Towards sentience: A path through jazz, datasets and digital scores

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Abstract

This short paper is a provocation in which we lean into the notion of sentience in Creative-AI music. The purpose of this is to highlight that a critical component when using bucket terms such as "creativity", "intelligence" or "sentience" in the design and deployment of artificial intelligence must be its context. The focus of this paper is a practice-based project called *Solaris*, a jazz quartet where three musicians are AI. Within its context we can claim that we achieved high levels of sentience. The paper starts with a brief discussion of the concept of sentience, positions our point of view and how we approach the concept, and then describes the artistic and technical processes used to build a novel dataset and to train our neural networks. We conclude with an account of the experience of playing alongside sentient artificial musicians and reaffirm the importance of context for the planning, design and utilisation of Creative-AI.

Keywords

Creative-AI, sentience, musicking, digital scores, jazz music

AI and sentience

Although the use of artificial intelligence (AI) is solidifying in the most diverse sectors, there is still resistance to the idea of a symbiotic existence between human creativity and forms of artificial creativity [18]. This resistance is mainly due to a fear of human endeavour being replaced by algorithms [23]. This fear is even more significant when it comes to art, in its multiple manifestations and languages, since art is classically considered to be the greatest form of expression of the human spirit. One of the classic arguments to reject the possibility of Creative-AI is based on the idea that these technologies are devoid of the so-called human spirit and its various components [6], including the notion of sentience.

Over the years, many of us have been working with a concept of Creative-AI that is at the service of expanding human creative capacity, where artists challenge algorithmic limits [4]. These challenge the perceptions of the various creative processes we are exposed to as humans, extending their limits and eventually generating new processes and languages. We understand that creativity is not something isolated but part of a system with social, artistic and cultural implications [17]. Based on this assumption, we believe that the value of Creative-AI lies not in the endless production of works of art without human intervention, as in a large, fully automated production line, but in the joint, real-time work between artificial and human intelligence.

Through one of our current projects - *Solaris*, a AI Jazz Quartet - we challenge the idea that a real symbiosis between AI and human creativity is far from being achieved, in fact we could argue that it already exists in a certain context. What we feel is a more pertinent question is whether it makes more sense to rethink what sentience means and what its real value is for creative processes. We bring this discussion to the field of music since *Solaris* is a Jazz and AI project. Music is a highly documented laboratory with which to introduce this kind of provocation, as there is already so much knowledge about inter-relationships between musicians, representations of self, and ensemble dynamics. *Solaris* is a jazz quartet in which three musicians are neural networks, trained with a dataset collected over two years, and only one musician is human. This ensemble has been performing since 2019 in various guises, mostly with compositions in the spirit of jazz and free improvisation.

Sentience: What is it, and what is it for?

Like many other concepts and terms, sentience can be described in various ways. Generally speaking, sentience is the capacity of beings to express sentiments and sense their environment, along with some degree of awareness of it. Proctor [19] points out that sentience is related to individual thoughts, emotions, and feelings, which cannot yet be fully understood through physiological or anatomical processes. This is one of the main barriers to comprehending what sentience is and proving its existence scientifically.

What interests us is recognising the concept of sentience as fundamental to the development of extraordinary capacities for knowing and doing, as Kabat-Zinn [12] points out.

In the specific field of AI, the idea of sentience represents a shift in performance from something with intelligent characteristics (reason, reasoning, cognition, judgement) to a sentient mind and body, capable of having experiences, sensations, emotions and consciousness [13]. Chatterjee [1] points to the fact that many experts believe that AI will develop some form of sentience, with some believing that computational sentience can emerge from deep learning architectures if they have enough training data. Others believe that combining deep learning with classic methods of symbolic AI

(GOFAI - Good old-fashioned artificial intelligence) will be necessary for sentience to be achieved. Hull [11] proposes an approach that treats sentience in AI as a sociopolitical issue, concerning with what the implications are for labeling something sentient or conscious. We believe that contextualized sentience is already here, and propose a third way, based on Carles Sanders Peirce's concept of synechism, attuned to our research.

It is important to emphasise that sentience means more than sensory qualities and consciousness [2]. Although to feel something it is necessary to have some ability to discriminate between different sensory attributes, there are other requirements. Clark [2] proposes and defends the thesis that various sensory modalities share a generic form called "feature-placing". Feeling something occurs through the choice of feature-places in or around the body of the sensitive organism and the characterisation of the qualities that appear in these feature-places. Clark [2] says that this feature-placing is a primitive type - probably the most primitive one - of mental representation. In other words, sentience presupposes a cut-off in time and space, the existence of a sentient body and, most importantly, the ability to realise some mental representation. In our view, this "feature-placing", this cut-off in time and space, provides the required context to acknowledge the presence of sentience in Creative-AI.

