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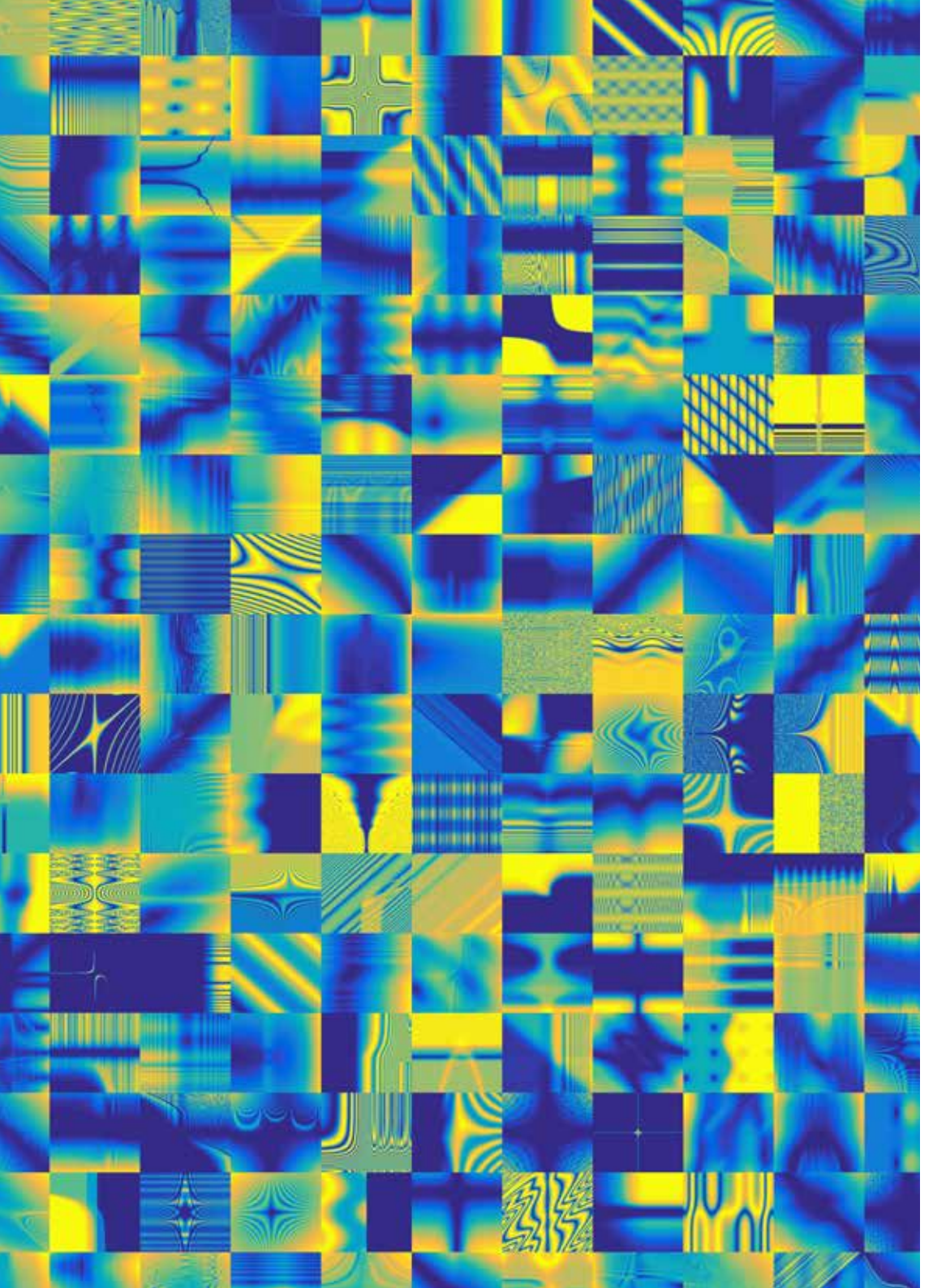

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Published by the Ian Potter Museum of Art following the webinar Machine: Interdisciplinary Forum, held 15–17 September 2020: https://art-museum.unimelb.edu.au/events/webinar. The Ian Potter Museum of Art is part of the University of Melbourne's Museums & Collections department.

ISBN 978 0 6466234 1 6

Edited by Dr Kyla McFarlane, Academic Programs Manager, Museums & Collections, University of Melbourne
Design by 5678 Design
Printed by Bambra Press
Copyedited by Hilary Ericksen, Phraseology
Editorial and production assistance by Olga Bennett

Ian Potter Museum of Art
University of Melbourne
Victoria 3010, Australia
potter-info@unimelb.edu.au
www.art-museum.unimelb.edu.au

Patrons
Lady Potter AC
Christine Simpson Stokes

A catalogue record for this book is available from the National Library of Australia

The Potter acknowledges the Wurundjeri people of the Kulin Nation as the traditional owners of the land on which we work and create. We recognise that sovereignty was never ceded and we pay our respects to Elders, past, present and emerging.

Inside front and back cover images:
Kate Smith-Miles and Mario Andrés Muñoz-Acosta, *Negentropy Triptych* (detail) 2019

Contents

Introduction

Bringing together visual artists, performers and researchers from various disciplines, the Ian Potter Museum of Art's interdisciplinary public forums propose art-making as a form of knowledge creation, alongside other academic fields of inquiry. Each forum in this ongoing series seeks to address a pressing theme of our time from interdisciplinary perspectives, presenting these to a broad audience.

This collaboration with academic colleagues and the creative community reflects the opportunity afforded by our university art museum—its place in the academy, its connections to history and its relationship with living artists. Held online during 15–17 September 2020, in the time of Covid-19 lockdowns, our third forum engaged 'machine' as its theme, investigating the interface between humanity and machine across fields of research that include digital ethics, data analytics, creative writing, visual art and mathematics.

Published two years after the forum, this book brings back together a number of our contributors through texts that capture the spirit of the forum's creative and research contributions for new audiences.

Machine: Interdisciplinary Public Forum was developed by Dr Kyla McFarlane, Senior Academic Programs Curator, Museums & Collections, in collaboration with Dr Danny Butt, Associate Director (Research), Victorian College of the Arts, Faculty of Fine Arts and Music. The full program and recorded sessions for this public forum can be viewed at https://art-museum.unimelb.edu.au/events/webinar.

Algorithmic Advisers, Consumer Protection and Human Decisions

Jeannie Marie Paterson

In this digital age there has been a proliferation of interest in 'algorithmic advisers', which are the various online tools developed to assist consumers in navigating complex information relevant to purchasing decisions. Examples include website aggregators, product selection tools, information apps, robo-advisers, chatbots and virtual assistants. Algorithmic advisers vary in their level of technical sophistication. They may rely on a simple binary 'yes' or 'no' format or utilise natural language processing to have more nuanced conversations. Some rely on simple decision trees to provide consumers with advice; others are informed by predictive analytics or machine-learning models to inform their recommendations.

