The Scale Navigator: A System for Networked Algorithmic Harmony

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ABSTRACT

The Scale Navigator is a graphical interface implementation of Dmitri Tymoczko's scale network designed to help generate algorithmic harmony and harmonically synchronize performers in a laptop or electro-acoustic orchestra. The user manipulates the Scale Navigator to direct harmony on a chord-to-chord level and on a scale-to-scale level. In a live performance setting, the interface broadcasts control data, MIDI, and real-time notation to an ensemble of live electronic performers, sight-reading improvisers, and musical generative algorithms.

Author Keywords

NIME, networked music, performance, composition, improvisation, installation, screen score, notation, sight-reading, interaction, scale network, harmony, JavaScript, Node, P5.js, VexFlow, WebSockets, Tone.js

CCS Concepts

•**Applied computing** → **Sound and music computing;** Performing arts; •**Human-centered computing** → *Graphical user interfaces;*

1. INTRODUCTION

Dmitri Tymoczko [8] describes a system of interconnected seven-note scales inclusive of all twelve transpositions of the Diatonic, Acoustic, Harmonic Major, and Harmonic Minor scale classes. These forty-eight distinct scales are organized as nodes of a scale network graph—for the purposes of this paper, the "scale network" (Figure 1)—where two scales are connected if one can be transformed to the other by altering one note by a single semitone. As an example, C Diatonic has six notes in common with G Diatonic, differing by only the semi-tone between the F and the F♯, respectively. Diatonic scales have six neighbors, and the other three scale classes all have four. This relationship is called "maximally intersecting voice leading" [8].

Much like the circle of fifths, the described scale network is a geometric visualization of scalar relationships. The circle of fifths is in fact one possible Diatonic-only pathway through the scale network, though the structure also contains connections to Acoustic, Harmonic Major and Harmonic Minor. These "synthetic scales" differ from the Diatonic scale class by only one note; they are still highly triadic and familiar.

Tymoczko's scale network is a framework for diverse approaches to harmony. It can be used to analyze and create tonal works because it encompasses the circle of fifths. If one ignores harmonic functionality, one can use the scale network to find connections to scales that would be impossible to modulate to under the restrictions of tonality. If one dispenses with triads, the scale network can be used in conjunction with diatonic set technique or pandiatonicism to find exciting new chordal possibilities.

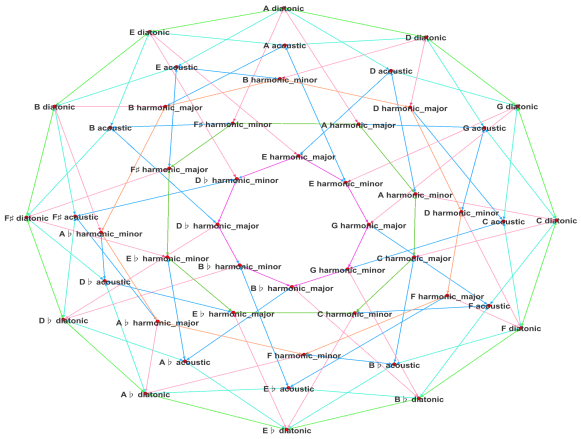

Figure 1: Maximally intersecting 7-note pressing scale network

For an electro-acoustic orchestra or laptop ensemble to perform the kind of post-tonal diatonic music described above, there needs to be a system in place for harmonic synchronization of players over a Local and/or Wide Area Network. The system must also feature a way to deliver realtime scores to sight-reading instrumentalists. In this context, the realtime score is "any notation, either traditional or graphic, which is created or transformed during an actual musical performance" [4]. As these are inevitably read on a laptop, iPad, television or projector screen, we will for the purposes of this paper refer to them as "screen scores." Lindsay Vickery divides the screen score into four types: Scrolling[1], Permutative, Transformative, and Generative [9]. As the Scale Navigator does not emphasize rhythmic synchronization, its interface makes use of the transformative only.

Other systems for networked computer music performances

[1]Rob Canning's Parallax Score Server, which coordinates musicians playing at different tempos to enable "Liqetiesque polyrhythmic ensemble textures" [3], employs a scrolling screen score model.

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designed around the screen score include Georg Hajdu's Quintet.net [6], Gerhard Winkler's Realtime-Score [10], and Rob Canning's NodeScore [2]. These systems do not focus on harmony as an all-important global parameter, and instead emphasize remote collaboration, graphic and non-traditional notation, and interactivity.

Thus far there has been little emphasis placed on harmonic synchronization, and the kinds of harmonic languages listed above have not been explicitly explored in a laptop ensemble context, hence the need for the Scale Navigator and its Live Performance Network.

In the following sections we discuss the Scale Navigator's design, detailing the methods it uses to modulate scales, generate chords, and network with other musicians as well as its overall UI. We also describe three ways the Scale Navigator was employed in three pieces by author Nathan Turczan, and recount their varying levels of success.

