GANspire: Generating Breathing Waveforms for Art-Health Applications

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Abstract

This paper introduces *GANspire*, a deep learning tool that generates expressive breathing waveforms for art and health applications. We describe our ongoing work and contributions, which include the development of a generative model of breathing pressure waveforms, the participatory design of an interface for creative exploration of breathing generation, and the artistic application of our tool to the creation of a soft breathing object.

Breathing is an automatic vital function allowing gas exchanges between organisms and their environment [1]. In humans, breathing also has emotional and behavioral dimensions. Indeed, it can reveal inner states to others through visible and audible inhale-exhale movements, it serves as a conduit for verbal and non-verbal communication, and it can convey connectedness between individuals, with their environment and with themselves, *e.g.,* through breathing synchronisation or mindfulness. Likewise, breathing can both generate and express empathic resonance, leading to empathic concern or empathic distress. While several works attempted to endow machines with empathic breathing attributes, either within art installations [2,3] or as means for health interventions [4,5], almost all of them relied on elementary models of breathing waveforms, *e.g.,* a sine wave with varying amplitude and rate, which means overlooking the role of breathing variability and of fine-grained individual differences in breathing (*personnalité ventilatoire* [6,7]) in conveying expressive and empathic cues in human-human interaction, and by extension, in further human-machine interaction.

As an interdisciplinary group of artists, designers, researchers, and clinicians, we were interested in exploring three entangled issues related to such breathing expressiveness. First, we wanted to leverage the representational power of deep learning to create a generative model of breathing pressure waveforms that accounts for fine-grained, individual variations of breathing among humans. Second, we needed to design a tool that facilitates exploration of the generative model for pulmonologists interested in better understanding breathing expressiveness. Third, we wished to apply our tool to the creation of a soft inflatable object by subtly controlling its inflatings and deflatings with generative deep learning, thus exploring breathing as a new form of creative and behavioural output [8,9], possibly vector of empathy in human-machine interaction.

We proposed to call *GANspire* this deep learning tool, which enables to generate expressive breathing waveforms for art and health applications (see workflow in Figure 1). Our current work seeks to design *GANspire* using a specific method, called diffractive [10], which enables to include joint art and health perspectives in deep learning and interaction prototyping. The present paper details our ongoing contributions, which include the development of a generative model of breathing waveforms based on a generative adversarial network (GAN) algorithm, the design of an interface for creative exploration of breathing generation based on participatory design with pulmonologists, and the artistic application of our tool to the creation of a soft breathing object based on a mechanical ventilator and an artificial lung.

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5th Workshop on Machine Learning for Creativity and Design at NeurIPS 2021, Sydney, Australia.

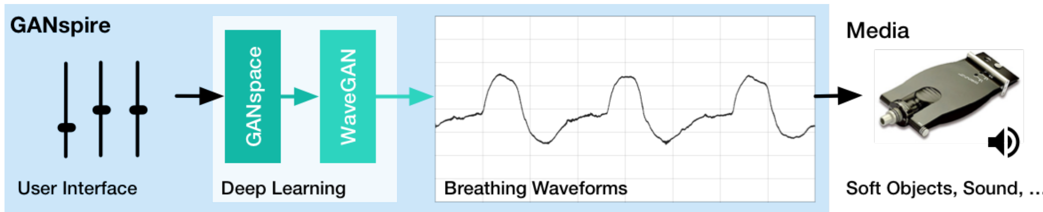

Figure 1: *GANspire* is a deep learning tool that generates expressive breathing waveforms to control temporal evolution of media, such as sound, image, or soft physical objects.

We started by crafting a generative model of breathing, approaching machine learning as a creative material, *i.e.,* privileging qualitative aspects of signal generation over quantitative aspects of signal modelling. We scraped a dataset of breathing pressure waveforms, harvested in previous physiology studies from twenty healthy individuals at rest, during exercise, or during sleep, amounting to six hours of breathing data sampled at 1 kHz. We then trained a *WaveGAN*, an audio GAN developed for raw waveform generation [11], over this dataset. We found that a DCGAN loss and a 10-dimensional latent space produced the best results in reproducing fine-grained variations of breathing, based on pulmonologists' qualitative observations of randomly-sampled, 16-second slices of breathing waveform (see Appendix A). Current work seeks to build a dataset of expressive waveforms from actors, musicians, and performers who have expertise in breathing, thus improving diversity in the generative abilities of the model.

