THE REACTIVE SCORE

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ABSTRACT

Scores designed to be displayed on screens provide the opportunity for composers to dynamically update information and musical instructions presented to performers during the moment of performance. Such scores may be responsive to the agency of performers or audience members, providing new forms of structural organization or ways in which denoted musical material can be transformed. This paper explores the creative possibilities of such *reactive scores* and situates them within a historical tradition of malleable notation. Two works by the author are discussed in which real-time features of the musical performance drive the notational transformations of the performance score.

1. INTRODUCTION

The concept of a score as an assemblage of malleable parts is not necessarily a new one [1, 2]. Stockhausen's *Refrain* (1959) which features a mobile transparent strip containing various articulations and ornamentations which apply to the printed score, and John Cage's works featuring transparencies and printed notation such as *Fontana Mix* (1956) which are assembled by performers to create a performance score, are two early examples of such approaches to notation.

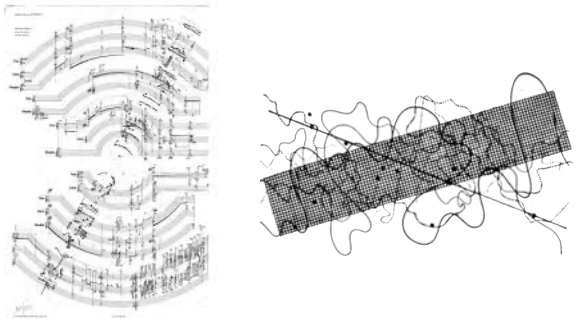

Figure 1. Stockhausen's *Refrain* (1959) with its distinctive circular score (left), and Cage's *Fontana Mix* (1956) which is assembled by the performers from preprinted sheets and transparencies (right).

While the malleability of a score is naturally constrained by the physical properties of the media upon which it is inscribed, the growing adoption of screen-based scores and the rapid development of networking technologies, has afforded new degrees of transformational agency to both audiences and performers. To an extent, such reactive scores are situated within a tradition of participatory art although there is an important distinction to be made in that much participatory art practice is motivated by themes of political and social engagement [3, 4], or a desire to situate the audience in performative, creative roles [5]. The type of reactive scores discussed in this paper, however, are designed to be interpreted by performers with their range of possible transformations affected by the dynamic play of audience or performer agency.

2. AUDIENCE AGENCY

The correlation of audience agency to a performance score's transformation typically follows one of two strategies – synchronous, where audience members are invited to help shape a performance score during the live performance, or asynchronous, where a score's instantiation is contingent on prior decisions or selections made outside of the live performance space. In both modes, audience agency typically operates within a preestablished framework, constrained to affect a select number of musical parameters.

Composer Jason Freeman has adopted both synchronous and asynchronous modes of audience engagement. In his *Saxophone Etudes* (2011), members of the audience are invited to help shape the musical properties of the score displayed to the saxophonist during the live performance [6]. Through a simple interface displayed on a smartphone, see Figure 2, audience members can vote on a range of tempo, dynamic and articulation options. The collective results of this polling are superimposed onto the score read by the performer, helping to guide their live interpretation.

Figure 2. The smartphone interface for Jason Freeman's *Saxophone Etudes* (2011) used by listeners to guide the performer's interpretation.

An asynchronous approach to audience agency is featured in Freeman's earlier work *Graph Theory* (2006), for solo violin or cello. In this work, audience members choose different pathways through short, looping melodic units presented on a dedicated website with these choices affecting the probability weightings used to generate a performance score, see Figure 3. Of particular note in *Graph Theory* is the UI design which adopts simple color mappings and a graph style visualization of a melodic cell's pitch-time structure, to facilitate understanding by users who may not be able to read common practice notation.

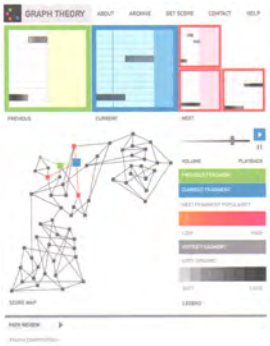

Figure 3. User interface for Jason Freeman's *Graph Theory* (2006).