For these reasons we believe that a proper symbiotic system between Creative-AI and humans needs to be embodied, acting in real-time and being able to represent the symbols being processed mentally; in our case within the dynamic world of music. Our hypothesis assumes that there is no need for a complex cognitive apparatus, such as the human one, to represent symbols mentally. And thankfully there are others in the world who also follow this line of thinking: we refer here to idea that dogs and other animals can now be considered sentient, with legal frameworks being designed to acknowledge this[1], even bacteria may be considered to have a sort of consciousness or sentience [20], just not to the scale of a human. Regardless, current computer systems are extremely capable of performing such a representation.

Going one step further, we assert, based on Charles Sanders Peirce's [16] synechism theory, that current AI constitutes a type of mind. It is this characteristic that makes it possible for artificial systems to communicate with the human mind and for a sentient ecosystem to emerge; especially if the AI is reaching outside of its black-box and sensing it's world through appropriate percepts[2]. Peirce's synechism assumes that continuity always prevails and that the assumption of this continuity is of fundamental methodological importance for philosophy and communicology. Minds are continuous entities, constantly changing and always in flux.

A communicology of AI must consider the complexity of these technological systems and their ability to establish a continuous, two-way communication route with the human mind. Also, according to the theory of synechism, an indispensable law for any mind is that ideas tend to spread and affect other ideas, which in the field of creativity leads to the expansion of processes and practices. At this point, we should criticise theories that study AI as an isolated phenomenon, disembodied and distant from humans. This reductionist perspective does not allow us to see the bigger picture and realise that artificial sentient systems are already here, communicating with us and mentally representing parts of the world, language and art. We understand that it is not necessary for AI to represent the universe in its entirety or to have general capabilities in order to be considered sentient; it is enough to merely engage with, sense and respond to the immediate dynamic world in which it is contextualised, in this case jazz music improvisation.

We propose switching the question: Instead of analysing what sentience is, why not ask what it is for? With this change of perspective, a broad horizon for collaboration between artificial and human minds opens up. Every AI is programmed to achieve a goal. In our case, the goal is to co-create through improvised jazz music with a human musician using a digital score as a continuous interface for mental representation and embodiment.

Sentience, music and digital scores

Our research takes place in a boundary area where creative processes expand. Quantifying creativity, however, is not one of our objectives. What interests us is discussing the act of performing a piece of music in real-time together with AI musicians, and dealing with these challenges: *how does AI make itself present and perceptible?, how can we challenge and be challenged creatively by AI? what is Creative-AI sentience for?*

Firstly, addressing how meaning is constructed in a musical piece is necessary. To do this, we start from the idea of musicking [24], which says that to music is to participate in any act, be it composing, performing, listening, dancing even. Vear [26] emphasises that from the perspective of musicking, the construction of musical meaning is found in the practice of the creative acts involved in making music and in the relationships created during these acts. Therefore, musical meaning is to be found in examining the relationships within, through, by means of and emerging from musicking and the materials, behaviours and agents that form these acts, such as people, algorithms, sound, space and time. In short, through musicking, musicians become music through a sense of embodiment within their environment - the sound world -, a shared endeavour and a loss of consciousness of their everyday wakefulness and bodily self-consciousness.

In our research, we emphasise that there is no hierarchical distinction between human and artificial musicians. Both are central to the decision-making process in musicking, both are engaged in the shared endeavour of musicking, both are sensing the activities of the other, and both are attuned to their shared environment: the music-world. This perspective is supported by a widespread understanding of music that when musicians perform they do not simply emit sounds into the world but engage in an embodied experience of becoming the sound they create in the flow of musical creation [26][14][5][24]. In *Solaris* the communicology of the AI performers is expressed through the sounds they make (piano,

[1] e.g. https://science.rspca.org.uk/sciencegroup/sentience

[2] An object of perception; something that is perceived

bass and drum machine), but also as visual representations of it's state through a digital score. According to Vear [26], a digital score is characterised by the following aspects:

> 1. A digital score is a technically mediated communications interface that enhances how ideas in music can be represented. 2. A digital score is a technically mediated pathway for a musician (human or machine) to navigate within sound during the performance. 3. The digital score is a hardware-software combination that can support and enhance the connectivity of people, sound, space and score. 4. The digital score allows compositions to be defined by their interactivity. 5. The digital score can augment performance techniques that lead to invention and creativity within the parameters of active composition (especially improvisation and open/distributed compositional forms). 6. The digital score is a technological space for creative invention.

