Virtual Concerts in Virtual Spaces - in Real Time

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Summary: Virtual concerts in virtual spaces are implemented by the Digital Interactive Virtual Acoustics (DIVA) research group. In this paper we introduce our Virtual Orchestra project which is an example of a real-time virtual concert experience. The Virtual Orchestra is an experimental interactive real-time virtual environment that contains synchronized sound and animation components. The system provides tools for real-time automatic character animation and visualization, dynamic behavior control of virtual actors, interaction through motion analysis, sound generation with physical models of musical instruments, and three-dimensional sound auralization. All of these research areas are shortly reviewed and future goals of the DIVA research are discussed.

INTRODUCTION

Creating a virtual concert experience, where both visual and aural elements are artificially generated is a challenging task. Visually, a photorealistic rendering of a virtual concert hall and musicians cannot be created in real time. Fortunately the photorealistic rendering is not obligatory if the animation of musicians is realistic. Aurally, it is possible to create a convincing virtual acoustic soundscape with effective digital signal processing methods but the problem is to produce artistically high quality music. Although, the modern sound synthesis methods provide realistic sound the automatic interpretation of music does not usually sound natural. In spite of all these limitations, a virtual concert experience can be created even in real time, with the interaction of the listener and virtual environment. One example of the system that enables virtual concerts in virtual spaces is the Virtual Orchestra developed since 1995 (1,2,3,4) by Digital Interactive Virtual Acoustics (DIVA) research group at the Helsinki University of Technology.

VIRTUAL ORCHESTRA

The DIVA research group studies the integration of important virtual reality elements: graphics visualization and animation, sound generation and auralization, and user interaction. Our main goal has been a concept of a virtual live music performance, which combines these research fields in the most intriguing way. The Virtual Orchestra is divided into four modules:

- tracking of tempo and other musical characteristics from a live human conductor

- visualizing animated virtual musicians and virtual spaces, e.g., concert halls
- generating sound with physical modeling of musical instruments
- virtual acoustics, i.e., auralizing sound sources in acoustical spaces using binaural or multichannel techniques

Although virtual environments (also virtual acoustic environments, e.g., (5)) have been extensively studied for the past decade, the significance of the work of DIVA group comes from the fact that it combines several important audiovisual simulation themes into one interactive virtual environment. Our animation system features motion capture, analysis and synthesis with behaviorally controlled synthetic human actors, packed into a modular and portable software architecture with advanced sound processing capabilities.

The structure of the Virtual Orchestra is shown in Figure 1. The arrows show the information flow between the modules through standard interfaces (MIDI, TCP/IP, ADAT), allowing the distribution of system components. All software components can run in a single computer or in separate workstations connected through a network. In the following sections we will shortly review the main components of the Virtual Orchestra.

