Collaborative human and machine creative interaction driven through affective response in live coding systems.

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Abstract. Co-creation strategies for human-machine collaboration have been explored in various creative disciplines. Recent developments in music technology and artificial intelligence have made these creative interactions applicable to the domain of computer music, meaning it is now possible to interface with algorithms as creative partners. The application of computational creativity research is beginning to be incorporated within the context of live algorithmic music known as live coding. However, as music is inherently coupled with affective response, it is crucial for any artificial musical intelligence system to consider how to incorporate emotional meaning into collaborative musical actions. This work will look at bestowing machine musicians within interactive live coding systems the ability to create affective musical collaborations and examine new ways of interfacing with musical algorithms.

Keywords: human-computer interaction, live-coding, affective computing, co-creation, computational creativity

Purpose of research and its importance to the field

Although natural language and programming languages are ontologically distinct, programming languages provide a way of interfacing with computers and music technology in a human way. Language has historically been used as an artistic medium due to its ability for emotional expression through uses of narrative and imagery. Music and language have also historically been symbiotic and the contemporary artistic practice of musical live coding attempts to further this symbiosis. Musical live coding refers to an artist-programmer who writes and manipulates code in real time to generate music (Collins et al. 2003). The practice considers computer languages as a form of musical notation. There are currently multiple programming languages that have been explicitly designed for the expression of algorithmic music; for example languages such as Csound, SuperCollider, patcher languages like MaxMSP Pure Data, or mini-languages such as TidalCycles (Tidal), Gibber and FoxDot.

With the advent of live coding as a novel form of musical expression, research is reaching saturation of new programming languages, all constructing their own linguistic representations for musical pattern. However, one potentially under-explored area within live coding is in the use of *virtual agents* or *machine musicians* as an interaction medium. Instead of designing more languages to interface with, more research is needed in designing new ways of interacting with algorithms and existing research in computational creativity and artificial intelligence might provide this. McLean and Wiggins obtained opinions from those currently working within the live coding community about the possibilities of future integration of computational creativity practices, particularly with respect to the computer's creative autonomy (McLean and Wiggins 2010b). The results of this showed around half of respondents agreeing that autonomous code could produce artistically valuable outputs, but less agreement for the Turing style question of whether "a computer agent will be developed that produces a live coding performance indistinguishable from that of a human live coder."

Recent advances in the fields of music technology and artificial intelligence have allowed for growth of the field of machine musicianship. Interactive systems capable of generation of live musical scores have become more prevalent, however live human performance of these scores is subject to the fundamental drawback that this requires the completion of complex musical tasks such as live sight reading and performance. This makes it a difficult terrain to navigate, even for accomplished musicians. Live coding might be a way to circumvent this, due to its ability to automate processes. Magnusson describes a live coder as "primarily a composer, writing a score for the computer to perform" (Magnusson 2011a) and thus live coding provides an interesting framework to situate work in autonomous generation.

Machine creativity in artificial intelligence is addressed by Boden where creativity is presupposed as an inherently human trait, defining it as "the ability to generate novel, and valuable, ideas" (Boden 2004). However, for artificial musical intelligence to be successful in its aim of creation of valuable music, perhaps less focus is needed on musical surface form and more on the subjective human response. Approaching the task of musical composition from a purely computational standpoint detaches it from its essence as music is inherently linked with emotional expression. In automatic language generation this seems obvious as most linguistic systems tend to consider the narrative and its intended message rather than simply generating based on syntactical information alone and thus the same considerations are needed for musical systems (Wiggins 2018).

Brief survey of background and related work

Many systems have attempted to simulate musical compositions through algorithmic means. Mozart's *Musikalisches Würfelspiel* (musical dice games) is considered one of the first pieces of algorithmic composition, whilst the first piece of music composed by a computer was Hiller's *Illiac Suite*- using the Illiac I computer to compose for a string quartet (Herremans, Chuan, and Chew 2017). Contemporary algorithmic music practices span from Google's artificial intelligence and music project *Magenta*, which harnesses the potential of machine learning and deep learning to generate music, to mathematical and probabilistic approaches, such as Markov models, evolutionary modelling or grammatical approaches.