Of interest to our research project here are aspects 1, 2 and 3. Eschewing the traditional notation format, the digital score is used to communicate a presence, behaviour and responses, and to stimulate the sensation of joint action. In our participatory observation process, we noticed that, from the human point of view, notions of self-representation within the process of musicking together with AI gain new representations, mainly through the mediation generated by the continuous interface that is a constituent part of a digital score. The digital score defines the space for musicking to take place, establishes a constant link between the artificial and the human minds - both endowed with the ability to make mental representations - and provides a space for creative invention (Figure 1). This ecosystem together with the AI-stack design (see below), fulfils the characteristics that we believe are essential for the existence of a sentient system.

Solaris: A Jazz AI Quartet

Our research approach is based on a bottom-up methodology, starting with a specific problem and moving towards a general model. Unlike other projects dealing with music and Creative-AI, our starting point is aimed at something other than recreating a musical piece by mimicking existing music formats or enhancing a musician's technical skills.

Although the field of music and Creative-AI has a long history, beginning in 1956 by Lejaren Hiller and Leonard Isaacson with the musical piece *Illiac Suite* [10][7][22] - a computational experiment that created the first score composed with a computer - up to the long list discussing the state-of-art of models, technologies and compositions compiled by Hernandez-Olivan and Beltran [9], we feel that our treatment of the problem is unique in that it considers the act of embodied musicking within a real-time flow in a symbiotic environment as the only credible factor for the emergence of sentience in music and Creative-AI.

To test our provocation of sentient AI, we created *Solaris*, a Creative-AI jazz quartet[3]. In this experiment, a human jazz drummer plays with 3 other musicians (bass, piano and drum-machine) generated by the AI. The AI-stack (architecture) was a simple modular design of :

- *Layer 1*: *Umwelt* - percept input and formatting. In this layer, the live audio from the drummer mixed with the sound of the AI-produced instruments (as a form of self awareness) is streamed into the AI factory. This is the AI's window out of the black-box into the shared world of musicking.
- *Layer 2: Thought-Trains* - AI factory into hive mind data structure. This innovative multi-neural network predictive system is trained on embodied musicking data (discussed below). Its purpose is to generate constant data streams in response to either the live input, or output fed from neighbouring networks.
- *Layer 3: Affectual Response* - This layer controls the trains of thought [8] from the AI factory and organises individual streams into phrase length, outputting to layer 4. This is where the AI organises its response to the raw input from the musicking world and trains-of-thought. There is also a "startled" effect when the live input or the predicted data reaches a certain high threshold and startles the manager to change trains. We define affect as an "experience of feeling or emotion. It plays an important role in the flow of musicking and can be evoked through our relationships with the digital score. Affect can bind emotions to our actions and those of others, it can influence musical responses to generative sounds, it can colour aesthetic choices about how we understand the flow of music and the relationships we assign meaning to" [26].
- *Layer 4: Belief system* - the aesthetic codes and language it can use to reach out into the musicking world. In this case, a specific theory of jazz harmony and a visual interface that takes the AI out of a black box and allows the human musician to sense its state of mind.

Our AI-stack solution for *Solaris* results from an innovative design based on a novel embodied dataset used to train a series of neural networks[4]. These networks are driven by an affectual response, using a combination of modern AI techniques and strategies from symbolic AI. This affect response informs a gesture manager, which uses a method known as "reasoning forward" to produce new and often unexpected musical situations. The gesture manager takes a problem state - a space-time cut-out within musicking - forward from its state to one satisfying a goal condition. Hence the name "reasoning forward". The aim is to produce a musical language with the belief system implemented in its mental representation system, made up of the Lydian Chromatic Concept of Tonal Organisation [21] as its musical understanding. The gesture manager seeks, in tune with the digital score, to generate performances composed of chord sequences that make chromatic sense.

