COMPOSING AND DESIGNING WEB-BASED DIGITAL SCORES: PRACTICES FOR NETWORKED MUSIC PERFORMANCE

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ABSTRACT

This paper presents a series of creative experiments, exploring performance practices with web-based digital scores built using JavaScript and related web technologies. It introduces several projects, including: five experimental scores, and two more fully developed prototypes "Modular-Touch" and "Inarticulate". Through an examination of the technical implementation of each project and design, rehearsal and performance experiences, this paper discusses how web-based technologies expand the possibilities for digital score design, notation, and collaborative performance.

Over a period of six months, this study designed seven score projects, which were iterated and performed by a total of 12 performers.

The potential of web-based technologies to support both local and distributed collaborative music making is shown to be a viable and emerging creative practice.

1. INTRODUCTION

Designing digital scores as web-based applications offers a cost-effective approach to ensuring broad compatibility across computer and mobile devices. [1]. To make digital score creation more accessible and allow composers to create scores without advanced programming skills, this approach relies on P5.js [1] as the primary framework. Building on this foundation, Node.js [2] (as a local JavaScript server) and Socket.io [3] (for real-time, bi-directional communication) are integrated to enable seamless interaction between client (for display and interaction) and server (for sending and receiving information) components in networked music performance scenarios. Furthermore, a locally hosted score can be deployed on an internet server, allowing the web-based digital score to be performed by musicians situated in different locations via the internet.

These experiments were developed with the following creative objectives:

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[1] P5.js is a JavaScript library designed for creative coding that allows users to generate and manipulate graphical content on the web with minimal programming experience. https://p5js.org/

[2] Node.js provides a framework for running JavaScript on the server, facilitating fast and efficient network application development. https://nodejs.org/

[3] Socket.io is a JavaScript library that enables real-time, bidirectional communication between web clients and servers. https://socket.io/

1. To ensure that the score information is intuitive and easily comprehensible for both performers and audiences.

2. To create scores that are open with respect to instrument choice, specific pitches, rhythms, and timbres, allowing these elements to be determined collaboratively by the conductor and performers during rehearsals.

3. To enable flexible performance content by allowing a single score program to generate multiple pieces through simple data modifications, thereby facilitating adaptation to a variety of performance contexts.

4. To ensure reliable operation of the scores on client devices (e.g., smartphones and tablets), the system is designed to maintain feasibility and robustness across distinct performance scenarios: co-located performances that rely on local networks and geographically distributed performances that rely on the internet.

2. FIVE EXPERIMENTAL SCORES

Before designing larger projects, five short demo scores were composed to explore concepts central to designing graphic notation with JavaScript. The themes explored were: physical modeling, mathematical counterpoint, randomness, machine learning model, and toporhythm performance. Consistent with the notion that "the graphic/visual imagery used to communicate ideas to the musicians will shift or mutate or change through time" [2, p. 95] , the first four scores were animated to demonstrate musical changes across time. [4] Each score is designed for two to four performers and has a duration of approximately one minute.

The design principles guiding these five experimental scores are as follows:

1. The core concept of each score should be straightforward for both performers and the audience to understand.

2. Instrumentation and playing techniques should remain open, to be decided upon during rehearsal.

3. Trajectory based scores should be predictable, allowing performers to play with confidence.

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[4] Video recording: https://www.bilibili.com/video/BV13xAheMEWa/

2.1 Three-Body Movement

The first score is inspired by familiar physical principles observed in daily life, specifically through a 2D graphical simulation of a three-body system [3]. In this piece, three on-screen orbs mutually attract one another, generating distinct trajectories for three performers to interpret. Key performance cues such as speed and direction changes, are highlighted through visual prompts, making the concept intuitive. Over the course of one minute, physical parameters like gravity and mass are dynamically altered at predetermined moments, transforming the system's behavior from stable to unstable states—a process the performers are encouraged to reflect musically.
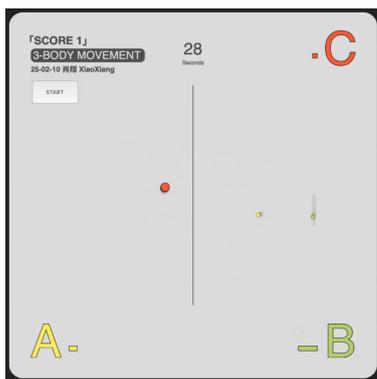
Figure 1. Experimental Score 1: Three-Body Movement
https://openprocessing.org/sketch/2531408/

2.2 Lissajous Curves

The second score explores rhythmic patterns through Lissajous curves, visualizing the interaction of two oscillations with different frequencies along perpendicular axes. Beats are defined as pairs of points 180 degrees apart within each oscillation's cycle, and one full traversal of the curve constitutes a performance pattern for the performer. The rhythmic characteristics of the two oscillations are visually embedded in the curve's form, helping performers internalize their material. These oscillations remain stable for most of the piece, changing only at predetermined moments to prompt shifts in musical content.