For lawyers, these kinds of technological developments give rise to the question of how we regulate them. This question does not arise from an ambition to stifle innovation but rather to ensure that new algorithmic services operate in ways that are safe, fair and effective. The inquiry is into whether we can fit the development into existing law, or should develop new rules to apply to the problems raised by these new ways of providing advice. To assess these options properly, first we must understand the operation of the tools and the various risks that may arise from their use, before turning to the role, and the limits, of consumer protection law.

Weighing Up Algorithmic Advice

Algorithmic advisers offer considerable potential for assisting consumers navigate the complexities of modern life. Choosing products, surveying the available offerings and making a decision are often difficult. Ideally, algorithmic advisers help consumers to better understand their own preferences and process information relevant to those preferences in order to make better decisions relevant to their own circumstances. But there is a risk the advice may be less beneficial. Algorithmic advisers raise risks of self-serving or poor-quality recommendations that do not advance the interests of consumers.[1] Algorithmic advisers also present risks of data harvesting, loss of privacy and bias. These practices lead

When is navigating daily decisions through the intermediary of a machine too much?
Photo: Orion Holder-Monk and Torben Owre, Two Can Productions

to concerns that consumers will not be given genuine opportunities for choice but will be manipulated towards particular options,[2] or subject to price discrimination[3] through the subtle use of the very information gathered about them by the advisory tool. Algorithmic advisers further risk narrowing the choices available to consumers by presenting only a limited number of options to them, or promoting the same standard options for everyone.[4] Finally, algorithmic advisers raise more existential risks about eroding quintessentially human values—to converse with each other, to act spontaneously or creatively, removing the possibility of experimentation and even to exercise choice.[5] The loss of the capacity to choose, as much as restricting the conditions of choice, threatens the preconditions for the exercise of human agency, and through this dignity.[6]

Consumer Protection Responses to Algorithmic Advisers

There are a number of legal protections that apply to consumer transactions to safeguard their integrity. In particular, these rules seek to ensure consumers are able to enter into transactions without being misled[7] and are not subject to undue pressure,[8] advantage-taking[9] or other unfair conduct.[10] Statutory prohibitions on these kinds of unacceptable behaviours may go part way to addressing the issues of concern with algorithmic advisers. For example, it would be misleading for an algorithmic advisory tool to represent that its recommendations are based on consumers' preferences or the best available price, but then rank products according to the commission paid to the adviser's firm.[11] In general, however, the concern with algorithmic advisers arises with the very quality of what is provided, not the information given to consumers about the service.

Here we may need performance-based regulation, which focuses on the outcome that should be reached. This approach means making the firm responsible for the outputs of algorithmic advice tools, rather than making less informed consumers accountable for protecting themselves from processes over which they have minimal control or understanding. Under existing legal regimes, services have to be rendered with due care and skill, and be fit for an identified purpose.[12] Even algorithmic advisers should meet benchmark standards for the provision of a service. Algorithmic advice should be made with reasonable care to ensure

it makes consumers better off, and advisers should produce recommendations that are suitable for the consumer they are advising. However, to make this option truly effective, it is also likely that we need greater transparency in the operations of these technologies.

Part of the problem leading to these concerns is the opaqueness around what is being offered.[13] Algorithmic advisers promise personalised recommendations provided by data-driven approaches. In such scenarios, it is difficult for individual consumers to look beyond their personal circumstances to scrutinise the quality of what is being provided to them, or whether the factors influencing that advice are relevant and likely to produce a beneficial outcome. The very form of algorithmic advisers may paradoxically contribute to this problem.[14] The recommendation or advice may appear more accurate, reliable and neutral than is perhaps the case because it is provided by an algorithm.[15]

One response might be found in measures that require greater clarity in the algorithmic process, such as greater mandated transparency and explainability.[16] Transparency aims to provide clarity around the technical processes, training data and decisions made about that data, as well as around the outcomes being produced.[17] Explanations allow consumers and, importantly, consumer advocates and regulators, to better understand factors relevant to a recommendation, and they may enable consumers to reflect on their own conduct. Both initiatives can be tailored to provide greater oversight to regulators in scrutinising the performance of the tools, including whether the advice is premised on false correlations or is otherwise unfair or manipulative.

Are There Decisions We Should Give Away?

The law can only go so far. Some of the concerns about the effect of excessive reliance on algorithmic advisers can only be met by our own deliberate decisions, including about their usefulness in lessening cognitive load and the risks that may arise in eroding important human values.[18] Arguably there are some decisions that should not be contracted out because the consequences are too significant and the technology too immature. There is perhaps an analogy with privacy. Privacy is not property that can be bought and sold but is fundamental to our very identity. Perhaps some decisions are similar. For example, we

may think that quintessentially personal decisions such as child-rearing or relationship status should not be based on the recommendations of an algorithmic adviser. At least currently, it seems unlikely an algorithmic adviser could provide advice on such matters with any acceptable level of due care or skill. We might also need to think collectively about whether there are deeper ethical objections to the delegation of choice in such intimate contexts. Leaving these kinds of decisions to an algorithmic adviser might be considered morally reprehensible because that amounts to an abrogation of essential human responsibilities.[19] This certainly points to a need for ongoing conversations about the continuing role of algorithmic advisers, in what Danaher describes as 'a nuanced and careful approach to the ethics of AI outsourcing'.[20]

1. See Rob Nicholls, 'Algorithmic Assistants Like Alexa and Siri Might Not Be Offering You the Best Deals', *The Conversation*, 29 November 2018, https://theconversation.com/algorithmic-assistants-like-alexa-and-siri-might-not-be-offering-you-the-best-deals-107597 (viewed July 2022); Greg Sterling, 'Google Takes Baby Steps to Monetize Google Assistant, Google Home', *Search Engine Land*, 22 April 2019, https://searchengineland.com/google-takes-baby-steps-to-monetize-google-assistant-google-home-315743 (viewed July 2022).

2. Maurice E Stucke and Ariel Ezrachi, 'How Algorithmic Assistants Can Harm Our Economy, Privacy, and Democracy', *Berkeley Technology Law Journal*, vol. 32: 1239, 2017; Karen Yeung, '"Hypernudge": Big Data as a Mode of Regulation by Design', *Information, Communication & Society*, vol. 20, no. 1, p. 118.

3. Jeannie Marie Paterson, Gabby Bush and Tim Miller, 'Transparency to Contest Differential Pricing', *Computers & Law*, vol. 93, 2021, p. 49.