We then sought to design an interface to facilitate exploration of the generative model, exploring whether control parameters related to breathing expressiveness could be discovered. We implemented *GANspace*, a technique for analysing and defining interpretable controls for image GANs [12], within our trained GAN. We found that performing principal component analysis at the first intermediate network layer enabled to capture most of the variability in breathing generation, based on quantitative analysis of variance of components. We used *Marcelle*, a web-based toolkit for designing interactive machine learning workflows [13], to code a parametric interface allowing exploration of the resulting generative abilities of our trained GAN (see Appendix B). Current work focuses on evaluating these control parameters in hands-on workshops with respiratory physicians, intensivists and physiologists to jointly refine interface and algorithmic design.

We eventually applied *GANspire* to create a soft inflatable object, whose inflatings and deflatings would be controlled by our generative model. Specifically, we created a prototype behavioural object, by using a mechanical ventilator and an artificial lung (see video in Supplemental Material). We used *TouchDesigner* to map pressure waveform values generated by *GANspire* to that of the mechanical ventilator. We found that fine-grained variations encapsulated by our trained model somewhat expressively materialised within the inflatings and deflatings of our prototype object. Different control parameter values yielded a diversity of breathing movements, whose variations provided the object with rich behavioural aesthetics, sometimes appeasing, sometimes uncanny, but in arguably all cases, life-like [14]. On the other hand, the elementary model of breathing implemented as standard in the mechanical ventilator produced a much narrower range of movements, with arguably less life-like qualities. Current work explores other creative applications of *GANspire* to control temporal evolution of other media, such as sound or image, *i.e.,* making them "breathe", as well as other shapes, materials, and actuators to fabricate a more advanced version of our soft breathing object.

One of the final aims of our work would be to use *GANspire* to control our soft breathing object in clinical settings, typically, observing how expressive breathings could produce empathic interactions between humans and the behavioural object, potentially appeasing the minds of patients suffering from chronic respiratory diseases [15]. We believe that such a use case would raise new issues related to the application of creative machine learning to the domain of health. For example, what would be the social impact of creating artificially-empathic machines for both patient and carer communities? Alternatively, are there any advantages in using breathing, as a form of biosignal, to train a generative model for health or well-being, instead of scraping culturally-richer materials, such as music? We hope to attend this year's workshop to discuss such socio-cultural issues with practitioners from the field of machine learning for creativity and design, along with artistic, design, and technical aspects of our ongoing work with *GANspire*.

Ethical Implications

The breathing waveform dataset scraped for training *GANspire* was fully anonymised. We know of no way to recover a person's identity based on their sole breathing waveform. Besides, we know of no way to regenerate one's breathing waveform from our trained model. We do not foresee any unwanted societal consequence of creating soft objects exhibiting realistic breathing behaviours.

Acknowledgments and Disclosure of Funding

The authors thank Philippe Gauthier, Joffrey Becker, Nicolas Wattiez, Maxens Decavèle, Kanty Rabenorosoa, Kévin Bailly, and Gauthier Tallec for their implication on this project, as well as Löwenstein Médical France for their loaning and customising of a *prisma VENT40* mechanical ventilator. This work was funded by a postdoctoral grant from Institut Universitaire d'Ingénierie en Santé (Sorbonne Université). Additional revenues come from two grants from Fondation du Souffle and Fondation de France for the art-science-health project *RÉESPIRATION* led by Samuel Bianchini and Thomas Similowski.