Figure 2. Experimental Score 2: Lissajous Curve
https://openprocessing.org/sketch/2531406

2.3 Random Instruction

The third score explores randomness through the random arrangement of pre-designed graphical elements, each linked to specific performance rules for three performers. While the graphical elements and their instructions are fixed, their order and combination are randomized, making each performance unique. Interpretations are negotiated during rehearsal, allowing the ensemble to develop shared improvisational strategies. Some deliberately ambiguous combinations are also included, providing room for performers' interpretation.
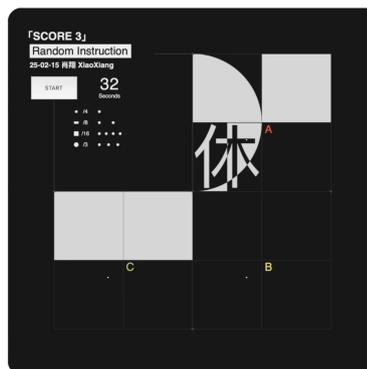
Figure 3. Experimental Score 3: Random Instruction
https://openprocessing.org/sketch/2544066

2.4 Hand-Pose

The fourth score employs hand-pose recognition to generate real-time cues for synthesizer performers, with a "score performer" whose gestures are tracked via webcam. Built on the ml5.js library [5], the system extracts 21 key points per hand and translates gestures—such as forming a circle or changing the distance between hands—into visual prompts for the ensemble. Unlike previous scores, precise rhythmic execution is not required; the piece emphasizes ambient texture and fosters an interactive relationship between the score performer and instrumentalists.
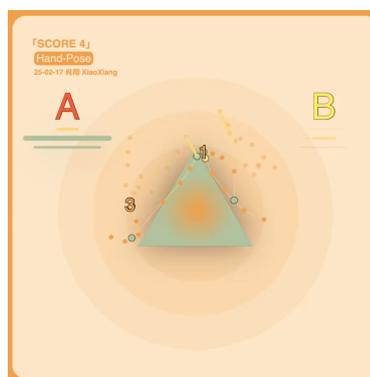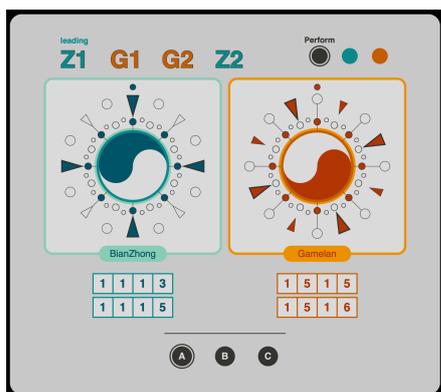

Figure 4. Experimental Score 4: Hand-Pose
https://openprocessing.org/sketch/2547417

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[5] ml5.js is a JavaScript library that brings machine learning to the web browser. https://ml5js.org/

2.5 BianZhong Gamelan Perform

The fifth score is a network music performance piece about toporhythm [4], inspired by Netronomia II project.[6] The score uses circles to display rhythmic patterns and utilizing the Netronome plugin[7] to manage the timing of audio streamed over the internet. It was performed via a live network connection between Beijing (two performers on Gamelan) and Wuhan (two performers on Bian Zhong[8]). The score adopts different performing orders in its three sections, allowing various playing perspectives under fixed network latency to produce different musical effects.

Figure 5. Experimental Score 5: BianZhong Gamelan perform https://openprocessing.org/sketch/2597323

2.6 Reflections on the Experimental Scores

The design and performance of these five experimental scores demonstrate that P5.js provides a convenient and effective framework for creating graphic scores. Although each score is relatively short in duration, non-linear musical structures were embedded directly into the notation, while the specific performance details—such as instrumentation and playing techniques—were intentionally left open for discussion and interpretation during rehearsal. Moreover, the integration of Socket.io highlighted further possibilities for score design, particularly in supporting real-time interaction, synchronization among performers, and distributed performance across networked environments.

3. "TOUCH MODULAR" DIGITAL SCORE

"Touch Modular" is a digital score designed to facilitate collaborative music performance with modular synthesizer system through integrated network technology. The score runs on a local Node.js server, and performers use their mobile phones as both a visual display for the score and an interactive user interface for their modular control. Each performer follows their own "performance curve" on their device, which guides their musical interpretation and interaction. Their performance data is transmitted across the local network using Socket.io. The server then aggregates this information and sends OSC (Open Sound Control) signals [5], which are converted to control voltage via a Max patch, directly interfacing with the modular synthesizer system, making the score system a voltage-controlled digital module [6].