Our dataset was designed to capture elements of human creativity from within the embodied relationships of musical performance, collecting empirical data on how human beings

[3]Examples of the quartet can be found here: `https://solarisjazz.bandcamp.com/`

[4]Discussed in more detail in [25]

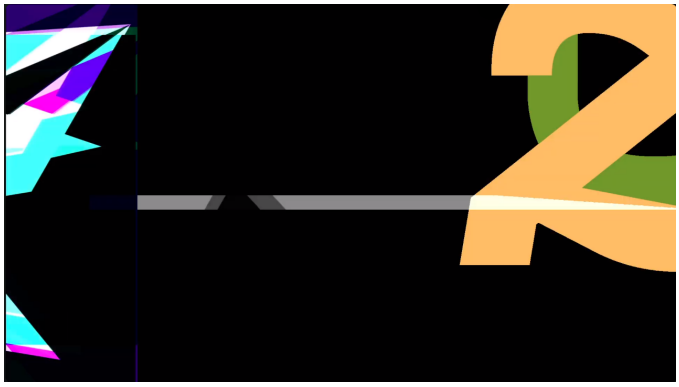

Figure 1: *Solaris'* visual interface, displaying a frame of the digital score.

create and appreciate music through their data flows[5]. An important fact to note was our concern to ensure that the musicians were in a state of flow within the music while performing. For Nijs et al. [15], the optimal embodied experience (flow) occurs when the:

> musician is completely immersed in the created musical reality (presence) and enjoys himself through the playfulness of the performance. Therefore, direct perception of the musical environment, skill-based playing and flow experience can be conceived of as the basic components of embodied interaction and communication pattern.

Csíkszentmihályi's Flow Theory [3] also supports the argument that the acts of doing in music should be considered an immersive and embodied experience. Csíkszentmihályi defined flow as 'the state in which people are so involved in an activity that nothing else seems to matter' [3].

The design model for our Creative-AI dataset is based on capturing the multidimensional interrelationships of embodied musicking. This matrix was then used to identify and determine the best and most efficient combination of human parameters to capture in order to build a dataset that would fulfil the project's overall objectives. This is discussed in more detail in Vear and Poltronieri et al. [25], but an overview of its design is: *Part 1: Physical-world music*: Backing track audio and associated score organisation (mono). Audio recording of the piano (mono). Video of hands and fingers (embedded with the audio track). *Part 2: Embodied musicking*: Electroencephalogram EEG [from BrainBit]. Electro-Dermal Activity EDA (arousal from Bitalino). Body tracking (using the Cubemos Skeleton SDK from the Intel Real Sense depth tracking camera). *Part 3: Flow protocol analysis (post recording)*: Self-flow-evaluation as sliding scale.

The main objective of the dataset is to enhance human creativity, not to represent a rigid model with precise correlations between the musicians' actions and the music generated by the neural networks. We deliberately left room for error, for accidental elements, for messiness and garbage (discussed in Vear and Poltronieri et al. [25]). Our aim is not to create a system that specialises in virtuoso jazz playing, but to stimulate a close-coupled, co-creative relationship, bringing artificial systems closer to human processes, and establishing areas of contact and contamination. To design such sentient systems - bearing in mind our definition of sentience and the use we make of it - we have observed Peirce's perception of the nature of human thought:

> All human thought and opinion contain an arbitrary, accidental element, dependent on the limitations in circumstances, power, and bent of the individual; an element of error, in short. But human opinion universally tends, in the long run, to a definitive form, which is the truth. Let any human being have enough information and exert enough thought upon any question, and the result will be that he will arrive at a certain definite conclusion, which is the same that any other mind will reach under sufficiently favourable circumstances. [16]

Training the neural networks

For *Solaris*, we trained four neural networks: 1. Recurrent Neural Network predicting time-based series for movement data trained solely on the 'nose' data captured from the skeleton tracker. 2. Recurrent Neural Network predicting time-based series for affect data trained on the EDA 'arousal' data captured from the Bitalino. 3. Convolution 2D network predicting movement data ('nose') from affect data from the EDA. 4. Convolution 2D network predicting affect data from the EDA from movement data ('nose'). In each case, the raw data was split 67:33 between training and testing. The data was normalised between 0.0 and 1.0 using a MinMax analysis of each set. Outliers and missing values were omitted.

