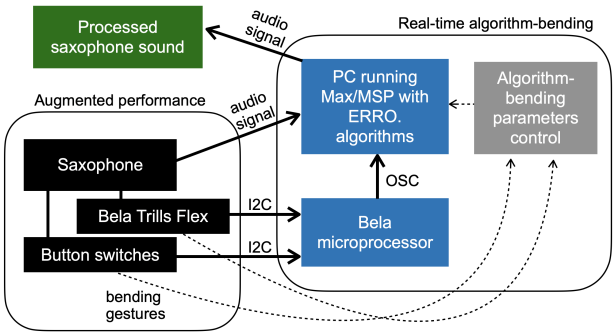


Figure 1.
Real-time bending process via saxophone augmentation.

which, we contend, constitute an appropriate symbolic and concrete space for tactical media practices and artistic hacktivism [16].

Galloway argues that identifying a target for hacking has become increasingly difficult in the contemporary sociotechnical realm (his analysis of protocol structures dates from the early 2000s) as power disperses across distributed protocological structures [37]. Avoiding polarized definitions, he proposes that a more allegorical view of hacking implies "an index of protocological transformations taking place in the broader world of techno-culture." In this reading, tactical actions are not aimed at destroying or ignoring the protocol, but at mastering it, pushing it "into a state of hypertrophy, hoping to come out the other side". *ERRO.*'s tactic operates in a similar vein but with certain distinctive features: it does not emerge only from algorithmic alteration and the deployment of its sonic output, but also from its intersection with acoustic sounds and embodied performance within a multimedia work, whose narrative and affective dimensions constitute an integral part of the tactical musicking process.

4.2 Algorithmic mediation

The critical framework of *ERRO.* responds to a broader diagnosis: the dissociation between the pace of techno-economic transformation and the temporalities and rhythms of social and cultural life, what Stiegler [23] defines as "*le temps historique*" of humans, now relegated to the role of powerless agents [17]. This dissociation has produced a regime of "algorithmic regulation" in which algorithmic systems increasingly influence behaviour through continuous computational generation of knowledge from real-time data [39], reducing variation and increasing standardisation in what Parisi [40] would define as a new AI-induced mode of technocultural production. Within this regime, as Steyerl [41] argues, data-recognition systems misinterpret patterns through probabilistic projection, reinforcing social categorisation through rankings, filters, classifications, and validation mechanisms based on the "proxy policy" of distinguishing "signal (information) versus noise." This classification process, driven by "speculative and probabilistic inertia", eliminates the possibility of unforeseen or aleatory interpretations, resulting in partial and non-neutral "hierarchies and vertical classes," which O'Neil [42] frames as a weapon for reinforcing injustice and discrimination. Errors within these systems acquire a political dimension: when anomalies occur, they are instrumentalised as unfortunate accidents, thereby concealing the extent to which they are structurally produced. *ERRO.* inverts this logic by deliberately engineering errors within DSP algorithms to expose, rather than conceal, the normative operations embedded in computational processes.

[16] "A complex practice that combines the affective power of the arts with the effective aims of activism." [36]

[17] We can trace the seeds of such critical analysis of the technological drive all the way to the Frankfurt School, for example, in Günther Anders' voice [38], who gave visionary insights on apocalyptic phenomenology.

5. CONCLUSION

This paper has presented algorithm-bending—deliberately deviance into DSP algorithms for sound synthesis and processing—and its integration with augmented saxophone performance as central practices of the *ERRO.* project. Two case studies, *erro.convolution~* and *erro.psola~*, demonstrated specific bending strategies at the implementation level, such as kernel truncation, index offset corruption, and pitch tracking destabilisation. The resulting sonic materials—generated through recursive interaction between performer, augmented instruments, and bent algorithms—are compositionally structured in a multimedia performance. The methodology is implemented in C/C++ within the Max SDK, and will be expanded in the future through the integration of further algorithms and the consolidation of the performative practice. *ERRO.* positions itself as a tactical musicking practice for resistance—one that refuses the logic of optimisation and fault tolerance that governs both contemporary software engineering and, by extension, the broader algorithmic regulation of social life. The project's contribution is threefold: technically, it proposes a replicable methodology for algorithmic deviance within a creative coding context; critically, it argues that artistic intervention at the level of signal-processing algorithms, and its embodied use in performance, constitute a meaningful form of artistic dissidence, and investigate the broader scope of tactical media musicking; artistically, it created a multimedia 40-minute-long show, which is the affective vehicle for communicating within society. The project also includes a website (`https://www.erro.zone`) serving as a transmedia collector, which provides access to the musical works, project references and text quotations, and a selection of codework's related projects. Future work will expand the collection of bent algorithms (with the aim of releasing an open-source critical coding library for Max), further develop the taxonomy of bending strategies, and explore performance practice through the systematisation of augmented gestures.

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