Visualizing the Semantic Structure in Classical Music Works

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Outline

- Introduction
- Related Work
- The Musical Structural Data
- Data Preprocessing
- Design Principles
- Visualization Prototypes
- User Interactions
- Case Studies
- Evaluation
- Conclusion
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  - Evaluation
  - Conclusion

- Background
- Motivations
- Contributions
Background

- Classical music is generally less friendly and approachable
  - Realizing structure is difficult for unskilled ears

- Learning with musical scores and essays are demanding
Motivations

- Visualizing the semantic structure of music
  - Impress with its sophistication and beauty
  - Reveal underlying musical structure
  - Assist music learning and teaching

- Previous approaches
  - Rarely on semantic structure for perceptual understanding
  - Mainly on sonic features or low-level physical properties

music visualizers examples
Contributions

- We pioneer a visualization solution to convey the semantic structure in classical music
- General users
  - Understanding the semantic structure
  - Appreciating the sophistication of music
- Music teachers, music students, and musicians
  - Teaching and learning different styles
  - Gaining new insights into features
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  - Conclusion
- Musical structure
- Abstracted scores
- Performance expression
- 3D music
- Commercial products
- Computer music
Musical Structure Visualization: Arc Diagrams [InfoVis’02]

- Extract repeated patterns from a MIDI file automatically
- May not be musically meaningful
- Show repetitions of only one track
Musical Structure Visualization: Isochords [GI’07]

- Visualize chord structure and progression with animation
- Show low-level notes and chords
Musical Structure Visualization: ImproViz [CHI’05]

- Shown by a melodic landscape and harmony palette
- Designed for one composition manually
Abstracted Scores

- Graphic Scores [EMS’05]
- Visual Music [SIGGRAPH’05 Poster]

- Simplified Scores [CW’02]
Performance Expression Visualization

- Understand music performance in cognitive terms
- Suggest that MIDI parameters do not link to human perception

Vertical Bar Display [AVI’04]

Chernoff Faces [Vis’02]

comp-i [SIGGRAPH’03 Sketches]

Music & Emotion [ICME’04]
3D Music Visualization

SIGGRAPH’03 Sketches & Applications

ICMC’98  VSMM’01  CG&A’07
Commercial Products

Exposition  Development  Recapitulation  Coda

TimeSketch

Music Animation Machine  Hyperscore
Visualization in Computer Music

Self-similarity grid for waveform [ICMC’01]

Harmonic visualization [ICMC’01]

Self-organization map for tonal content [CIE’05]

Spiral layout for tonal evolution [CIE’05]
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Problem Formulation

1) Macro-relationship
   Vertical texture among layers (depth)
   - Collaborate
   - Accompany
   - Blend
   - Contrast

2) Micro-relationship
   Horizontal foundation across time (breadth)
   - Themes: Recurring main melodies
   - Repetitions: Balance in time
   - Variations: Interesting details

3) Macro-micro relationship
   Interactions between layers and themes
   - A layer plays some themes
   - A theme is played by some layers
Defining the Data: Macro-Level

Layers
- Musically known as parts or voices
- Generic view of “instrument tracks”
- Determined by musical significance, not physical section

Layer Roles
- Functional role of a layer in the harmony of all at a time
- Change over time
- Shared by layers in the same functional group
- Multiple roles at the same time possible
- Not specified for transitional materials
Defining the Data: Micro-Level

**Themes**
- Main melodies and musical ideas
- Also known as motifs and subjects
- Only a few in a composition
- Repeated to bring unity and contrasted to introduce variety

**Theme Variations**
- Melodic, rhythmic, instrumental, and transformative means
- May reoccur at different layers
Data Uniqueness

- Different levels of viewpoints
- Coordinated relationships

Macro
- Interrelated layers with different roles

Micro
- Repeated and varied themes across time

Macro-micro
- Macro layer roles vs. micro theme variations
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Data Preprocessing

- No existing algorithm to parse high-level structure
- Manually retrieve from essays
- Front-end processing can be automated, but is beyond the scope of visualization

**Processed Data**

- Beginning and ending beat
- Instruments involved
- Layer roles and theme variations

*Processing Beethoven’s Symphony No.5, first movement*

- 2 days without computer assistance
- At most a few hours with simple user interface
Outline

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- Data Preprocessing
- **Design Principles**
  - Design criteria
  - Color scheme for layers
  - Theme glyph grammar
- Visualization Prototypes
- User Interactions
- Case Studies
- Evaluation
- Conclusion
Design Criteria

Consistent
- Avoid confusion
- Assign basic visual channels carefully

Intuitive
- Be comprehended rapidly without training
- Introduce some familiar metaphor

Effective
- Gain insights into the structure effectively

Aesthetic
- Reflect both artistry and complexity
Design Overview

- A color scheme for layers
  - More flexible than instrument icons
- A theme glyph grammar with typographical concepts
  - Conveys semantic meanings of the variations
Color Scheme for Layers: Music and Color

