MuSA.RT: Music on the Spiral Array . Real-Time

1. Research Team

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2. Statement of Project Goals

MuSA.RT is a collaborative research project integrating real-time music processing and content-based graphical rendering in interactive immersive environments.

3. Project Role in Support of IMSC Strategic Plan

The main outcome of this project is the development of systems for real-time analysis and interactive visualization of tonal patterns in music. From a project design and implementation point of view, MuSA.RT is an experiment in complex, cross-disciplinary multi-modal real-time system integration that serves as a model for larger scale integration experiments.

4. Discussion of Methodology Used

A defining feature of tonal music is the unfolding of pitch structures over time. Real-time tracking of tonal patterns in music has widespread applications in music analysis, information retrieval, performance analysis and expression synthesis. Each piece of music consists of a sequential arrangement of notes that generates pitch structures over time. An expert listener is able to ascertain the keys and harmonic patterns traversed over time. But a novice or a computer would benefit greatly from a geometric model that can provide visual cues and numeric quantifying of these tonal properties.

MuSA.RT maps real-time MIDI (Musical Instrument Digital Interface) input, for example from a live performance, to the Spiral Array [1], a 3D model for tonality. The analysis and graphical rendering reveal the presently active set of pitch classes, and higher level constructs, such as the current chord and key.

A MIDI stream consists primarily of pitch onset and offset events. The MuSA.RT system maps MIDI pitch numbers to their appropriate spellings and corresponding positions on the Spiral Array. The onset and offset times for each pitch is synchronized with the display of a 3-D animated rendering of the Spiral Array and its embedded tonal structures.

There are numerous challenges to visualizing a 3D model on a 2D screen. In MuSA.RT, we overcome many of these problems by allowing the user to dynamically and concurrently control the camera using a gaming device. The user can zoom in and out, tilt the viewing angle and circle around the spiral to get a better view of the tonal structures. In addition, an automatic pilot option will seek the best view angle and center the camera at the heart of the action.

Figure 1 shows the system in action with its various components.

Figure 1 – Components of the MuSA.RT System

We use the Spiral Array model to quantify, analyze and visualize tonal patterns. The Spiral Array model [1] is a geometric model for tonality rooted in the theory and perception of music. It has been shown to be an effective tool for assigning context-appropriate pitch spellings to MIDI numbers [4], for chord tracking [1] and for key-finding [2]. Its nearest neighbor entity from each of the spirals to the CE reveals the appropriate pitch spelling, and its chord and key memberships.

To allow modular development, seamless integration and to facilitate evolution, while at the same time achieving real-time performance, the system is designed using the SAI architectural style [9] developed at IMSC (see Volume Two report). MuSA.RT is implemented using MFSM (mfsm.SourceForge.net), an open source architectural middleware implementing the core elements of SAI.

5. Short Description of Achievements in Previous Years

N/A

5a. Detail of Accomplishments During the Past Year

We designed the MuSA.RT system using the SAI architectural style [9], and implemented the MuSA.RT Opus 1 and 2 prototypes using the open source Modular Flow Scheduling Middleware (MFSM, mfsm.SourceForge.net). Figure 2 shows the integrated application flow graph shared by both systems.