The graphic design of the score reflects the logic of the modular synthesizer; its design serves as an extension of the modular synthesizer dispositif[9] [7]. Each performer controls an oscillator on their device, with the oscillators mutually modulating one another to produce a complex and responsive soundscape. Each performer's touch point generates a gate signal, while the x–y position data and movement acceleration are captured by the server and translated into OSC messages. The server computer then connects either to a virtual audio interface (for software modular environments such as VCV Rack) or to dedicated hardware—such as a high-quality DAC (e.g., the MCP4728)—which converts these messages into Eurorack-compatible control voltages.

Since the information provided by this curve-based score is limited, achieving a shared understanding among the performers requires some pre-established guidelines. Therefore, specific rules are communicated during rehearsals before the performance. For example, for the premiere, three performers are given follow instructions:

1. The music should gradually accelerate from a slow tempo to a pace where it becomes impossible to synchronize with one another;

2. The shape of each touch point is more important than its precise position;

3. When playing with two fingers, ensure that the main touch point remains on the note curve. Only add a second finger when it is necessary to propel the music forward;

4. When players' touch points approach each other, slow down the performance.
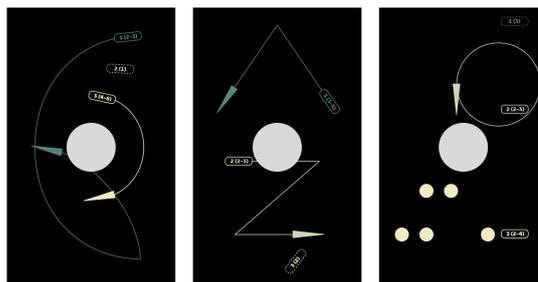
Figure 6. "Touch Modular" Score Performance Curves

The first edition of "Modular Touch" operated over a local network.[10] In this version, the routing of sound and

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[6] https://digiscore.github.io/2025-05-22-Netronomia-II/

[7] https://github.com/pparocza/Netronome

[8] BianZhong is an ancient Chinese musical instrument consisting of a set of bronze bells, played melodically.

[9] "Dispositif" here refers to the integrated system of interfaces, technologies, and practices that together shape the interactive musical environment.

[10] First edition performer: Wang XiJia, Zuo MoQi, and Xiao Xiang. Video: https://www.bilibili.com/video/BV1VDQXY3E8B/

control signals was managed within Ableton Live. A custom Max for Live device was developed to receive OSC messages from the local server, which collected performance data from each player's device and converted it into audio-rate control signals. These control signals were then routed into VCV Rack via a 16-channel virtual audio driver "BlackHole".[11]

The second edition of Modular Touch extended the system for online operation. The score project was migrated to an online environment, allowing performers to connect from remote locations. For this version, a dedicated application, OSC Client[12], was implemented to receive performance data from the online server and translate it into signals compatible with the modular system.

4. "INARTICULATE" DIGITAL SCORE

"Inarticulate" is an interactive digital score that uses audio analysis and a pre-trained neural network to dynamically shape the performer-score relationship, creating a shared performative context for both musicians and the audience. The piece involves three instrumental performers and one score performer. The score system begins with one or more audio samples as input, analyzing and transforming the sounds to create a 'score instrument.' The performance of this score instrument, informed by a pre-trained neural network, simultaneously generates the notations displayed on the animated score and serves as the electronic ambient part of the piece, providing both a sonic and structural model for the instrumentalists to perform. The animated score, enhanced with dynamic visual effects, is projected for the audience. This approach ensures that performers and audience members experience the same score in real time, promoting a sense of synchrony between musical performance and its visual representation.[13]

Figure 7. "Inarticulate" Premiere

This work further investigates the relationship between "notation and performance" that was explored in previous digital score experiments. The score's tempo gradually accelerates throughout the piece, shifting from a very slow pace at the beginning to rapid speeds by the end.

The symbols generated by the score performer lead to constantly changing musical content, as instrument performers must interpret them differently depending on the varying tempos and their instrument. In the final, fastest section of the piece, the rapidly changing symbols and extreme speed force the instrument performers to continually adapt their performance strategies—ultimately reaching a point at which it is impossible to fully follow the score's "instructions" and entering an unconscious, instinctive state of performance.
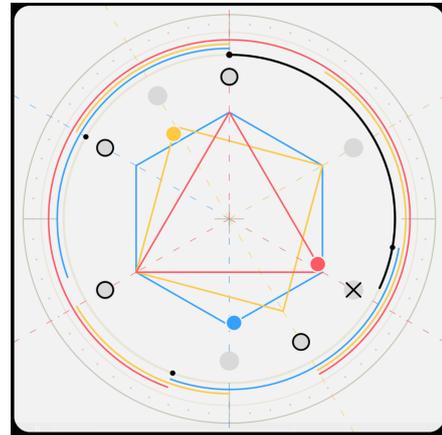