**Tone Color**
- Quality of a sound
- Depending on performance style

**Psychology**
- Emotions invoked
- Human perception of sound

**Physics**
- Mapping between sound and color spectrum
- Rational but lacks perceptual justification

None is relevant to semantic structure
Color Scheme for Layers: Proposed Solution

- **Hue**: physical color of instrument families
- **Lightness**: pitch range
- **Percussions in an outlier color**
- **Non-orchestral layers based on users' preferences**

<table>
<thead>
<tr>
<th>Woodwind:</th>
<th>flute</th>
<th>oboe</th>
<th>clarinet</th>
<th>bassoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass:</td>
<td>horn</td>
<td>trumpet</td>
<td>trombone</td>
<td>tuba</td>
</tr>
<tr>
<td>Percussion:</td>
<td>triangle</td>
<td>snare drum</td>
<td>timpani</td>
<td>bass drum</td>
</tr>
<tr>
<td>Strings:</td>
<td>violin</td>
<td>viola</td>
<td>cello</td>
<td>double bass</td>
</tr>
</tbody>
</table>
Theme Glyph Grammar: Glyph Candidates

- No universal design which is the best to represent theme, depending on visualization purposes
Theme Glyph Grammar: Typographical Grammar Rules

- **Duplicate a sub-part of the glyph**
  - Feasible as number of themes is usually limited

- **Change the core ‘x-height’ shape**
  - Categorical attribute
  - Overall appearance is preserved with obvious changes

- **Adjust the ascender or descender part**
  - Changes to rhythmic pattern or partial appearance
  - One-dimensional variation

- **Transform the core ‘x-height’ part**
  - A theme is structurally transformed into other shapes
  - Only modify ‘x-height’ part to remain similar and consistent

- **Add indicative decorations**
  - Special variations
  - Indicator can cope with more information if available
Theme Glyph Grammar: Typography in Our Framework

- How to size and modify type glyphs
  - Content clearly defined
  - Visual impact formally applied
  - Context to be delivered maximized

- Proposed grammar can be generalized to any glyph designs for optimal visual impact and legibility

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**x-height**
- Part of a lower case letter that equals height of ‘x’

- ascender
- capline
- meanline
- type size
- baseline
- descender
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- Design Principles
- **Visualization Prototypes**
  - Layer braid
  - Theme fabric
- User Interactions
- Case Studies
- Evaluation
- Conclusion
Visualization Prototypes

- Macro-relationships among layers
- Micro-relationships of theme occurrences
- Macro-micro relationships between layer roles and theme variations
Textile Art Metaphor

- Intuitive and efficient with familiar metaphor
- Similarities with musical structure
  - Delicate cloth as art piece
  - Structure along x- and y-axis
  - Detailed textile pattern
Layer Braid: Overview

Threads
- Respective layer colors
- Interact and correlate over time
Layer Braid: Plaiting Process

- Layer threads follow the musical score order
- Braid patterns determined by interweaving positions in 2D
- Layers of the same functional group are plaited together
- Multiple roles: spread, plait, and rejoin
- Threads may cross unwanted roles during interpolation
  - May darken segments without specific role
Theme Fabric: Arranging Glyph Nodes

- Overlay theme glyphs on a musical score layout
  - $x$-position: when the theme is played
  - $y$-position: which layer plays the theme
Theme Fabric: Stitching Styles

- Repetitions of glyphs not obvious without visual clues
- Stitch glyphs in various textile art styles

![Plain Style](image1)
![Bundled Style](image2)
![Collapsed Style](image3)

Decreasing levels of detail of micro-relationships
Theme Fabric: Plain Style

- Connect same glyphs in orthogonal direction
  - Horizontal curved weft
  - Vertical straight warp
- Utilize color and lightness of threads

plain weaving
Theme Fabric: From Plain Style to Bundled Style

- Replicated horizontal threads
  - Bundle horizontal threads
  - Remove redundant vertical threads
- Maintain betweenness centrality of glyphs
Theme Fabric: Bundled Style

- Reveal more high-level thematic structure
  - Same glyphs across layers are visually clustered
  - Structure is outlined by thread bundles and knots
- Thread blending: address overlapping
- Thread patterns: highlight special glyph groups
Theme Fabric: From Bundled Style to Collapsed Style

- Collapse identical glyphs at different layers into one single glyph
- Cluster threads into arcs
- Become some Arc Diagrams layout
Theme Fabric:
Collapsed Style for Sole Micro View

- Specific arc height for every unique glyph
- Rainbow arc for layers
- Split for former and latter glyph
Theme Fabric: Collapsed Style for Macro-Micro View

Specific arc height for each layer roles

Split for former and latter glyph

layer role A

layer role B

Rainbow arc for layers
Theme Fabric: Collapsed Style for Macro-Micro View

- Combine arc height with layer roles in layer braid
- Duplicate arcs for multiple roles
Theme Fabric: Summary

Plain
- Most expanded and detailed

Bundled
- Connects same glyphs with thread bundles

Collapsed
- Most abstract with compressed layers
- Macro-micro with arc heights for layer roles
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- Design Principles
- Visualization Prototypes
  - User Interactions
    - Case Studies
    - Evaluation
    - Conclusion
### User Interactions