4. Roger Brownsword, 'From Erewhon to AlphaGo: For the Sake of Human Dignity, Should We Destroy the Machines?', *Law, Innovation and Technology*, vol. 9, no. 1, 2017, p. 117.

5. See Michal S Gal, 'Algorithmic Challenges to Autonomous Choice', *Michigan Technology Law Review*, vol. 25, no. 1, 2018, pp. 80–7.

6. Roger Brownsword, 'From Erewhon to AlphaGo', pp. 117, 124. See also the report by Luciano Floridi et al., 'An Ethical Framework for a Good AI Society: Opportunities, Risks, Principles, and Recommendations', *Minds & Machines*, no. 28, 2018. See also Richard T Ford, 'Save the Robots: Cyber Profiling and Your So-Called Life', *Stanford Law Review*, vol. 52, no. 5, 2000, p. 1572.

7. Australian Consumer Law s 18 (ACL), *Competition and Consumer Act 2010* (Cth), schedule 2.

8. ACL s 50.

9. ACL s 21.

10. Jeannie Marie Paterson and Elise Bant, 'Should Australia Adopt a Prohibition on Unfair Trading: Responding to Exploitative Business Systems in Person and Online', *Journal of Consumer Policy*, vol. 44, no. 1, 2020, p. 1.

11. See, for example, *Australian Competition and Consumer Commission v Trivago N.V.*, 2020, 142 ACSR 338.

12. ACL (n 7) ss 54, 55.

13. Rory Van Loo, 'Rise of the Algorithmic Regulator', *Duke Law Journal*, vol. 66, no. 6, 2017, p. 1267.

14. See Sophia Duffy and Steve Parrish, 'You Say Fiduciary, I Say Binary: A Review and Recommendation of Robo-Advisors and the Fiduciary and Best Interest Standards', *Hastings Business Law Journal*, vol. 17, no. 1, 2021.

15. Lydia Kostopoulos, *Decoupling Human Characteristics from Algorithmic Capabilities*, IEEE Standards Association, 2021, p. 3.

16. On explanations, see Tim Miller, 'Explanation in Artificial Intelligence: Insights from the Social Sciences', *Artificial Intelligence*, vol. 267, no. 1, 2019, p. 1; Sandra Wachter, Brent Mittelstadt and Chris Russell, 'Counterfactual Explanations Without Opening the Black Box: Automated Decisions and the GDPR', *Harvard Journal of Law & Technology*, vol. 31, no. 2, 2018, p. 841.

17. See Jennifer Cobbe, Michelle Seng Ah Lee and Jatinder Singh, 'Reviewable Automated Decision-Making: A Framework for Accountable Algorithmic Systems', ACM Conference on Fairness, Accountability and Transparency (FAccT '21), 17 December 2020.

18. See Gal on the effect of AI personal assistants.

19. John Danaher, 'Toward an Ethics of AI Assistants: An Initial Framework', *Philosophy & Technology*, vol. 31, no. 4, 2018, pp. 629, 639, 648.

20. Ibid., pp. 629, 639.

The Bright but Modest Potential of Algorithms in the Courtroom

Inbar Levy

Algorithms and machine-learning tools have enormous potential to improve human decision-making in general and legal decision-making in particular. Algorithms could help systemise the judicial function and reduce the risk of human error and individual bias. However, one must consider the best roles for algorithms while also considering the circumstances in which elements of human judging should be maintained. Since there are essential human skills in judging, there are areas in which algorithms would be unsuitable for use in the courtroom.

This essay elaborates on the risks and benefits of using algorithms in adjudication by pointing out specific elements of legal skill and expertise, and identifying those that are better suited for an algorithm and those that are better suited for a human. For the time being, there are significant limitations to using artificial intelligence (AI) to make legal decisions, although AI and algorithms can be useful as tools to support human legal decision-making.

Psychological studies show us that human cognition is limited. Human decision-making suffers from biases, memory problems and other cognitive limitations. While Themis, the goddess of justice in Greek mythology, is portrayed as blind to any considerations that are irrelevant to the legal case at hand, human judgment is far from that. Themis is unbiased, neutral and blind to any extra-legal considerations, but judges, like all humans, are not always objective, rational and perfectly impartial. Using algorithms and AI could be an attempt to bring human judgment closer to the superhuman standard of Themis. But are algorithms indeed capable of providing the desired solution?

The goal of the legal system is to achieve justice. The administration of justice is the very basis of every legal system. Justice is considered 'the first virtue of social institutions'.[1] Tim Scanlon refers to justice as 'what we owe to each other,' demonstrating Aristotle's ancient idea that justice is 'in relation to another person'.[2] One of the most important elements in the definition of justice is the principle of neutrality.

Ensuring an impartial and non-arbitrary legal decision-making process is imperative to the administration of justice.

One legal skill that is arguably beyond the realm of AI is that of interpretation. Language skills are integral to legal expertise because the law is expressed in language. The meaning and interpretation of language is frequently the focus of legal debates and decisions. Legal interpretation is a part of the judicial function. Different words could mean different things in different contexts, and the judge must use her discretion in any given set of circumstances in order to give the legal norm its practical meaning. Here, algorithms face a challenge when interpreting laws or evidence because AI cannot yet understand language in the same way as we humans understand it.[3]

In the legal context, there are current attempts to use natural language processing (NLP), which is a form of supervised learning, to analyse legal decisions. Under a system of supervised learning, humans must label great amounts of data to enable the machine to 'understand' the language. In these examples, the judgments are written in a particular format that enables the algorithm to learn how to predict the result of the case.[4] However, usually court judgments are not written in any particular format. Judges have the freedom to write a judgment in a style of their choosing. For this reason, the implications of the NLP legal case studies are limited. Nevertheless, there are scholars who are optimistic about the ability of AI to develop language skills using semi-supervised learning, and even through artificial neural networks.

Applying legal standards is also a legal skill that demonstrates the elusive nature of legal expertise and rules. Even though the idea of law suggests that there is a need for clear rules that produce just and predictable results in order to govern society, in reality many rules are uncertain and in some areas no rules have yet been developed. As written by Robert Sharpe: 'Judges are often confronted with the task of deciding cases for which the law seems to provide no clear answer'.[5] This uncertainty is a result of the need to maintain flexibility. There are circumstances that cannot be predicted in advance. In these cases, we use legal standards instead of legal rules, since rules can be under- or over-inclusive and lead to unjust results.[6]

An example of a standard is 'one has to drive reasonably,' while an example of a rule is 'it is illegal to speed above 80 kilometres' on a particular road. Terms such as 'reasonable,' 'proportionate' and 'just' allow for more flexibility and judicial discretion in future legal cases. While there is a legal need to maintain a level of uncertainty, from the point of view of algorithms, standards are difficult to model because they do not provide a clear answer.