Figure 8. "Inarticulate" Score Graphic

A significant portion of the score's logic is implemented in Max, while the score display and fundamental rules are designed in JavaScript, and Ableton Live is used to route the sound. With the support of FluCoMa's[14] audio analysis and neural network objects for Max, the system analyzes sample input to generate the "score instrument" and provides an interface for live performance. The Max patch also transmits performers' data back to the Node.js server. Part of this information is processed by the server to generate the visualized score display, while other data is forwarded to the visual artist to support the creation of real-time visual effects for the audience.

The practical setup for this score involves running a local Node.js server and Ableton Live project on a computer. This computer creates a local wireless network, allowing each instrument performer to connect their tablet to a local website and read the score in real time. The system allows each client to select which version of the score they receive, enabling the distribution of different information for different roles. For example, the version received by the visual artist is specially programmed to meet the needs of their visual content and can be directly integrated into TouchDesigner.

5. STRATEGY IN REHEARSAL AND PERFORMANCE

Throughout these six months of performing with web-based digital scores, rehearsal has proven to be an essential component. Each score incorporates distinct forms of digital

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[11] https://github.com/ExistentialAudio/BlackHole

[12] The app was designed by Lin XiangBin

[13] Premiere performers: Yue Yan(Piano), Wu XueMeng(Gu Qin), Zhou YiNi(Er Hu), Xiao Xiang(Score Performer), and Zuo MoQi(Live Visual). Video: https://www.bilibili.com/video/BV1hcNDzpEAg/

[14] FluCoMa (Fluid Corpus Manipulation) Max libraries offer a suite of objects for advanced audio analysis, machine learning, and corpus-based sound manipulation in Max. https://github.com/flucoma/flucoma-max

technology, opening up distinct possibilities for rehearsal and performance, and reflecting how technological mediation can shape the very conception of a musical work. [8] The graphic design of these scores aims to be as simple and intuitive as possible. For some scores (such as Experimental Score 1: Three-Body Movement, Experimental Score 2: Lissajous Curve, and Inarticulate), the graphics emphasize visual cues for rhythm. In other scores (such as Experimental Score 4: Hand Pose, Touch Modular, and the performer's view in Inarticulate), the graphics focus more on shapes and gestures, providing visual cues related to form rather than specific playing techniques. As a result, much of the information needed during performance is abstract rather than concrete. During rehearsals, collaborative negotiation between the composer (or conductor) and performers determines how the visual themes are musically interpreted."

Much of the score design took place in parallel with rehearsals, ensuring that the scores could be effectively adapted for the performers. Throughout this process, a variety of performance strategies were explored, including the use of open improvisational structures versus pre-composed material [2, p.30]; performing over local networks versus over the internet [9]; and implementing a unified score versus content tailored for each performer. These explorations served not only to refine the score designs, but also to test their musical possibilities and practical feasibility across different settings and diverse groups of musicians.

Rehearsals for "Touch Modular" and "Inarticulate" were more complex. For "Touch Modular," professional musicians and their familiar acoustic instruments were not used; instead, performers engaged with specially designed interactive interfaces and modular synthesizers. As a result, a significant portion of the rehearsal was dedicated to familiarizing the performers with these instruments and making necessary adjustments. In the case of "Inarticulate," since input audio samples became part of both the music and the score, the audio samples were finalized before each performance to ensure consistency across rehearsals. Additionally, a key aspect of the rehearsal was the development of coordination between the score performer and the instrument performers, as the score performer offered musical direction or material, while the instrument performers' reactions, in turn, influence the score performer's strategies.

6. CONCLUSION

These web-based digital score projects aim to create participatory performance environments, and to allow composers to create such works with minimal programming skills. Although implementing digital scores as web apps has its limitations—such as restricted access to mobile device functions like Bluetooth, NFC, and cameras—more powerful features can still be developed with the help of various JavaScript libraries and music programming environments such as Max. The replacement of traditional music notation with graphic design forms a central theme of this research. In this way, certain musical intentions can be expressed and communicated to performers and audiences more intuitively, resulting in a unique approach to

performance. Moreover, the nature of networked music performance makes it possible to realize various design approaches—such as establishing a relationship between the score performer and the instrumentalists, or enabling each performer to influence the playing of others—thus opening up possibilities for interactive performance. Ultimately, these explorations demonstrate how web-based technologies can redefine both the conception and practice of musical notation in the networked age.

7. REFERENCES

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