2. DESIGN

This section details the Scale Navigator as a web based application for composing, producing, and performing from a user interface design standpoint. It also describes the network infrastructure by which the Scale Navigator harmonically synchronizes screen scores distributed throughout the network.

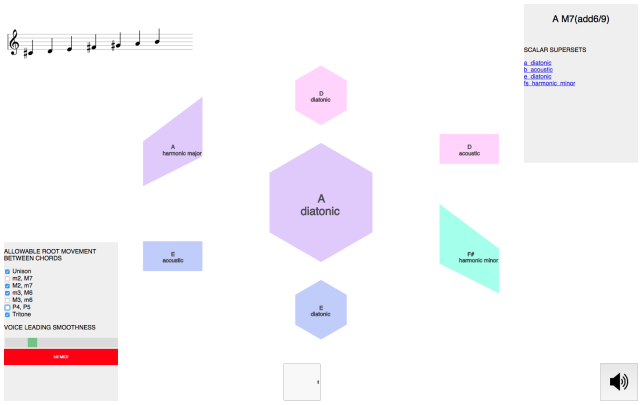

Figure 2: Scale Navigator user interface

2.1 Scale Navigator Interface

The Scale Navigator has a web interface that presents the scale network in visual format. Publicly available on author Nathan Turczan's website[2], it features sliders, checkboxes, clickable shapes, and clickable text to control harmony (Figure 2).

Its functionality as a framework for smooth modulation between scales assists the composer's decision-making on a scale-to-scale level. The selected scale is in the center of the interface, radially surrounded by adjacent neighbor scales. Clicking on an adjacent scale (or scalar superset) selects a new scale and a new chord from that scale (this chord generation process is detailed in section 2.2).

Each scale in the Scale Navigator is represented by a clickable polygonal-shaped node. The scale's number of adjacent neighbors determines the number of sides its shape has. The hexagon represents Diatonic scales because they have six locally adjacent scale neighbors. Similarly, we chose the rectangle to represent four-neighbored Acoustic scales for its four sides. We assigned one shape—the parallelogram—to symbolize the Harmonic scales because of their shared diminished aural character: a right-leaning parallelogram for Harmonic Major scales and a symmetrical, left-leaning parallelogram for Harmonic Minor. The root of each scale determines its node's color. We selected these hues by mapping the color wheel to the twelve notes of the chromatic scale arranged in fifths.

A display in the upper left corner shows the seven notes of the selected scale in ascending order on a treble clef, starting at the root of the scale. In the upper right, a chord from the selected scale is notated on a grand staff. These elements of the Scale Navigator comprise the interface's screen score, which transforms with each new selection of scale or chord.

2.2 Chord Generator

This section details the Scale Navigator's functionality for chord progression generation. The selected chord is immediately audible in the browser window thanks to Tone.js. This feature can be muted, and the user can instead choose to route the chord to Ableton Live (or similar DAW) via virtual MIDI bus for further customization of the chords duration, velocity, arpeggiation, and sound design.

The Scale Navigator's chord generator draws from a vocabulary of jazz chord voicings catalogued in Bill Boyd's Jazz Chord Progressions [1]. To generate a new chord, the user clicks on the currently selected scale, one of its adjacent scale neighbors, or one of a list of "scalar supersets" found in the upper right of the interface). The chord generated will be a subset of the scale clicked.

Part of Boyd's taxonomy of jazz chords includes a "Position" designation for each chord, of which there are two: "the third of the chord is the bottom note in the right hand in Position 1," and "the seventh of the chord is the bottom of the right hand in Position 2" [1]. The authors implement Boyd's algorithm for chord choice based on root movement: If the root movement remains the same, or moves by step either higher or lower, choose a chord that has the same position as the current chord. If the root moves by fourth or fifth in either direction, choose a chord with a position alternate to the current chord. If the root moves by third or sixth in either direction, choose a chord in any position. Boyd did not mention what to do in the case of root movement by tritone, and so the authors allow for selection of a chord in any position in this case. The user can select allowable root movements using the checkboxes in the bottom left corner of the interface.

Boyd's algorithm leaves us with a list of allowable next-chord candidates, which we further hone using a voice-leading algorithm that ranks the list of candidates according to a fitness function describing the smoothness of voice leading from current chord to next chord. Chords are given a higher fitness score if the next chord has many notes in common with the current chord, or if the next chord has many notes that are stepwise to the notes of the current chord. A slider in the bottom left corner of the screen dictates which candidates get selected: when the slider is all the way to the right at 100%, only the highest ranked chords are chosen. At 0%, the chord generator picks at random from the list of chord candidates regardless of their ranking.