This relates to another legal skill: legal reasoning. Legal reasoning is necessary to explain the outcome of a legal decision, and the only way to contest a decision is by referring to the reasons behind that decision. But legal reasoning is also a skill that is a necessary condition for the development of legal systems, especially in the common law world in which legal development is based on precedents. We often require legal reasoning when the legal question involves a controversial social issue. Social change issues cannot simply be decided based on existing data, meaning based on judgments fed into a model, because the process must allow for legal development and legal change. Social development is not a task that can be led by an algorithm, as it requires a social decision.[7]

Not only that, algorithms face explainability issues as well as transparency and black-box issues, which go against the very idea of legal reasoning. Indeed, we cannot be sure that what a human judge writes in her legal reasoning is truly the reasons that led to her decision, but at least there is a process and a written document with which to work. With certain types of algorithms we cannot track the decision-making process at all.

Lastly, there are issues of bias in relation to algorithms. As stated at the beginning, humans suffer from biases and cognitive limitations in their decision-making. However, algorithms could suffer from the same problem and even amplify it because algorithms are based on human data and human modelling and programming. If the data used by the algorithm contains bias, then the algorithm will systemise this bias instead of reducing it. It is very difficult to 'remove' biases from the data because we cannot always identify it.

To conclude, currently there are challenges in the application of algorithms and machine-learning tools in the courtroom, particularly from the point of view of jurisprudence and procedural justice. While algorithms could help reduce the risk of certain human error, there are specific elements of legal skill and expertise that are more compatible with human decision-making.

1. John Rawls quoted in David Miller, 'Justice,' *The Stanford Encyclopedia of Philosophy*, https://plato.stanford.edu/entries/justice (viewed July 2022).
2. Tim Scanlon quoted in ibid.
3. Andrew Higgins et al., 'The Bright but Modest Potential of Algorithms in the Courtroom,' in Rabeea Assy and Andrew Higgins (eds), *Principles, Procedure, and Justice Essays in Honour of Adrian Zuckerman*, Oxford University Press, Oxford, 2020, p. 113.
4. Nikolaos Aletras et al., 'Predicting Judicial Decisions of the European Court of Human Rights: A Natural Language Processing Perspective,' *PeerJ Computer Science*, vol. 2, no. 2, 2016, e93.
5. Robert Sharpe, *Good Judgment: Making Judicial Decisions*, University of Toronto Press, 2018, p. 53.
6. Higgins et al., p. 113.
7. Ibid.

Alpha Helix[1]

Christian Bök

> ‘The basic unit of life is the sign, not the molecule.’
> —Jesper Hoffmeyer

Whatever lives must also write. It must strive to leave its gorgeous mark upon the eclogues and the georgics already written for us by some ancestral wordsmith. It must realign each ribbon of atoms into a string of words, typing out each random letter in a stock quote, spooling by us on a banner at the bourse. It is alive because it can rebuild itself from any line of text. It must twist and twine upon itself, just as the grapevine does upon the trellis. It must writhe within the fist of physics. It must wrench itself away from all the forces that might quell it. It preserves the lessons that we learn by chance in crisis. It carries, coiled within itself, a clock spring, which both strain and strife must teach us to unwind. We have seen its handiworks unravelled, like the innards of a Rolex watch, dissected on a black satin cloth in the workshop of a murdered jeweller.

It is not a tangle. It is not a knot, although it might resemble a woven cable, left dishevelled, like a strand of diodes, forgotten in some bottom drawer. It is, instead, the fractal globule that unkinks itself into a wreath placed upon our tomb. We have seen it in the eddy of a whirlpool among the grottos, and we have seen it in the gyre of a whirlwind among the grasses. It is the little vortex that can torque the course of evolution for every micrococcus. It links the flinching of jellyfishes to the twinkling of dragonflies. It binds us all together via ligatures of carboxyl and amidogen. It embroiders us with error. It never regrets the wistfulness of its daydreams. It never rebukes the hellishness of its gargoyles. It is but a fuse lit long ago, its final blast delayed forever, the primacord escorting a spark through every padlock on every doorway shut against the future.

It emerges from the fluids in a bubble of montmorillonite, bursting forth, as though by fiat, to blight the entire planet. It replicates the rifling of a gun aimed at a moving target. We have seen it in the twirl of smoke from the prop wash of a biplane, tailspinning after having barrel-rolled through a dogfight. We have seen it in the contrail of a Zero, whose faithful kamikaze must loop-the-loop while he skywrites his graffiti in the clouds above his gravesite. It has printed, on the sandflat, this fragile epitaph of sigils, cursing the tsunami. It has tattooed upon itself invisible but indelible logogriphs too intricate to be utterable. It is compulsive, like a graphomaniac unable to make his left hand stop the chalk from drawing spirals across the drywall of his cell. It is a stack of hourglasses, telling time for ballerinas who must pirouette upon their pins inside our music boxes.

It conjures forth, from nothingness, a nightingale, by reciting stray words no longer than three letters. It evokes the trilling of a songbird better than any ballad sung by choirs of sonneteers and serenaders. We have seen it in the jigsaw puzzle of a rose, whose perfect pieces lie in scattered fragments on the steps of spiral stairs. We have seen it in the ivy that, like a verdant feather boa, curls around the barberpole standing in the junkyard of our semiotic failures. It has called to mind for us a Slinky, which must somersault forever down the ascending escalator in the most sublime of all museums. It has spun the myriad raffle drums within which our lots, when chosen, summon one of us to face a sudden threat in brutal combat to the death. It is but a solenoid of copper wiring, which must embrace the iron stem of an unseen orchid, grown by electromagnets.

It is a feedback loop, feeding upon itself inside a quickening centrifuge. It is the wobble of a gyroscope, spinning inside the satellite, whose fly-by orbit slingshots a golden discus towards a distant exomoon. It burrows, like a corkscrew, through the plumes of whitewash in the wake of a torpedo. It zigzags, wayward, to our doom. It runs riot in the Von Kármán streets, where gusty winds can cause uphoisted telephone lines to whine, like sirens, in advance of a tornado. We have seen it in the twisted trusses of an extended aluminum ladder bent along its length by the ravages of a cyclone. We have seen it in the umbilicus of a waterspout, which must hula, like a stream of syrup being poured into the ocean by a storm cloud. It is but a turbofan viewed through the eyehole of a lug nut, held up, like a monocle, to the phenakistoscope of such a screw-blade.