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customization</strong></td>
<td>Configure layer colors and theme glyph type</td>
</tr>
<tr>
<td><strong>Zooming and Panning</strong></td>
<td>Less flavored than focus + context</td>
</tr>
<tr>
<td><strong>Selection</strong></td>
<td>Select any visual entities on screen</td>
</tr>
<tr>
<td><strong>Filtering</strong></td>
<td>Adjust the brightness or opacity value</td>
</tr>
<tr>
<td><strong>Linking and Brushing</strong></td>
<td>Brush to explore different modules, Link different views by overlaying them</td>
</tr>
<tr>
<td><strong>Abstraction</strong></td>
<td>Render in different levels of detail, Aggregate small changes in data</td>
</tr>
<tr>
<td><strong>Focus + Context</strong></td>
<td>View with bifocal display</td>
</tr>
<tr>
<td><strong>Details on Demand</strong></td>
<td>Show more details when zoomed in</td>
</tr>
<tr>
<td><strong>Synchronization with Music</strong></td>
<td>Animate with music</td>
</tr>
</tbody>
</table>
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- User Interactions
- **Case Studies**
  - Macro-relationship
  - Theme and variations
  - Macro-micro confluence
- Evaluation
- Conclusion
Macro-Relationships
Mozart's Symphony No. 40, 1\textsuperscript{st} Mov’t

- Development exhibits highly complicated relationships
- Ensembles are only heard once at the end of exposition
Macro-Relationships
Mozart's Symphony No. 40, 1st Mov’t

- Violins are mostly dominant
- Bassoon becomes dominant more frequently
Blue threads (first subject) are usually played by strings

Vivid variations are seen in development and recapitulation
The fate motif never dominates the music
The inverted, shortened motif in the lower strings contrasts the music at macro-level
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- User Interactions
- Case Studies
- **Evaluation**
  - User study
  - User survey
- Conclusion
User Study

- Novice users gain insights promptly without prior training
- A pictorial guidance for music learning and appreciation

### Accuracy and Time (min)

<table>
<thead>
<tr>
<th>Prototypes</th>
<th>Accuracy</th>
<th>Mean</th>
<th>SD</th>
<th>Time (min)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer Braid</td>
<td>86%</td>
<td>4.17</td>
<td>12%</td>
<td>1.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theme Fabric (Bundled)</td>
<td>95%</td>
<td>5.13</td>
<td>9%</td>
<td>0.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theme Fabric (Collapsed)</td>
<td>89%</td>
<td>3.67</td>
<td>15%</td>
<td>1.83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Details
- 10 college students
- 12 questions
- 5-min introduction
Braid and fabric are excellent metaphor of music
Layer braid is useful as the layer role concept is abstract
Bundled theme fabric is preferred by advanced users
Collapsed style is concise and aesthetic
Prototypes cooperate with or complement one another
Expert Feedback Highlights

**Educators**
- Reading essays diminishes learning interest
- Layer information is important

**Students**
- Layer feature helps differentiate instruments
- Comparing compositions become easier

**Musician**
- Audience find classical music more approachable
- Listeners grow from appreciation to learning

**Improvements**
- Include more attributes, *e.g.* dynamics, tempo, tone color
- Add descriptive texts
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- Demo
- Summary
- Conclusion
- Future Work
Demo

Visualizing the Semantic Structure in Classical Music Works
Wing-Yi Chan, Huanmin Qu, and Wai-Ho Mak
The Hong Kong University of Science and Technology

Traditional ways of learning music with musical scores and technical essays...

Using color to represent instrument families...

Woodwind
Brass
Percussion
Strings

Revealing the layer braid patterns...

Encoding theme variations with a configurable glyph...

Connecting the glyphs in plain style...

Connecting the glyphs in bundled style...

Providing levels of detail with different styles...

Mapping arc heights to layer roles for showing the macro-micro confluence between layers and themes...
Summary

- Innovative visualization solution for semantic structure in music
  - Macro-level layer relationships
  - Micro-level theme variations
  - Macro-micro interactions between layers and themes
- Design principles
  - Color scheme for layers
  - Glyph grammar founded on typography
- Visualization prototypes derived from textile art
  - Layer braid
  - Theme fabric (plain, bundled and collapsed style)
- Representative case studies
- Encouraging user evaluation
Conclusion

- Apply information visualization to other discipline
  - Strong human factors
  - Artistic sensation
- Introduce art and design analogies to address perceptual issues
  - Typography
  - Textile art metaphor
- Generalize the techniques for applications with semantic context
  - News visualization
  - Story-telling visualization
Future Work

- Visualize more compositions to fully realize its potential
- Implement a simple user-interface for data input
- Seek the possibility of using the visualization as teaching tool
Publications


After silence, that which comes nearest to expressing the inexpressible is music.

- Aldous Huxley, “Music at Night”, 1931

... Thank you!