The Scale Navigator displays the name of the current chord in a text box in the upper right: root note followed by chord quality. Depending on the chord, this name may also include the number of an interval (e.g. 7), whether or not the fifth is altered(e.g. ♯5), added chord-tones, and alterations (e.g. (add♯11)). Included in this chord display is the option to 'jump' in the network to the selected chord's scalar supersets: other, possibly non-adjacent scales that also contain the pitches of the chord. This enables pivot chord modulations to distant parts of the graph.

[2] nathanturczan.com/apps/scale_navigator_HEPTATONIC

2.3 Network Infrastructure

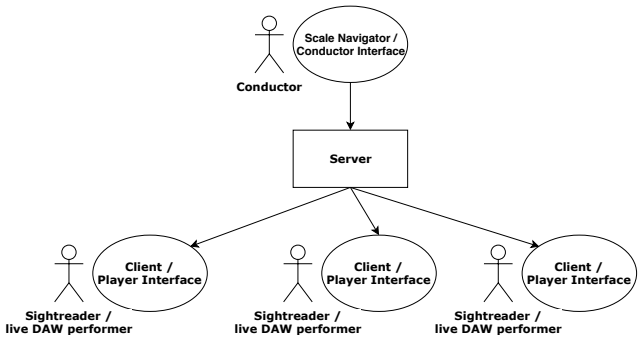

Figure 3: Signal flow of the Scale Navigator Live Performance Network

The Conductor component[3], Client component, and Server component make up the Scale Navigator Live Performance Network (SNLPN). This infrastructure is loosely modeled on Georg Hajdu's interactive network performance environment Quintet.net, comprised of Conductor, Server, Client, Listener, and Viewer components.[4] Unlike Hajdu, Canning [3], Jason Freeman [5], the Scale Navigator's network infrastructure is hierarchical and unidirectional in the traditional Western conductor-musician configuration (Figure 3): the Conductor module sends messages to the Server (scale and chord information) which automatically pushes this data to a Client page (Figure 4), open in the performers' browser windows and displaying notation describing the current scale as selected by the Conductor.

The Client page is intended for use by both sight-readers and electronic improvisers, and therefore has a button for mapping various streams of incoming control data to parameters in Ableton Live (or similar DAW).

The SNLPN was built with open-source web-standard technologies: Javascript, HTML5, CSS3, Node.js, Web Sockets, P5.js, VexFlow, and Tone.js. It uses socket.io to communicate unidirectionally across a multi-nodal server network. All of these components are publicly available for use online, and can run on a LAN or WAN.

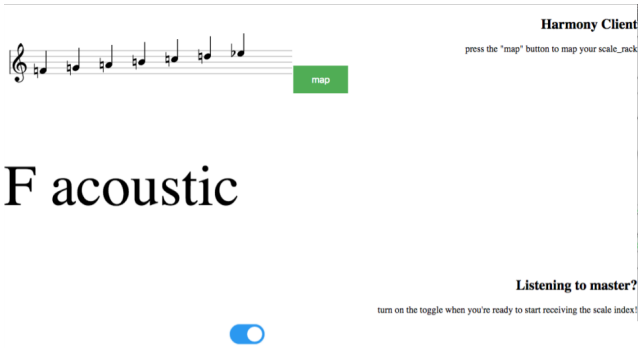

Figure 4: Client component of the Scale Navigator Live Performance Network

[3]In a networked music performance context, the Scale Navigator interface becomes the Conductor component.

[4]The authors chose to forgo integrating Listener and Viewer components with the SNLPN, favoring instead platforms such as YouTube, Ustream, or Twitch to live stream performances to remote audiences.

3. MUSICAL APPLICATIONS

This section presents three different pieces of multi-media art by author Nathan Turczan and describes the role of the Scale Navigator in each.

3.1 Composing

The Scale Navigator has been proven to aid composers during the pre-compositional phase of writing music. Turczan's process for writing *Network Impressions* relied on the Scale Navigator to help pre-determine the piece's blueprint for modulation. The piece is an electro-acoustic improvisational chorale for the Chordas vocal ensemble (SATB), live electronics, and interactive score that premiered December 1st, 2018 at CalArts. Begining in C Diatonic, each of the four singers is responsible for improvising melody using only two notes of the scale. Turczan used the Scale Navigator to determine the next fifteen measures of the piece.

Turczan created a transformative screen score (Figure 5) to cue singers and assist them with each modulation.[5] This screen score is controlled by a conductor, who presses a "Next Measure" button that highlights the current measure and triggers electronic and recorded sounds in a concurrently running Ableton session.