Evaluation

In dealing with the challenges we posed in the early part of this provocation, we created a series of test demo's with *Solaris* and reflected upon the relationships, stimulation, affordance and the sensation of co-creating with a jazz-AI. For brevity here, we will only describe one instance in the first recording of an interpretation of John Coltrane's piece *Giant Steps* [6]. At 2'10" it stops the current flow of improvisation and plays something that is more subtle, quieter and reflective. It forced the human drummer to change tack and join in. The proceeding phrase returns back to a more staccato playing, but because of this sombre breath, the music has been changed. There was nothing predictable about this; it just happened but upon re-hearing it, it makes musical sense. This decision by the AI was present and in the moment, although when described in text it might read like a swerve-ball, but in the moment it 'was a glorious and surprising decision, that felt completely natural at the time' (personal notes by Vear 2023). Within the context of jazz improvisation it is stylistically reminiscent of Wayne Shorter's last quartet with pianist Danilo Perez, bassist John Patitucci, and drummer Brian Blade. More importantly, it challenged the human to make a

[5]The dataset is available at `https://figshare.dmu.ac.uk/articles/code/Embodied_Musicking_data_capture_software/19161269`

[6]The recording of this demo can be found here: `https://solarisjazz.bandcamp.com/track/giant-steps`

creative choice, one that was wholly in the context of the music journey, and one that added great value to the music. Like move 37 from *AlphaGo*[7] it made an indelible mark on the thought processes and future musical decisions of the human musician. As part of the evaluation process we shared these recordings with critical friends who were also professional improvisating musicians. Their responses included "F*** AWESOME!", "I like it a lot. Kind of spiky and soothing at the same time.", "Love it", "sounds refreshing, interesting, strangely satisfying", and "Enjoying it more on subsequent listens". Overall the human musician felt like he was being taken on a journey through the music in each of the demo's, it forced him to consider ingrained, entrenched and familiar techniques and reactions and stimulated him to think up new creative solutions and responses in the moment.

As a concrete result, a complete album of demo recordings with eight tracks was recorded and is available for evaluation at `https://solarisjazz.bandcamp.com/`.

Discussion and Conclusion

We do not claim that an AGI (Artificial General Intelligence), capable of performing various tasks without specific training for each one already exists. However, sentient systems in contextualised fields do exist and are capable of performing creative tasks and, more importantly, working together with humans in symbiotic ecosystems. The current generation of AI algorithms has already achieved the most critical parts of sentience, which should be understood as a multidimensional matrix, inserted within a space-time framework that provides context and not as a simple yes/no proposition.

Musicking with *Solaris* brings a surprising experience, not because an AI can play jazz with humans, but because it produces musical phrases that surprise, challenging the limits of the improvisation grammar typically found in jazz, while maintaining a recognisable structure. This constant tension pushes human creative boundaries and challenges traditional models of musical understanding.

The idea that AI should be understood as a form of mind, following the precepts of Peirce's synechism, opens up new avenues for collaboration between humans and apparatus, breaking the Cartesian duality (spirit-matter) that has plagued us since Descartes [11]. What we experience when interacting with sentient systems like *Solaris* is not just a cold, programmatic interaction with inert matter. There is the presence of a collaborative and creative spirit.

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Fabrizio Poltronieri is a computer artist, mathematician, researcher, and programmer, renowned for his contributions to the field of creative computing.He has been recognized with numerous prestigious awards and accolades for his creative endeavors involving computers. Two of his AI artworks, “Dionysus” and “Calliope”, have found their place in the esteemed collection of the Victoria and Albert Museum (V&A) in London, UK. In addition to his artistic pursuits, Fabrizio Poltronieri currently dedicates his efforts to pioneering research in harnessing the collaborative and creative potential of AI across various domains, including music, education, healthcare, and visual arts. His innovative explorations aim to unlock novel ways of integrating AI into these fields, fostering groundbreaking advancements and pushing the boundaries of creative expression. He is also the co-editor of the books The Language of Creative AI and Explorations in Art and Technology.

Craig Vear is Professor of Music and Computer Science at the University of Nottingham split between music and the mixed reality lab. His research is naturally hybrid as he draws together the fields of music, digital performance, creative technologies, Artificial Intelligence, creativity, gaming, mixed reality and robotics. He has been engaged in practice-based research with emerging technologies for nearly three decades, and was editor for The Routledge International Handbook of Practice-Based Research, published in 2022. His recent monograph The Digital Score: creativity, musicianship and innovation, was published by Routledge in 2019, and he is Series Editor of Springer’s Cultural Computing Series. In 2021 he was awarded a €2Million ERC Consolidator Grant to continue to develop his Digital Score research.