Kevin Baird's *No Clergy* (2005) adopts both an asynchronous and synchronous approach to the real-time creation and transformation of a score [7]. During performance, members of the audience can affect a range of musical properties such as articulation and dynamics which affect subsequent development of the score displayed with GNU LilyPond. Like Freeman's *Graph Theory*, the interface presented to the audience avoids common practice notation, and features simple slider controls and buttons, see Figure 4. Similarly, the user interface for Zhang et al.'s *Open Symphony* web-based interactive system [8], has been carefully designed to present an easily intuited control system for presenting different styles of musical performance, see Figure 4.

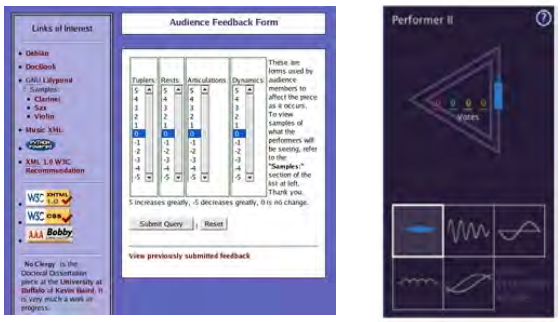

Figure 4. User interface design for Kevin Baird's *No Clergy* (2005) (left) and Zhang et al.'s *Open Symphony* (right).

Rather than interacting through a software interface, Wulfson's LiveScore system features a hardware controller which audience members can manipulate during performance to affect the textural density, pitch, rhythmic, and dynamic properties of a screen-based score [9]. Such an approach to audience engagement, where the actions of audience members are so obviously foregrounded, promotes a very different experience than those works in which the agency exercised by the audience is more concealed.

3. PERFORMANCE AGENCY

Perhaps not surprisingly, works featuring reactive scores responsive to audience agency form a small number. More commonly, score transformations tend to be correlated to decisions made by performers prior to performance, as in works such as *Refrain* or *Fontana Mix*, or synchronously through response to decisions or musical activity made during the moment of performance itself.

A key technical factor in the evolution of performance-driven reactive scores has been the development of score following techniques and softwares such as AnteScofo [10] and software technologies for facilitating the real-time display of musical notation including INScore [11], MAXScore [12], and Bach [13]. While most score following software has been designed to track the nuances of a live performance and provide synchronous electronic accompaniment, see for example works such as Marco Stroppa's *...of Silence* (2007) or Philippe Manoury's recent *Das Wohlpräparierte Klavier* (2021), more simple techniques of providing control over a score's evolution have included the use of foot pedal cues such as those employed in Seth Shafer's *Terraformation* (2016) in which the performer controls progression through the screen-score through various pedal cues [14].

In his work *Semaphore* (2014), composer Richard Hoadley has developed a reactive notation system in which the physical gestures of dancers are tracked with a Kinect interface and used to transform the display of a predetermined text [15]. Spectral features of the spoken text are then used to generate music notation which is in turn presented to performers through the INScore system [11]. The musical performance is, in turn, interpreted by the dancers establishing a complex feedback loop.

A more unusual mapping of performance physicality to notation occurs in Erich Berger and Peter Votava's, performing as the duo Terminalbeach, work *Pixelache* with the Heart Chamber Orchestra [16]. In this work, the heartbeat of each member of the orchestra is monitored with electrocardiogram sensors. This data is then used to generate a musical score which is displayed on screens placed in front of each of the performers, see Figure 5.

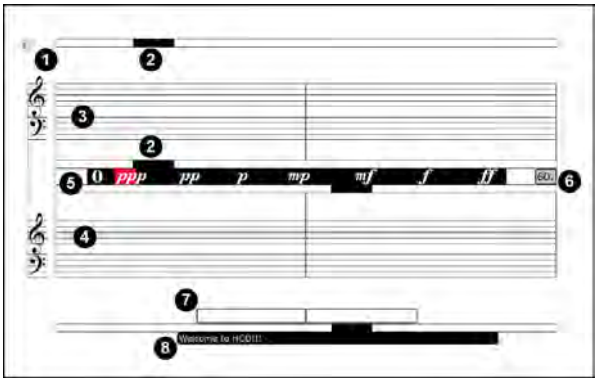

Figure 5. Performance score generated from ECG data in Berger and Votava's *Pixelache* (2012).