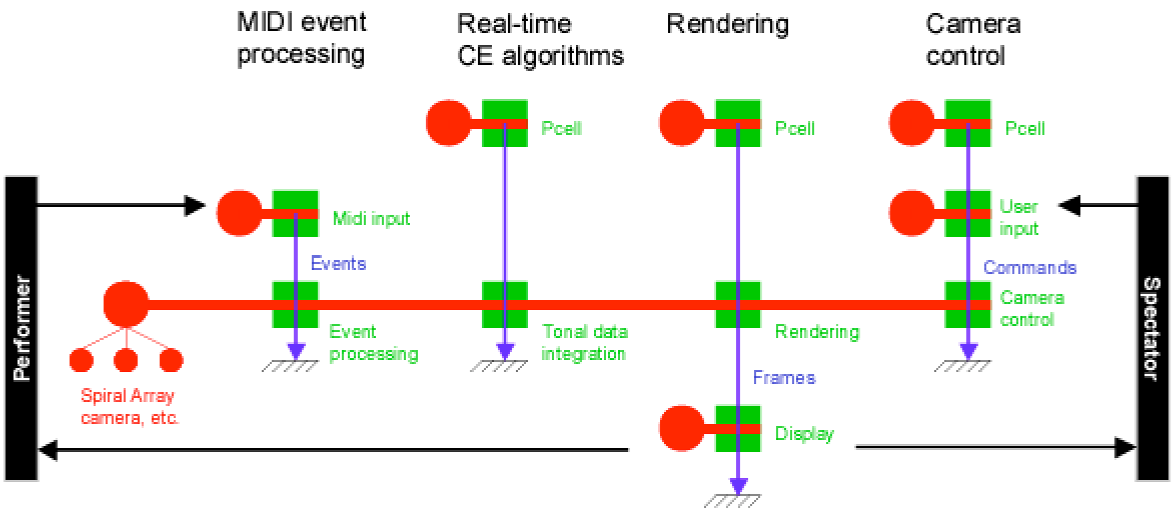

Figure 2 - MuSA.RT application flowgraph

A fundamental idea in SAI is the distinction between volatile data flowing in streams (such as, the video frames for visualization) and persistent data held in shared repositories (for example, the Spiral Array). The system consists of four independent data streams defined by the composition of well-studied architectural patterns [8]. The four streams are: (1) MIDI input and event processing; (2) tonal analysis (real-time CE algorithms); (3) rendering of the Spiral Array structures; and, (4) control device (gamepad) input and camera manipulation. These four streams potentially operate according to different modalities (push or pull) and at different rates.

Figure 3 shows our rendering of the Spiral Array's analytical structures. The graphics preserve the inherent simplicity and elegant geometric for the model while providing an informative and visually pleasing dynamic picture.

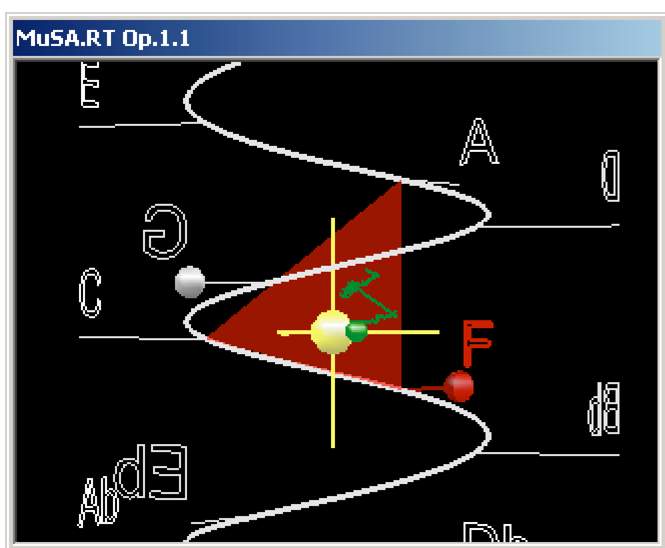

Figure 3 - Rendering the Spiral Array and its structures.

The MuSA.RT system was demonstrated at the ACM Multimedia conference, held in Berkeley, CA in November 2003 [5]. Figure 4 shows a picture of the demonstration setup. Live input from a MIDI keyboard is analyzed and rendered in the Spiral Array space in real-time. The two-hour demonstration received excellent reviews and discussions are underway for a MuSA.RT demonstration and performance at MM 2004.

Figure 4 – MuSA.RT demonstration at MM 2003.

An invention disclosure was filed with the USC OTL (#3533), who in turn filed a provisional patent application (#28080-118) for the MuSA.RT system.

6. Other Relevant Work Being Conducted and How this Project is Different

As far as we know, there has been no comparable effort in interactive 3D visualization of analytical content for live music. The most closely related projects are Garbers' Rubato software platform [10] and Sapp's Tonal Landscapes [11]. The former emphasizes music analysis and performance rendering; and, the latter represents pitches, chord roots and keys in a line of fifths to create 2D color maps of tonal patterns. Other research efforts have focused on visualizing performance parameters such as tempo (speed) and dynamics (volume) [6].

7. Plan for the Next Year

MuSA.RT incorporates modules for both interactive music visualization as well as real-time music analysis. The proximity of closely related musical entities makes the Spiral Array a useful tool for visualizing tonal structures and testing algorithms for music analysis. Note that the system is not restricted to the CE method for chord and key tracking. MuSA.RT provides a generic platform for testing and validating algorithms for real-time music tracking.

Future research include: using MuSA.RT to visualize tonal trajectories and inspire algorithms for similarity assessment; exploring other artistic ways to render music information in the Spiral Array space; and, incorporating different modalities for interacting with the 3D space.

Discussions are underway for a demonstration of MuSA.RT to be part of the 2004 ACM Conference on Multimedia. To enable data capture from non-MIDI instruments, we are exploring ways to use audio input for the analysis module.

8. Expected Milestones and Deliverables

MuSA.RT Opus 3 will integrate the latest pitch spelling and key tracking algorithms. A voting technique for chord tracking is currently being developed for more robust chord recognition. More publications and demonstrations are being prepared for the MuSA.RT system in the coming year.

9. Member Company Benefits

Real-time tracking of tonal patterns in music has widespread applications in music analysis, information retrieval, performance analysis and expression synthesis. From a project design and implementation point of view, MuSA.RT is an experiment in complex, cross-disciplinary multi-modal real-time system integration that serves as a model for larger scale experiments.

10. References

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