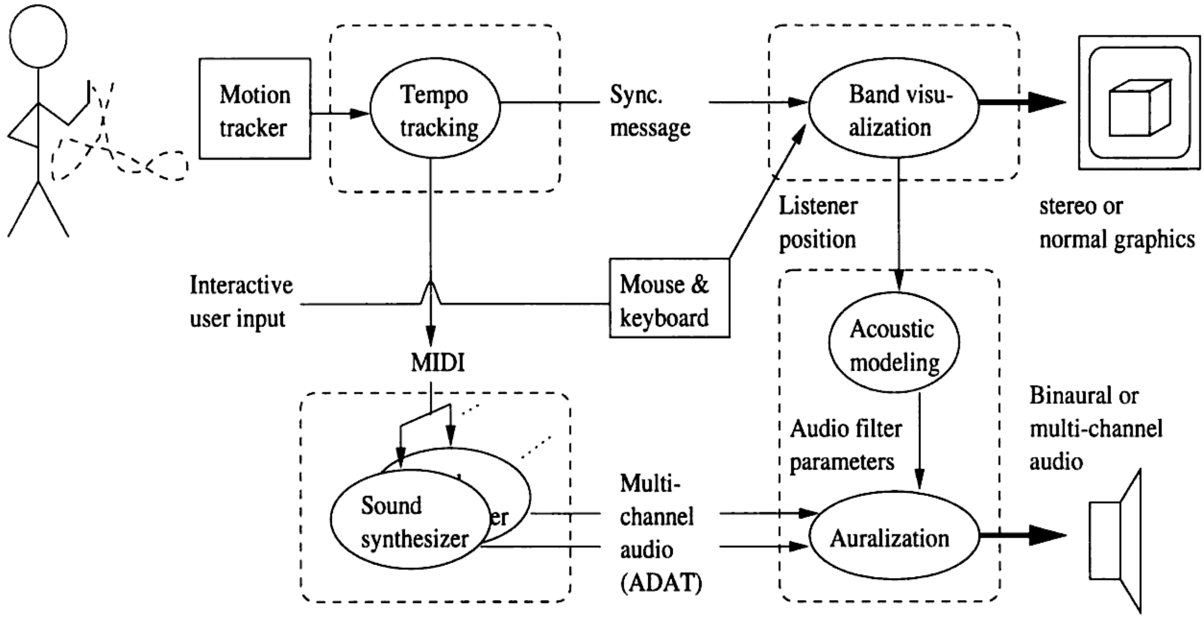

FIGURE 1. The Virtual Orchestra components. The tempo tracking module sends synchronization signal to the animation (visualization) module and MIDI signals to sound synthesis modules. The other user can control the viewpoint of a virtual concert hall with mouse and keyboard.

Tempo tracking: Motion tracking, pattern recognition, and artificial neural networks are used to extract tempo information and other musical characteristics from the conductor hand movements (6). The tempo tracking module interprets conductor hand and baton gestures and translates them into real-time information about music tempo and other characteristics. For input data we use two alternative techniques: a magnetic motion tracker device (Ascension, MotionStar) that records the position and orientation of small sensor devices relative to a transmitter, or small accelerometer chips (VTI Hamlin) that record the accelerations of conductor's movements.

Animation and visualization: Visualization includes kinematic modeling of musicians and their instruments, automatic animation generation, and animation playback control. The musicians also react to changes in their environment, e.g., they turn their head towards the camera. The visualization module generates automatically instrument manipulation animations from MIDI music. The animation generator (7) analyses a music score, and with the help of an instrument property database, converts the notes into a minimum-length list of end-effector goals. For fast playback, the list of end-effector goals is then preprocessed with inverse kinematics into a kinematic movie that contains only forward kinematic parameters. These actions of virtual musicians are animated and synchronized with a synchronization signal generated by tempo tracking module.

Sound synthesis: Physical modeling techniques of musical instruments (model-based sound synthesis) are used to produces sound that resembles that of the real instruments. (8,9) The sound synthesis module consists of several physical instrument models that are controlled with standard MIDI interface. Currently implemented instruments are guitar, bass and flute which are synthesized in a single workstation in real time. Standard MIDI-compatible synthesizers can also be connected to the same workstation. The synthesized sound is delivered to the auralization module through an optical ADAT interface or through an analog audio output.

Auralization: The auralization module uses a parametric room impulse response rendering technique that enables dynamic auralization of concert hall acoustics in real time. Such phenomena as sound source directivity, acoustical material properties, air absorption and listener's three-dimensional spatial hearing cues are taken into account in the time-domain hybrid modeling procedure. Headphone as well as multi-channel reproduction is supported. (10,11)

In real-time auralization the listener (and camera) position can be freely controlled. In parametric room impulse response rendering the direct sound and the first reflections coming to the listener are computed using the image-source method. The late reverberation is generated with an efficient late reverberation algorithm that produces natural sounding diffuse reverberation. High-quality auralization needs a lot of computational capacity. Dynamic calculation and rendering of direct sound, a few early reflections and late reverberation can, however, be achieved in real time using one workstation.

CONCLUSION AND FUTURE WORK

In this paper we have presented realization of a real-time virtual concert experience. Our Virtual Orchestra, consists of four subparts which are briefly presented. The tempo tracking module interprets the movement of a real conductor and provides synchronization information for animation and sound synthesis modules. The animation module animates the virtual musicians and sends the camera position information to the auralization module which produces a realistic 3-D soundscape to the conductor.

The Virtual Orchestra was demonstrated for the first time in Siggraph'97 Electric Garden (2). During one week about 700 people conducted the Virtual Orchestra. In summer 1998 the virtual players were accompanied by a real string quintet in a concert given in Kiasma, the museum of contemporary art in Helsinki. The first PC-version of the Virtual Orchestra was installed in the Finnish science center Heureka at the end of 1998.

The DIVA research group is further developing the Virtual Orchestra. The future goals of each subpart are the following. For conducter following we try to interpret also the emotional information from the conductor's movements and express that in the performance. The temporal group-behavior of the virtual musicians will also be studied. For animation we are seeking new animation mechanisms where kinematics and sequencing of motion are performed with artificial neural networks. We also plan to make the virtual humans more autonomous and reactive. For sound synthesis the focus will be on the new control methods and protocols as well as on designing descriptive control parameter sets for the sound synthesis models. For acoustic simulation and auralization we are evaluating our models and trying to make them more accurate.

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