

MOTION-SENSING MUSIC: ARTISTIC AND TECHNICAL CHALLENGES IN TWO WORKS FOR DANCE

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ABSTRACT

David Rokeby's Very Nervous System (VNS), offers a sophisticated level of computer control for detecting the accurate speed and location of dancers on stage. The VNS, coupled with software written in Opcode's Max, is used in two recent dance productions in which music is produced by dancers' movements. *Dark Around the Edges*, a collaboration with Walter Ferrero, uses mechanical motion to create rhythms and musical phrases. In *Songs for the Body Electric*, choreographer Gerry Girouard's fluid gestures influence compositional algorithms and signal processing parameters. Video projections and lighting changes also generate sound in counterpoint with the dance.

1. The Collaborative Process

From Stravinsky and Nijinsky to Cage and Cunningham, history tells the stories of the mutual influence between composers and choreographers. New technology using motion sensors to trigger computer music ups the ante on this close collaboration by inviting dancers to become musical performers. This requires many hours of experimentation and testing for each new work in order to discover music and response mechanisms that feel "right" to the dancers for specific types of movement. One artistic challenge is to go beyond the novelty of producing music "out of thin air," by finding links between the body and sound that are both convincing to an audience and which serve the expressive purpose of the dance.

This paper presents two years of research and creative work in interactive dance, culminating in the productions, *Dark Around the Edges* and *Songs for the Body Electric*. Both works utilize the Very Nervous System (VNS), a motion-sensing device, created by David Rokeby, which reports the location and speed of dancers to Max software written by the author. The software generates a musical response based on an interpretation of the movement data using compositional algorithms and mapping strategies. MIDI data is then sent to a Kurzweil K2500, a sample-based synthesizer with 64 MB of memory, and an Ensoniq DP/4 signal processor. Similar systems have been used by the author for tracking participants in motion-sensing audio and video installations. Technical information, response techniques and working methods used to create the dances are described here. For a more theoretical discussion on the connection between movement and music, see "Making Motion Musical," from the 1995 Proceedings of the International Computer Music Conference (Winkler, 1995).

Dark Around the Edges is a twenty-minute solo with Walter Ferrero, an actor and choreographer living in Stockholm. It premiered in Rhode Island on April 20, 1997. Since the capabilities and idiosyncrasies of the VNS were unknown to us, we began with several months of improvisation and experimentation so that our artistic decisions would naturally evolve out of a spontaneous, physical understanding of the system. Ferrero, who is also trained in the circus arts, experimented with juggling balls, walking on stilts and using toys to trigger the VNS. The final production includes theatrical moments characterized by humor and clowning, such as a section showing Ferrero whipping and snapping long scarves into space to start and stop different layers of music. Other sections are characterized by precise robotic and repetitive movements creating rhythms with machine and percussive sounds; and slow, fluid movements producing thick evolving sounds continuously altered by speed. Software developed for this dance production served as the basis for all of my subsequent VNS projects.

Songs for the Body Electric is an one hour production featuring two dancers, theatrical lighting, and multiple video projections. Work on the project began in the summer of 1997 as a commission from the American Composers

Forum to work with Gerry Girouard, a choreographer/dancer with a background in gymnastics. Stephen Rueff, a lighting and video designer, was invited to collaborate with us early on in the process. Since we were living in different cities, we developed ideas by exchanging video and audio tapes frequently through the mail. In two separate week-long work sessions, we came together to test and realize our ideas. Since the choreography had to be rehearsed without the VNS, I developed response strategies that allow the dancers to move freely without worrying about hitting an exact location. These techniques include using larger sensing areas on stage and relying on overall speed and video projections to create sound. Only two out of eleven sections require precise placement to trigger specific sounds. The work premiered in Minneapolis on December 12, 1997.

2. Movement Sensing and Analysis

The VNS is a SCSI device running on an Apple Macintosh computer, with two video camera inputs (Rokeby, 1997). The view from each video camera can be thought of as the active sensing area used for motion analysis. However, the VNS doesn't actually measure motion; it measures changes in light. By comparing the amount of light in one video frame to previous frames, it determines what part of the video image has changed, and by how much. The VNS captures each video frame as a black and white image with a gray-scale resolution of 6 bits (64 shades of gray) and an image resolution of 128 (horizontal) by 240 (vertical) pixels. The user specifies a grid size onto which the video image will be mapped, with each square of the grid defined by a group of pixels. This group becomes an active "region" corresponding to a location on stage. Any change within a region is reported to Max by subtracting the total gray-scale value for all pixels in one region from the same region in the previous frame (or frames). If there is no movement in a particular part of the stage, then Max reports a zero in the corresponding region (no change in light was detected). Faster movement across regions will yield higher values, since the light values will change more dramatically from frame to frame. In effect, each region acts similarly to a continuous controller, with numbers streaming into Max representing the activity in each area. The range of these values and the rate at which they are reported to Max are variable. Up to 240 regions may be active at a time, although in practice, fewer regions are often more practical and effective. A region may also be irregularly shaped using on-screen drawing tools to draw a region directly on the video image as it appears on the computer screen.