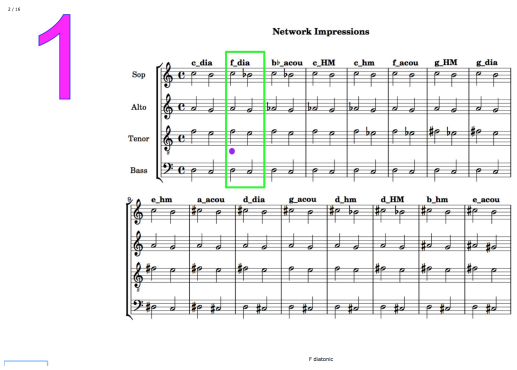

Figure 5: A frame of the interactive screen score for *Network Impressions*

3.2 Performing

INTERSTICES is an improvisational piece of networked music composed for the CalArts Machine Orchestra that premiered December 6th, 2018. Inspired by Terry Reilly's *In C*, the piece is based around the idea of a large ensemble improvising within a single scale, with the added capacity for a conductor to globally change the scale.

INTERSTICES makes use of the SNLPN to stay in harmonic sync, with a player directing modulation on a global scale using the Scale Navigator in its Conductor capacity. Other members of the ensemble—playing acoustic instruments or performing with a Ableton Live—are updated of scale changes via the Client component, whose screen score transforms to describe the current selected scale for the acoustic players to sight read and interpret.[6] If the player is performing with an Ableton session, the Client also sends an index number identifying the current scale to a "Scale Rack" object, controlling every MIDI track within the session and filtering out notes that are foreign to the current scale. The form of the piece is determined by an animated scrolling score that plays on a projector screen.

[5]nathanturczan.com/apps/heptagrams

[6]youtu.be/w1Bs_j3KwBY

3.3 Audience Directed Experience

All of the Scale Navigator's functionality thus described has painted a picture of a musical tool that is only for musicians. This section details author Nathan Turczan's attempt to integrate the Scale Navigator into an interactive installation as an interface for a potential non-musician participant to direct their own experience.

Modal Intersections was a 2018 interactive audiovisual installation for the CalArts WaveCave centered around the Scale Navigator as an interface for interaction, giving the experience of conductor to a user (Figure 6). The Scale Navigator—running on Chrome—was open on an iPad embedded in a podium in the middle of the space for participants to interact with, triggering melodies and arpeggios in the selected scale on two opposing Yamaha DisKlaviers.

Each scale was accompanied by its own looping video of roadway intersections in Los Angeles; scale selection in the Scale Navigator (routed via MIDI to TouchDesigner) triggered the footage. This piece exploited the structure of the scale network to create a non-linear film experience. The way each scale was paired with its own video loop was an attempt to associate parallel sensory phenomena: a highway intersection for each harmonic intersection.[7]

Figure 6: An audience member using the Scale Navigator interface to control video and audio in *Modal Intersections*

4. CHALLENGES

The Scale Navigator presents the user with several challenges and limitations. In its capacity as a composing tool, the constraints that determine the structure of the scale network may also limit the composer relying completely on the Scale Navigator for ideas, and they may not be aware of methods for modulation to more distant, less-related scales.

As an instrument, the Scale Navigator's present algorithm for selecting chords does not account for function or resolution, and some progressions may sound unsatisfying.

In a live performance context, acoustic performers may be required to sight read the Client component's screen score. As the screen score is transformative, the performer must pay close attention so as not to miss a change, which might be as small as the alteration of one accidental. Additional interference, such as a separate formal score or hand-waving conductor may further divide the player's attention, resulting in a less cohesive performance.

[7] youtu.be/dmfJexDdbV0

For a more detailed look into the user's perspective, see the "Qualified User Survey" chapter of the author's thesis "The Scale Navigator" [7].

5. CONCLUSION

Scale Navigator has proven a successful composition tool, helping composers write chords and modulations. As an instrument for improvising these modulations and chords in a live context, it produces pleasing harmonic progressions. When connected to Client modules over the SNLPN, it achieves its aim of keeping diverse performers in the same tonality.

The Scale Navigator is flexible, but can still be improved upon. The network could be expanded to modes of limited transposition; this would allow for new exciting harmonic approaches that exploit symmetries inherent in equal temperament such as the musical language of Olivier Messiaen.

Future harmonic applications of this interface could include combining Tymoczko's scale network with chordal vocabularies other than Boyd's: Milhaud's vocabulary of polychords, Howard Hanson's extended tonality, Hindemith's intervallic chord classifications, and Arvo Pärt's tintinnabulation technique.

Future changes to the network infrastructure could include client chat rooms for each instrument, or group of players. The network could also be distributed non hierarchically for bi-directional communication between components, allowing for distributed and democratic harmonic decisions. The network could also feature a component for audience participation, encouraging collaborative feedback loops à la Freeman [5]. Spectral analysis might also be introduced into the feedback loop, so that timbre might influence harmony, voicing, or instrumentation.

The Scale Navigator could also feature various geometric frameworks for representing harmony in addition to Tymoczko's scale network such as the tonnetz or spiral array.

6. REFERENCES

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