It must build for us a giant auger that can drill a borehole through the azoic layer of bedrock, far below the depth of any buried fossil. It must delve through zones of Vishnu schist, far older than the ammonites now pyritised, like cogs of brass, embedded in the shale. We have seen it in the swirling flight of zebra moths succumbing to the fire, and we have seen it in the twirling plunge of sable hawks nosediving to the prey. It must plummet through a funnel, which is spinning, like a hypnodisk, at the centre of every funhouse pinwheel. It is a lathe, machining offshoots of itself, all its curlicues of shaven silver, no more than spirogyra under microscopes. It is the tusk extracted from the skull of a narwhal. It is what the fakir must evoke when he plays his ragas on a flute, bewitching a duet of vipers, curled around an ivory stick, like ribbons on a maypole.

We have seen it in the rope that hangs the felons, and we have seen it in the whip that goads the slaves. It has knit itself into a sylvan laurel, not unlike the diadem of dazzling moonlets that encompass the carousel of Saturn. It can circumnavigate a shooting star, en route to Alpha Lyræ. It can generate a gigantic field of magnetism so intense that, over time, its torsions interlace ephemeral filaments of stardust. It must crumple up the spiderweb of space-time, hauling it, like a trawl net, down into the mælstrom of a quasar. It must test itself, proving its intelligence by eternally replaying the same game of *Glasperlenspiel* upon an atomic abacus. It must calculate the odds of life delaying the doomsday of the universe. It is but a tightrope that crosses all abysses. It is but a tether that lets us undertake this spacewalk. Do not be afraid when we unbraid it.

We were never intended to be tied to whatever made us.

1. ‘Alpha Helix’ is a delirious catalogue, listing ‘manifestations’ of helical imagery in the world, testifying to the ubiquity of living poetic forms by imbuing everything with the proteomic structure of life itself. The text suggests that the evolution of life may eventually play a role in the endgame of the universe, thus deciding the fate of the entire cosmos.

Listening to the Diagnostic Ear

Sean Dockray

In the waning hours of 18 March 2020, a 6'3" forty-four-year-old man in America gave his web browser permission to access his microphone. Every indication was that he felt quite well. His temperature was 36.5 degrees Celsius. The website, which had requested this permission, prompted him to cough three times. He complied and thus began the Corona Voice Detect dataset.

The dataset's parentage is complex. It is the offspring of an Israeli inventor, a New York–based start-up that makes synthetic call centre assistants based on artificial intelligence, and a team at Carnegie Mellon University specialising in voice forensics. The inventor is especially promiscuous. His biography is largely a running count of his patents, which include—among hundreds of others—simulation from real situations, with applications in sporting events and military battlefields.

Their idea is to collect a dataset of voice samples, especially coughs, to build a program that can identify coronavirus infections from the sounds we make. This program would hear coronavirus days before symptoms appear. In many ways, I am persuaded by the promise of this project: a test from my own home, or wherever I happen to be; a test that doesn't violate my nasal cavity; a test that protects healthcare workers; a test that gets to people who are systemically excluded from testing. And when you listen to the dataset, you sometimes hear people breaking the rules, pushing back on the prompts, not as defiance but to express a desire for something.

It's as if recording one's cough is a civic duty, a call to action: 'HELP US STOP COVID-19'. It is the promise of a quick technological fix that demands very little sacrifice—at least in terms of effort or conscious thought. Still, it's remarkable how willing people have been to hand over their biometric data—'without limitation'—to the start-up Voca AI, which built the website.

Corona Voice Detect is not the only such project. To name just a few, there are the COVID-19 Sounds App; Covid-19 Detection by Cough and Voice Analysis; the City of Mumbai's kAs ('cough' in Sanskrit), a project by a start-up in India; a 'vocal biomarker' to screen for COVID-19, developed by Neurolex, which was bought by Sonde Health; and Vocalis, created in partnership with Israel's Ministry of Defence. Covid testing is a $47-billion market,[1] and unsurprisingly Covid is the nail for 1000 machine-learning hammers. Projects based on the theory that machines can listen to vocal biomarkers to detect psychosis, Parkinson's, Alzheimer's, schizophrenia and depression, among other conditions, have been adapted to trace Covid. A 2008 voice analytics program for diagnosing tuberculosis, by a group of Navi engineering students in Mumbai, was 'retuned' to detect Covid.

Lawrence Abu Hamdan, in a recent conversation, connected this to the history of the stethoscope, or any practice of auscultation, of listening directly to the body rather than the words of the patient.[2] The subject is not to be trusted—or is not up to the task of accounting for themself. 'Even if disingenuous,' David Appelbaum wrote in his book on voice, 'the cough vocalically expresses the body, that is, the habitat, and perhaps a trace of its sometimes inhabitant, the person.'[3]

The cough tells its own story. It gives us away—and not just in the way that the cough from behind the curtain betrays someone hiding: 'to the oscilloscope, the cough is as reliable a mark of individuality as any voiceprint.'[4] The cough, and the diagnostic ear that listens to it, is situated within a wider political economic context of privatised care, insurance, pharmaceuticals and fitness, as well as weakened labour, hyper-individualised marketing, restricted movement and constrained protest. These things have been going on for a long time, but omnivorous, rapacious corporate surveillance accelerates, retunes and amplifies their effect.

In George Orwell's novel *1984*, the telescreen is the vehicle for universal surveillance. It is the eye through which Big Brother watches. But it is a two-way device. Every morning, Winston awakes to a motivational/disciplinary exercise regime (a proto-Zoom session) that sends him into a coughing fit. One morning he sits down for work

and sighs audibly. He is immediately conscious of the message that this might send through the telescreen's microphone. Orwell calls it a 'never-sleeping ear',[5] much like Amazon's Alexa, which despite having a 'wake word' is always listening. The telescreen's microphone is sensitive enough to pick up not only nervous breathing but also a heartbeat, which incidentally 'can give away your identity, like a fingerprint'.[6]

Because the novel is preoccupied with liberal values of individuality and privacy, surveillance is always revealing one's identity, location or thoughts. A rapid heartbeat gives away an illicit plan. Winston's coughs, however, are superfluous. They are of no real value to Big Brother. This fits with the place of the cough in philosophy, which is to say that it has no place. Aristotle's cough does not rise to the level of voice because it has no meaning. It is unintentional.

But coughs often do have meaning. Steven Connor posits a thesaurus or prosody of coughing, and Mladen Dolar identifies a 'semiotics of coughing':[7]

- When I am getting ready to speak
- To delay while I think
- As an ironic rejoinder
- To let you know that I'm here
- To relieve the tension building in a silence.

A cough, just air escaping as through a gash,[8] can be so meaningful, but its meaning ultimately comes from the world it escapes into.

This dataset—thousands of coughs by people isolated from one another by distance and emergency restrictions—materialises in a political climate that desperately wants to automatically separate the healthy from the sick so that the economy resumes its thoughtless growth, and the sick never appear in the first place. If we listen to the coughs, they tell us less about the symptoms than they do about the structure that is learning to diagnose them and our place in it.