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A Generative Model

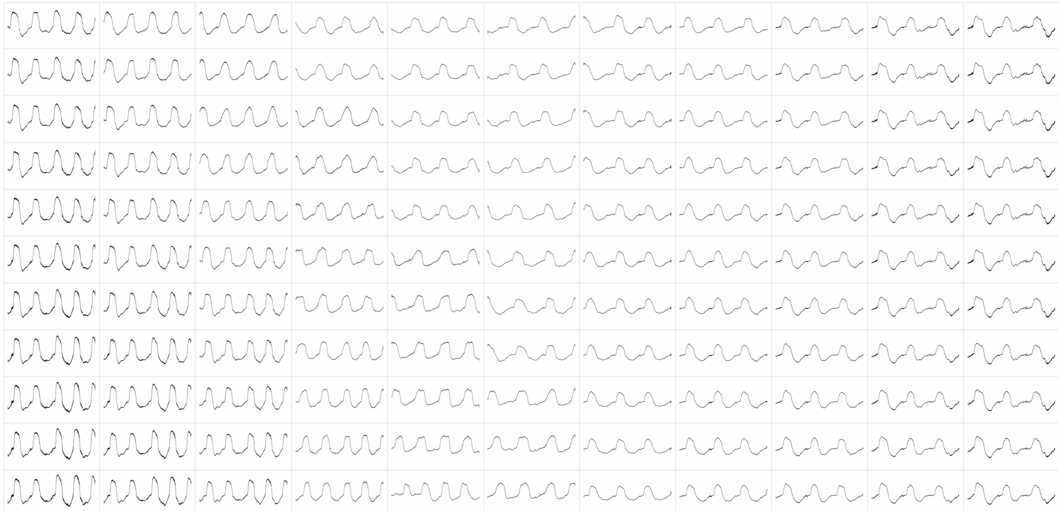

Figure 2: Sample breathing waveforms generated by *GANspire*. Here, breathing waveforms are sampled following the two first components computed with *GANSpace*. Qualitative observations of pulmonologists underlined that fine-grained cycle-by-cycle variations, inspiratory and expiratory pressure slopes and threshold values, and frequency and amplitude fluctuations are typical features of breathing expressiveness or *personnalité ventilatoire*.

B Interface

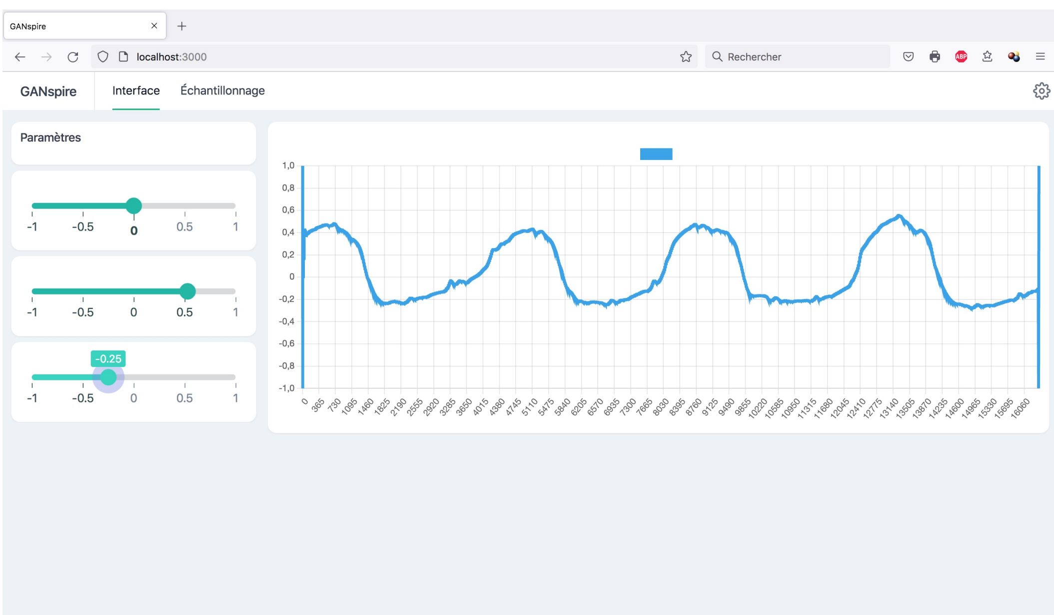

Figure 3: *GANspire* interface, implemented using *Marcelle* [13]. The tree sliders (left) lets users set values of components computed with *GANSpace*, thus exploring diverse breathing waveforms (right) generated by our trained *WaveGAN*.