Contemporary algorithmic music practice spans a wide range of disciplines. One recent subset of the field looks at *affective algorithmic composition* (AAC) which describes the process of combining computer-aided emotional evaluation and methods and techniques for generating music based on given sets of rules or instruction. AAC expands on current research on dynamics between music and affective response in interactive systems. This can take the form of using emotion data to choose or control existing music, for example Barthet et al. create interactive systems for collectively controlling music and lighting to express desired emotions (Barthet et al. 2015), or to synthesise new music, using AAC methods. Various practices are used to implement affective response into algorithmic composition. Two of the most commonly found are *categorical* (using discrete labels to categorise affective response states) and *dimensional* approaches (affective phenomenon as a set of coordinates in a low-dimensional space). The *Metacompose* system provides an example of AAC that uses a dimensional approach and evolutionary methods to create "a compositional, extensible framework for affective music composition" (Scirea et al. 2016).

The term *machine musicianship* describes the application of intelligence concepts and algorithms to computer music systems and where systems have the ability to demonstrate and learn creative behaviour. Some notable examples of the field include Patchet's Continuator which continues musical phrases based on user input (Pachet 2003) or the OMax system which uses factor oracles to learn in real-time typical features of a musician's style and plays along with them interactively (Assayag, Bloch, and Chemillier 2006). Machine musicianship provides new approaches to computational music making, widening the field of HCI.

Given live-coding's standing in human-computer interaction, it is unsurprising that the challenge of co-creation with machine musicians has already been attempted through different strategies. Notable examples include *LOLBot* (Subramanian, Freeman, and McCoid 2012), a virtual agent that can collaborate with humans, Magnusson's autonomous live-coding virtual agent *Autocode* implemented in ixi lang (Magnusson 2011b). Further to this, Xambó et al. consider how collaborative human and machine interactions situated within collaborative music live coding practice (CMLC) can be used in both educational and performance contexts and how these practices can inform both students to improve their programming practices and musicians to augment their creativity (Xambó et al. 2017). Within Tidal there have also been attempts at implementing machine musicianship, with an autonomous performer *Cibo* using sequence-to-sequence style neural net algorithms (Stewart and Lawson 2019), or using evolutionary algorithms to evolve musical patterns in Tidal using the Extramuros platform (Hickinbotham and Stepney 2016).

For the construction of creative systems within the context of live coding, Wiggins and Forth advocate for three key components (Wiggins and Forth 2017). The first is the ability of a computer to relate the meaning of a program to its syntax. Secondly, the computer should be able to model the coder's aesthetic preference. Then thirdly, the system should have the ability to manipulate the available syntactic constructs to take some creative responsibility for the music. The proposed approach for the research outlines how these ingredients are to be applied to the interactive system being designed.

Description of the proposed approach

This work looks at implementing machine musicianship and computational creative strategies through affective modelling, specifically within the Tidal programming mini-language. Tidal is a real-time embedded domain-specific language for live coding (McLean and Wiggins 2010a). It is implemented as an extension of the functional programming language Haskell (Thompson 2011). The symbolic nature of this language allows the live-coder to pair program fragments with their associated symbols and its type-checking system makes it suitable for real-time algorithmic composition, making it a conducive environment for the research outlined.

The proposed approach looks first to existing literature on music and emotion (Juslin and Sloboda 2001) and how this can be used to build accurate models of affective response. The functional relationships proposed based on the literature seek to map intended target emotion-related parameters onto musical structural aspects such as tempo, loudness, rhythmic density, pitch register and modality. This is done using the circumplex dimensional model of affective response with valence and arousal, parameterised as $v, a \in [-1, 1]$. Some literature suggests the use of three dimensional models for additional clarification (with dimensions for tension or dominance parameters) (Scherer, Johnstone, and Klasmeyer 2003) however these are omitted from the current research at this stage.