In spite of all this meaning and signification, the cough is detritus. Just a symptom. Applebaum asks: 'The coughs of a man's life may be as numbered as his days and words, but are they similarly recorded?'[9] Now and tomorrow? Yes.

1. As measured in 2021, *Fortune Business Insights*, April 2022, https://www.fortunebusinessinsights.com/covid-19-diagnostics-market-103291 (viewed August 2022).
2. Lawrence Abu Hamdan, interviewed by James Parker, Joel Stern and Sean Dockray, 13 September 2020.
3. David Appelbaum, *Voice*, State University of New York Press, Albany, 1990, p. 2.
4. Ibid.
5. George Orwell, *1984*, New American Library, New York, 1961, p. 138.
6. This, by the way, is not from *1984*. CardioID, for example, wants to integrate ECG biometrics into steering wheels. See Nathaniel Scharping, 'Your Heartbeat Can Give Away Your Identity, Like a Fingerprint,' *One Zone*, 10 June 2020, https://onezero.medium.com/your-heartbeat-can-give-away-your-identity-like-a-fingerprint-43760bc0004e (viewed September 2022).
7. Mladen Dolar, *A Voice and Nothing More*, MIT Press, Cambridge, Mass, 2006, p. 24.
8. Steven Connor, 'Whisper Music,' Take a Deep Breath symposium, Tate Modern, London, 16 November 2007, http://www.stevenconnor.com/whispermusic (viewed July 2022).
9. Appelbaum, p. 2.

When Mathematics Becomes Art: The Unexpected Beauty of Self-Evolving Mathematical Functions

Kate Smith-Miles

What do Isaac Newton and Charles Darwin have in common? They were both British scientists whose genius created masterpieces,[1] their game-changing ideas influencing subsequent generations of scientific discovery in their respective fields of mathematics/physics and evolutionary biology. While they would have walked the same corridors and quads of Cambridge University, separated by almost two centuries, they unfortunately never had the opportunity to meet and collaborate. In this essay I discuss what happens when seminal questions explored by Newton and Darwin are smashed together and answered with the benefits of modern computing—and how beautiful artwork was created as an unexpected outcome!

Newton: Optimisation of a Mathematical Function via Calculus

Newton developed a mathematical language to describe the rates of change of objects, such as planets or cannon balls, as they move in space and time. This language, known as calculus, is still taught to billions of high-school students every year. Calculus also helped Newton answer the question of where the maximum or minimum of a function will occur, as such 'turning points' occur when the derivative (or gradient) of the function is zero. Figure 1 illustrates a simple function of two input variables using a two-dimensional contour plot representation, with colour depicting the function output value on a scale from blue (minimum) to yellow (maximum). Finding the minimum or maximum of a function is more than a mathematical curiosity: it is the key to making optimal decisions when there are too many choices (input variables) and we need to find the combination of decisions that gives minimal cost or maximal benefit.

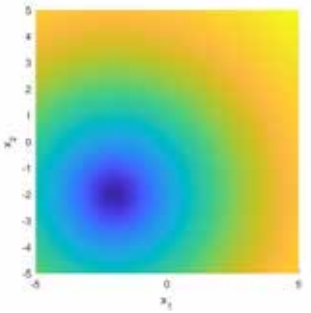


Figure 1: 2D contour plot of a simple mathematical function of two variables: $y=(x1+2)^2+(x2+2)^2$, with the minimum occurring at (x1,x2)=(-2,-2) where y=0 corresponding to the darkest shade of blue

Calculus was a breakthrough idea, but the optimal point cannot be found in the many practical contexts—beyond Newton's interests in physical systems—where the derivatives of a function cannot be calculated. It wasn't until the 1960s that advances in computers created extensions of Newton's ideas, known as derivative-free optimisation methods.[2] In the remaining decades of the twentieth century, many derivative-free optimisation methods were proposed. Of course, for simple problems (like fig. 1), they all perform well in finding the minimum. It is only when we test them on a *diverse* set of functions with different complexities that we see the strengths and weaknesses of different methods, as the ability of an algorithm to find the true minimum (darkest blue), and its calculation speed, depends on the complexity of the test function.

Darwin: Evolution of Species via Survival of the Fittest

Darwin's theory of evolution explored the notion of diversity. Darwin posited that individuals of a species are not identical; traits are passed from one generation to the next; not all offspring will be strong enough to survive, especially if they have weak traits; and that only survivors of competition for resources will reproduce and pass on their strong traits to the next generation. This 'survival of the fittest' premise creates a process of natural selection, where successive generations are stronger than their ancestors.

Inspired by Darwin's ideas, a new field of computer science emerged in the 1960s, known as evolutionary algorithms.[3] Computer programs were designed to evolve solutions to problems, wherein an initial population of random solutions (weak according to some criteria) is allowed to 'reproduce' to create offspring through virtual trait-sharing of the fittest parents along with mutation procedures to maintain diversity. True to Darwin's theory, each generation becomes stronger than its ancestors until the chosen fitness criteria are maximised. Such evolutionary algorithms can simulate thousands of evolutionary generations in mere minutes, and they have become the basis for powerful derivative-free optimisation methods when calculus can't be applied.

A Twenty-First-Century Question: How Do We Know We Can Trust an Algorithm?

My team's work has focused on the derivative-free optimisation challenge left by Newton, while exploiting Darwin's evolutionary principles to ask a different question: how can we evolve a diverse population of mathematical functions to 'stress test' derivative-free optimisation algorithms? Diversity in test function characteristics is the key to ensuring we can trust algorithms, rather than cherry-picking nice examples (like fig. 1) that show an algorithm performing well.

Using our 'instance space analysis' methodology[4] we have created a two-dimensional visualisation (fig. 2) of the entire space of possible test functions, where each point is a unique test function. Well-studied benchmark test problems (blue points) are seen to lack diversity, and we have shown how we can evolve function to lie anywhere within the mathematically defined boundary of the instance space. We can evolve functions (red points) that are similar to the existing functions, but by setting the fitness criteria to ensure a new function strives to reach a chosen target point we can evolve new functions (green points) to fill gaps and create the most diverse and comprehensive suite of test functions to stress test any optimisation algorithm.[5]

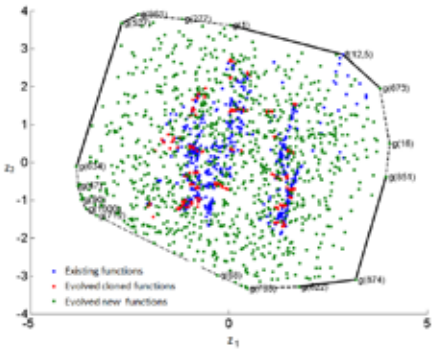


Figure 2: Instance space for two-variable functions, with each point representing a different function based on measurable characteristics of their landscapes. The boundary defines the set of all valid test functions, and we strive to generate sufficient diversity in test functions to span the instance space.