Feedback systems, which are a natural paradigm of reactive notations, are more overtly featured in Andrea Valle's *Dispacci dal fronte interno* (2012) for strings and live electronics. In Valle's work, audio features of the live string performance are analysed and used as control material for processes which generate music notation that is printed during performance, see Figure 5, passed on in the form of dispatches to the live musicians and reinterpreted [17].

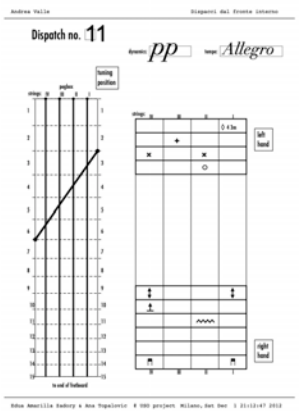

Figure 6. Notation generated in response to performance input for Andrea Valle's *Dispacci dal fronte interno* (2012).

For composers exploring the affordances of notation responsive to performance agency, the extraction of audio features of a live performance is necessary. Composer Sam Hayden and violinist Mieko Kanno have recognized this in current work being undertaken in the development of their live notation system NEXUS [18], which is integrating real-time audio analysis into the generative processes used to create notation. This is being achieved through a range of external Max external objects which provide real-time information on musical parameters including pitch, amplitude, and timbre.

4. FEATURE EXTRACTION AND MAPPING

The author has explored the creative affordances of reactive scores in two recent works, both of which feature three-dimensional graphic performance scores presented to the performers in mixed reality space. Both works rely on the real-time analysis of a live performance to extract audio features which are subsequently mapped to visual properties of the performance score.

4.1 5x3x3 (2019)

5x3x3 (2019) was developed for the ELISION ensemble and uses the HoloLens, an augmented reality head-mounted display developed by Microsoft, to project a three-dimensional holographic score in the performance space for each of the three performers. The score itself is dynamically transformed during performance and consists of a three-dimensional construct of colored nodes connected by lines, or edges in network graph nomenclature, of various colors and curvature. Each of the nodes represents the onset of a musical note with the node's color denoting a type of articulation. Pitches are specified by edge colors and the duration of notes by an edge's spatial length.

As performers physically explore the performance score holographically situated within the performance space, an FFT analysis is performed upon the sonic results within a Max patch. Data derived from this analysis is then scaled and sent via OSC to transform the curvature of the edges connecting nodes within the performance score and the size of the nodes themselves, see Figure 5. Edge curvature is interpreted by performers in the form of timbral transformation with the scale of curvature directly correlating to the scale of transformation while relative node size is mapped by the performers to different dynamic levels.

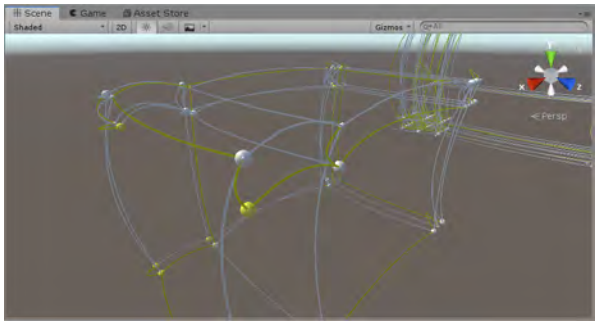

Figure 5. Selection from the score for *5x3x3* (2019) within the Unity 3D development environment showing various edge curvatures between nodes. A real-time FFT analysis is used to map control points of the Bézier curves drawn between nodes.