Validation of the accuracy of these models in representing affective correlates will then occur through online listening tests. This will obtain data on how the intended mapping of affective co-ordinates matches with the perceived evaluation of the patterns produced through their audio output. These models will then be incorporated as part of the algorithmic composition strategies employed by the creative agents to allow control over these structural aspects of the music. As Tidal is an extension of the functional Haskell language, functions or external modules and libraries provide the framework for implementing these models of affect.

On creation of a valid framework to situate affective algorithmic composition, these can then be implemented to create the collaborative machine musician. Strategies for computational creativity will be explored within the live coding framework, such as those outlined in the related research. Current research has begun with a focus on the inclusion of algorithmic composition strategies that can be used for autonomous composition of musical pattern. The application of these composition strategies have been examined, such as the use of first-order Markov chains and random walks, or implementations of neural network structures within the Haskell environment. This will be followed by an exploration of how to combine these affective models and computational creativity strategies, so as to implement affective algorithmic agents capable of creating some artistically valued contributions.

Existing research on language and system design in live coding can be used to inform the methodological approaches employed for this research. Kiefer and Magnusson obtain qualitative data through surveys on the design of language and environments for live coding (Kiefer and Magnusson 2019) by obtaining responses from practitioners in the field of language design and machine learning. The authors use a speculative approach: seeking to examine why people use live coding systems and questioning both why people use live coding systems, and what features enable them to live code successfully. Their results are broad in scope, but produce various findings of interest, such as the success of live coding practices as not only a performance practice, but a general way to converse with computers and explore emerging ideas. Similar methodological approaches could be applicable, where design of the system outlined in this paper would be informed by supporting qualitative analysis.

Expected contributions

This work will address research questions and perform exploratory studies grounded in and contributing to a wide span of research areas, including human-computer interaction, musical interface design, algorithmic composition, and psychology of music. This work aims to contribute to these domains through exploration of live coding as an interface for providing meaningful musical interaction between human and machines and through exploration of artificial aesthetics and automated emotional intelligence.

Moreover, current research in interactive music and computationally creative systems make limited use of formal evaluation methods, and many systems are not described in sufficient detail for their re-implementation. As well as the design of a system for interaction with affective autonomous agents, this work intends to apply evaluation metrics to any musical output of the system.

Some existing frameworks exist that aim to provide universal evaluation of computationally creative systems. Jourdanous (Jordanous 2012) proposes a Standardised Procedure for Evaluating Creative Systems (SPECs), its approach based around a set of 14 'components of creativity' that evaluators should consider. Kantosalo also identifies this disparity between the production and evaluation of creative systems and proposes hybrid approaches from field of user-experience design and computational creativity research (Kantosalo and Riihiaho 2019). This work will aim to contextualise the existing research on evaluation of computationally creative systems within the framework of live coding. However as the research on this specific domain is currently sparse, perhaps some significant contribution of this project is in the application and adaption of existing methodologies to create new critical evaluation models of both musical output that is produced and the interaction between human and machine agents.

Progress towards goals

The first stage of this research has looked at developing strategies to implement some constructed model that can be used to simulate affective response in musical composition. Affective modelling equations based on the existing music psychology literature have been implemented. From this, various functions have been implemented using the Haskell language and embedding within the TidalCycles environment that aim to programmatically update musical structural parameters of the system, through the use co-ordinates of the two-dimensional model of affective response outlined by Russell as input values. This then provides the framework for automation of production of musical phrases conforming to some intended target affect.

The research will then look at the validation of the chosen rules for this implemented model. To do so, a current ongoing research study is looking at whether the intended affective response is conveyed accurately to listener's through patterns with target affect. The intended valence and arousal parameters will be verified against the listener's perception of these, through use of statistical testing measures such as Pearson's correlation. Once the implemented model can be verified by the results of listening tests, the next stage of the research is to look at integrating these models with various computational creativity strategies and then finally to apply evaluative techniques to attempt to measure the successes of such a system.

Acknowledgements. This work was supported by EPSRC and AHRC under the EP/L01632X/1 (Centre for Doctoral Training in Media and Arts Technology) grant.

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