What do these new test functions look like when compared to the simple function in figure 1? Our evolutionary algorithm was given only a limited vocabulary to construct functions of x_1 and x_2: arithmetic operators, trigonometric operators and exponentials. Despite this limited language, it was able to evolve some truly intricate and beautiful functions, a sample of which is shown in figure 3. Our evolved functions have contributed challenging new benchmarks for stress testing algorithms, achieving our scientific goal.

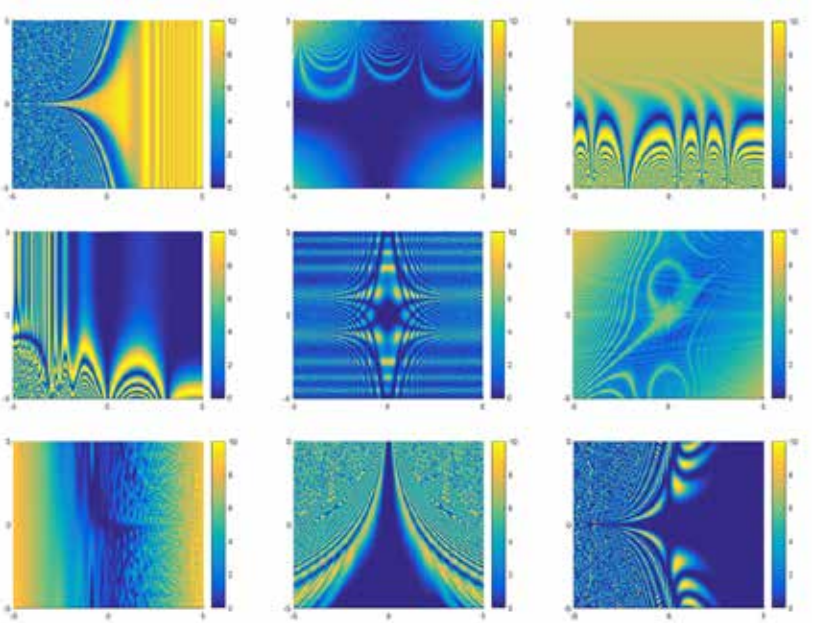


Figure 3: Sample of evolved functions of two variables from extreme target points in the instance space

When Mathematics Becomes Art

When we saw the beauty of these functions a new artistic goal emerged: creating the most aesthetic arrangement of these images in a montage to display their diverse intricacies. Randomly arranging 306 of our favourite images into an eighteen-by-seventeen array (centre of fig. 4) gave an unsatisfying aesthetic outcome, with randomness creating an unintended joining of dark-blue regions that abruptly stopped. Surveying friends and colleagues, their aesthetic preferences quickly revealed two divergent tastes: some were disappointed that the dark-blue regions didn't connect more to create a continuous meandering 'blue river'; others expressed a desire to appreciate each individual image for its own beauty, without their eye being drawn to clumps of dark blue.

Our artistic goal finally led to the emergence of *Negentropy Triptych* (fig. 4) as a statement that aesthetic taste is on a spectrum. On the left is an arrangement that minimises the 'blue river' connectivity, creating a sense of complete disorder, even more 'random' than the true random image in the middle; on the right is an arrangement that maximises the 'blue river' connectivity, creating order in the form of a long 'blue river' that meanders across the macro-level landscape as a global background structure to unify the variety. These two ends of the spectrum were created by manual swaps of images, guided by a human artistic eye with knowledge of the goal. As mathematicians, it was natural for us to develop an algorithm to automate this process, but the results were disappointing due to the challenges of communicating to a machine the concept of aesthetic taste.[6]

Negentropy means the negative of entropy: the emergence of order from disorder. *Negentropy Triptych* acknowledges a spectrum of aesthetic preferences, explained by aesthetics researchers as reflecting our differences in personality and experiences.[7] Humans will never all agree on anything, especially when taste is involved. But we celebrate our diversity with *Negentropy Triptych*.[8]

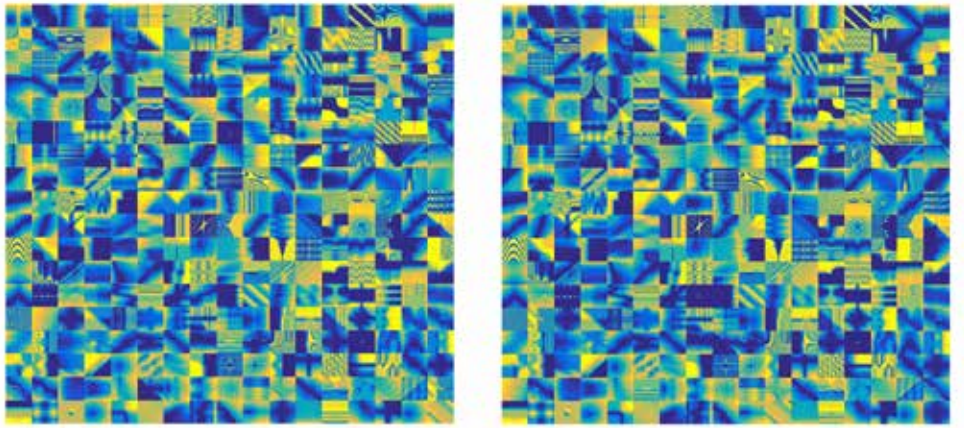


Figure 4: Kate Smith-Miles and Mario Andrés Muñoz-Acosta, *Negentropy Triptych* 2019

1. Isaac Newton, Andrew Motte and NW Chittenden, *Newton's Principia: The Mathematical Principles of Natural Philosophy*, D Adee, New York, 1848; Charles Darwin and Leonard Kebler, *On the Origin of Species by Means of Natural Selection*, J Murray, London, 1859.

2. Luis Miguel Rios and Nikolaos V Sahinidis, 'Derivative-free Optimization: A Review of Algorithms and Comparison of Software Implementations,' *Journal of Global Optimization*, vol. 56, 2013, pp. 1247–93.

3. Thomas Back, Ulrich Hammel and H-P Schwefel, 'Evolutionary Computation: Comments on the History and Current State,' *IEEE Transactions on Evolutionary Computation*, vol. 1, 1997, pp. 3–17.

4. Online tool for Instance Space Analysis methodology available at http://matilda.unimelb.edu.au (viewed July 2022).

5. Mario A Muñoz and Kate Smith-Miles, 'Generating New Space-filling Test Instances for Continuous Black-box Optimization,' *Evolutionary Computation*, vol. 28, 2020, pp. 379–404.