4.2 reTweets (2022)

5x3x3 was the first work of the author's to explore the musical affordances of reactive notation. Given the technical complexity of the performance system, the mapping of real-time performance data to features of the graphic score was deliberately kept relatively straightforward. *reTweets* (2022) adopts a more sophisticated approach. Like *5x3x3*, it features a three-dimensional score presented in mixed reality space but in *reTweets*, the performance score is generated through a real-time linguistic analysis of tweets posted to Twitter.

reTweets is run from a Jupyter Notebook and uses the Tweepy Python library to access the Twitter public API and return tweet data on predetermined keywords.[1] A dependency parse is performed on the returned tweet with spaCy,[2] a powerful natural language processing library, and the word vectors of each token are called from Gensim using a model trained on Google news.[3] While it is beyond the scope of this paper to delve deeply into the theory of word vectorization and embedding, for this the reader is referred to [19], the basic Natural Language Processing concept is that words may be represented with high dimensional vectors, where words that are semantically similar, e.g. "bathe", "wash", "clean" will return word vectors closer than words semantically dissimilar, e.g. "apple", "laundry", "smoke". In Gensim, word vectors are of default size 100, which in order to be mapped to a Cartesian coordinate, as is required in the *reTweets* visualizations, must be reduced to three. In *reTweets*, this dimensional reduction is performed with scikit-learn,[4] with all returned data subsequently visualized in a three-dimensional node graph within a VR scene. An example of a retrieved tweet, its dependency parse, and subsequent visualization is presented in Figure 6. Each token within the tweet is represented by a node and the dependencies between tweets denoted by white-colored edges.

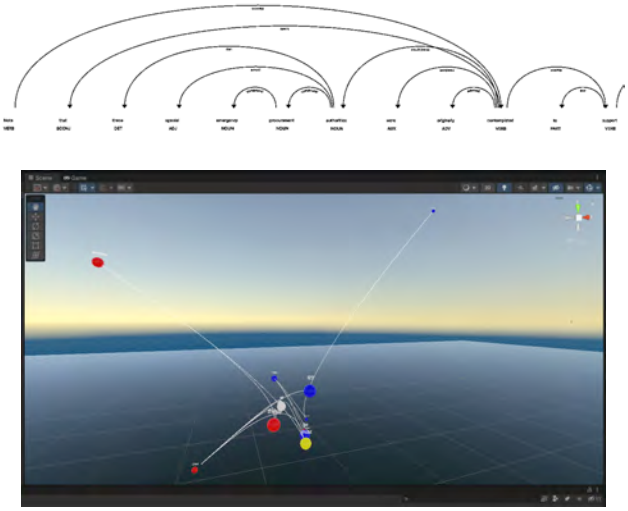

Figure 6. Original tweet (upper), partial dependency parse (middle) and three-dimensional visualization (lower) in the Unity 3D development platform of a tweet retrieved on keyword "Ukraine".

reTweets adopts a similar mapping strategy to previous works by the author where nodes denote the onset of sonic events with their color indicating specific pitches. The duration of these events is denoted by the spatial separation between nodes while connecting edges suggest how performers may determine the sequence of events. Visualized tweets are positioned in a series within a VR scene as shown in Figure 7.

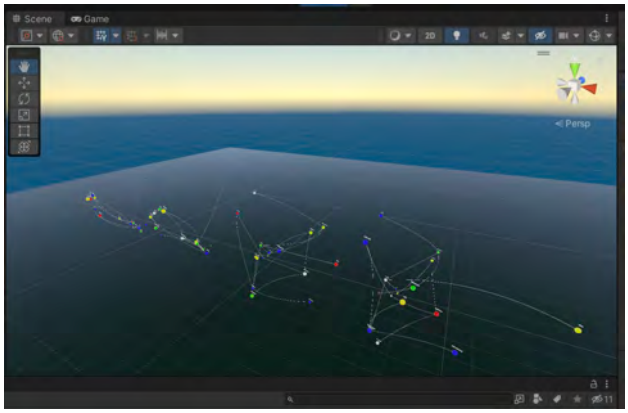

Figure 7. Positioning of tweet visualizations within the VR scene in the Unity 3D development platform.