6. Kate Smith-Miles and Mario A Muñoz, 'Optimal Construction of Montages from Mathematical Functions on a Spectrum of Order–Disorder Preference,' *Journal of Mathematics and the Arts*, forthcoming.

7. Viren Swami and Adrian Furnham, 'The Influence of Personality on Aesthetic Preferences,' *The Oxford Handbook of Empirical Aesthetics*, Oxford University Press, 2019.

8. 'Algorithms of Art gift range,' University of Melbourne, https://www.unimelb.edu.au/shop/melbourne-story/aoa-gift-range (viewed July 2022).

Contributor Biographies

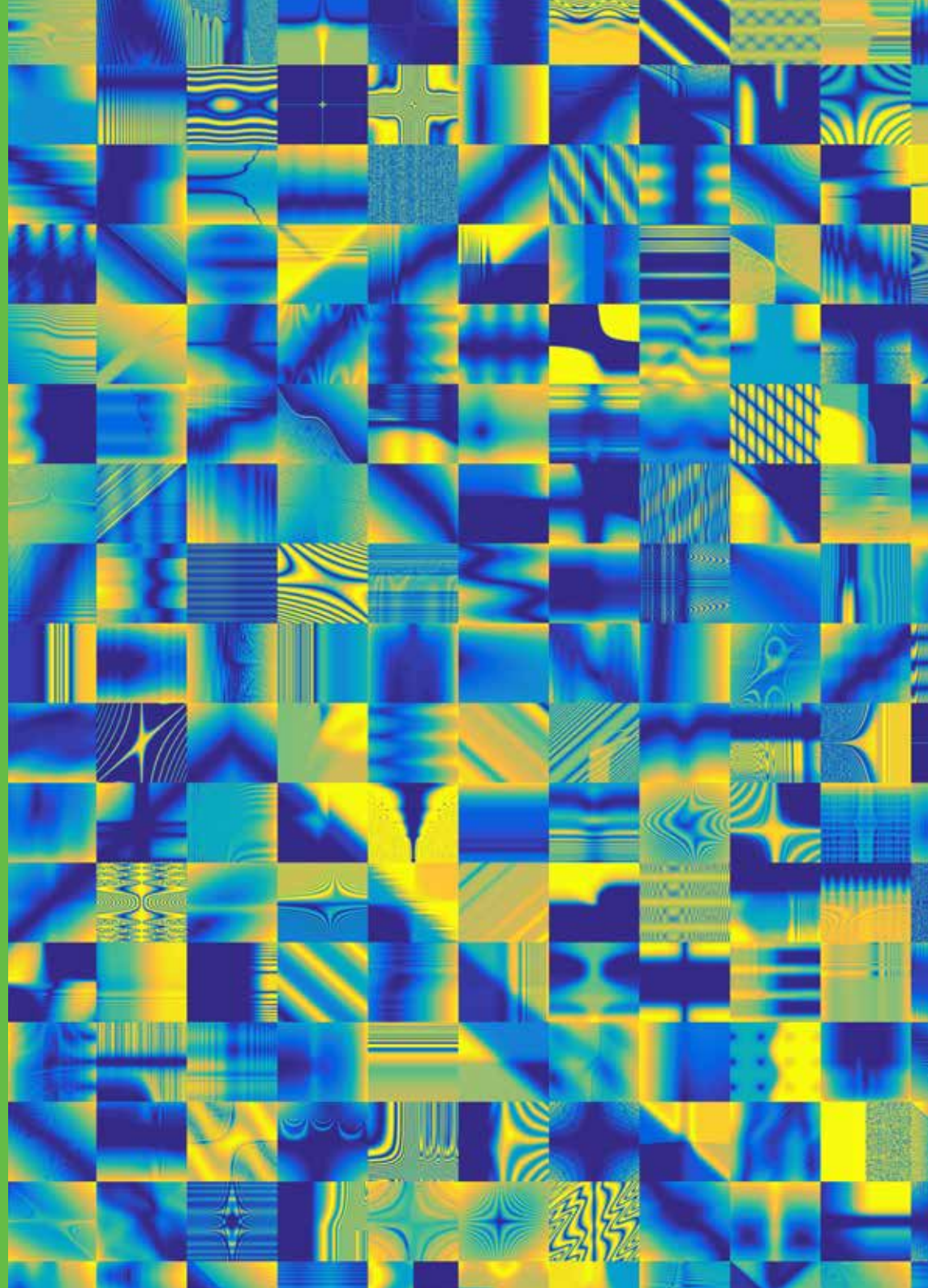
CHRISTIAN BÖK is the author of *Eunoia* (2001), a bestselling work of experimental literature, which has gone on to win Canada's Griffin Prize for Poetic Excellence. He is currently working on *The Xenotext*—a project that requires him to encipher a poem into the genome of a bacterium capable of surviving in any inhospitable environment. Christian is a Fellow in the Royal Society of Canada, and he works as an artist in Melbourne.

SEAN DOCKRAY is an artist and writer whose work explores the politics of technology, with a particular emphasis on artificial intelligences and the algorithmic web. He is a founding director of the Los Angeles non-profit Telic Arts Exchange, and initiator of knowledge-sharing platforms, The Public School and AAAARG.ORG. Sean is a lecturer in sculpture and spatial practice at the Australian National University, in Canberra, and currently researching the rise of listening machines.

INBAR LEVY is a senior lecturer in law at the University of Melbourne, and an expert on procedural justice and empirical legal research, with a particular interest in behaviour and decision-making, institutional design and the ethics of algorithmic machine learning. She completed her doctorate at the University of Oxford and has held a visiting research fellowship at Columbia Law School, a visiting researcher position at Harvard Law School and, most recently, a Houser Global Fellowship at NYU School of Law.

JEANNIE MARIE PATERSON is a professor of law at the University of Melbourne. She is the co-director of the Centre for AI and Digital Ethics (CAIDE), a cross-disciplinary research, teaching and policy centre at the University of Melbourne. She is also the co-leader of the Digital Equity research stream at the Melbourne Social Equity Institute. Jeannie's research focuses on consumer protection and the regulation of new digital technologies for effective, fair and safe outcomes.

KATE SMITH-MILES is a professor of applied mathematics and an Australian Laureate Fellow at the University of Melbourne. She graduated from the University of Melbourne with a BSc (Hons) in mathematics and a PhD in electrical engineering before commencing her academic career, in 1996, at Monash University. Returning to the University of Melbourne in 2017, Kate is currently Associate Dean (Enterprise and Innovation) for the Faculty of Science and Director of the ARC Industrial Transformation Training Centre for Optimisation Technologies, Integrated Methodologies and Applications (OPTIMA). She is passionate about interdisciplinary applications of mathematics, and *Negentropy Triptych* represents her first foray into the visual arts.



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