During the live performance, various audio features of the musical performance (pitch, amplitude, spectral centroid, and spectral flux) are extracted with the zsa.descriptors library [20]. This data is then used to transform the spatial distribution of nodes within each of the tweet visualizations which establishes new temporal relationships between events.

Supplementing the feedback loop established between the score and the performers, *reTweets* features an

[1] https://tweepy.org
[2] https://spacy.io
[3] https://radimrehurek.com/gensim/index.html
[4] https://scikit-learn.org

additional feedback mechanism whereby the spatial repositioning of nodes generates new word vectors and tweets which are subsequently posted back to Twitter. This process is built on the computation of Word2Vec similarities within Gensim [21] and effectively creates a greater pool of tweets which may be sampled for recurrent visualizations. A schematic of the entire performance system for *reTweets* is presented in Figure 8.

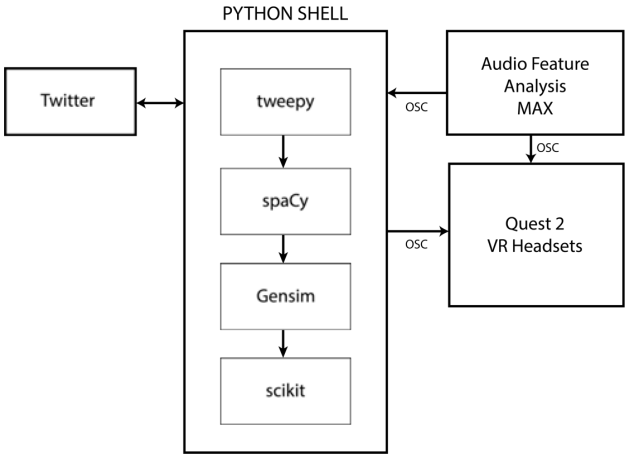

Figure 8. Schematic of the performance system for *reTweets* (2022).

5. CONCLUDING THOUGHTS AND FUTURE DIRECTIONS

The correlation of audience or performance agency to notational features within a performance score presents numerous compositional challenges. Foremost amongst these, perhaps is the extent to which scores are affected by agency and how this might in turn affect the large-scale organization of musical material. In the author's work, while performance agency affords some flexibility of musical results, this agency is always bound within certain pre-determined constraints allowing consistent musical structure to be realized. In *5x3x3*, for example, the timbral transformations folded into the score are always bounded by certain limits while in *reTweets*, the degree of score transformation becomes its own compositional determinant. Similarly in works in which audience agency is correlated to score transformations such as those described earlier, this agency becomes a carefully mediated action of choice. Through the foregrounding of such choice, members of the audience are encouraged to exercise their agency which, ironically perhaps, discourages any willingness to linger within a moment. Chan frames this dichotomy in terms of the *vita activa* and the *vita contemplativa* arguing that the push away from the contemplative life fundamentally transforms our experience of duration and time towards one of consumption [22]. How audience agency is reconciled within such an aesthetic framework is a particular challenge.

While there are certainly many areas of promising enquiry with the potential to yield fruitful musical results, the rapid evolution of GPT-3 models suggest one particularly interesting area of investigation. Aligned with features obtained through a more sophisticated stylistic analysis of live performance, perhaps through the application of previously developed techniques of learning a musical corpus [23], real-time predictive modelling could be used to create live, reactive scores that facilitate particular types of musical collaboration within members of a small ensemble. Scores could be adaptive to certain musical styles, fostering new types of musical collaboration and indeed enabling collaboration itself to assume structural valence. However these possibilities might play out, it seems inevitable that more sophisticated techniques of feature extraction will be an important contributor to any future development of reactive scores.

How works which feature reactive scores might offer new aesthetic affordances is of course an open question. Deleuze frames the collapsing of the past into the present, an experiential characteristic of any work built on feedback systems, through his concept of the plane of immanence and perhaps that is a helpful place to begin such an analysis [24]. Whatever the outcomes, reactive scores would seem to offer unique pathways for aesthetic investigation and exciting opportunities for creative expression.

6. REFERENCES

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