The sheer number of possible configurations for the VNS makes it effective for a wide variety of projects and lighting conditions. For the dance pieces, we tested various lenses, grid spaces, and camera placements, finally establishing a basic setup for each work so that the dancers could become familiar with a single spatial environment. The basic setup for *Dark Around the Edges* uses a single Panasonic black-and-white camera with a wide angle lens, placed on the floor in the front of the stage, with a simple 4 x 4 grid, updating every 33 milliseconds. In *Songs for the Body Electric*, a second camera, also with a 4 x 4 grid, is added to the right of the first to cover a wider area of the stage. To help the dancers identify the borders of each region, we marked the floor and back wall with tape during the development period. In performance, the tape is replaced by small, unobtrusive markers showing crucial locations on stage. By becoming very familiar with the basic setups, the dancers could perform and improvise with some degree of expertise.

The sixteen active grid areas (regions) per camera provide plenty of challenges and variety, particularly since the size of an active area changes as the performer moves upstage and downstage. Furthermore, the function and response of one or more grid points can change through software at any time. Each region has the ability to trigger a particular MIDI note or a series of notes, report continuous changes in movement, reconfigure the software, and start or stop a musical process. Two or more regions can be added to form a single, larger active area, or to define an area that the system will ignore. (Although the VNS software is capable of combining several grid spaces into single regions, and blocking out or "masking," various areas, it proved easier to automate and structure these changes via Max). In this way, further variations of the initial 4 x 4 set-up are created, such as using all of the middle regions of the grid to determine the overall tempo, while using the outer regions to start and stop specific processes. For some sections, the space is divided into left/right, or high/low regions.

3. Software Design

Max-based software designed for the dance projects has three functions: to further analyze, interpret, and scale movement data; to provide a user interface to facilitate composition, rehearsal and performance; and to generate, process and mix sound. Raw values are received by Max via the VNS object, an object written by Rokeby to handle system configurations. From there, changing values representing the grid are displayed graphically, then scaled,

mapped, or otherwise prepared to enter the system's response modules. The response modules are a collection of self-contained programs that are designed to produce music based on location triggers and continuous motion. They range from very simple data structures designed to map regions to specific MIDI note numbers, to highly complex algorithms, such as those using overall movement to continuously change parameters representing tempo, register, and timbre. Any number of these modules may be active at a given time using on/off toggle switches.

All of the possible software settings are available through a master "preset" object, which is used to automatically recall and store all system parameters for performances and rehearsals. Individual parameters can be changed in real time through on-screen graphics, or automated in response to particular movements. Specialized editing modules are all linked to the master preset object in the front panel. These include modules for mapping triggers, timbre selection, mixing, and signal processing. During a performance, the presets are advanced from one cue to the next, with each preset having its own behavior and response. This strategy was especially helpful in our initial working sessions, since everything from the selection of sounds to the configuration of the VNS could be quickly stored and recalled at a later time.

Two types of movement data influence all musical responses: continuous data (reported by the VNS), and triggers (discrete values representing a particular location on stage). A simple threshold strategy sends a trigger whenever activity within a region goes above a specified level. If a value goes above the threshold, a corresponding grid number (1 to 16) is sent out. The region can be retriggered only after the values drop below the threshold level, by either leaving the space or by less motion or stillness within the space. In this way, constant movement in one region avoids sending repeated triggers, but a short pause, or leaving a region and returning, allows for the next trigger. The threshold setting proves to be invaluable since it can be changed frequently to avoid errors, acting as a sensitivity gate to optimize the response for each action. Set high, the system ignores basic lighting changes, while forcing the dancers to make large gestures to trigger sound. Set very low, a single finger acts as a trigger. (At its most sensitive setting, the VNS can register the blink of an eye at four feet away from the camera!) Two or more threshold settings are used in conjunction to identify a range of fast, medium, or slow speeds within regions and across the stage.

Continuous data entering response modules is scaled to usable values, with a smoothing algorithm applied to reduce some of the rapid fluctuations in the signal. Since the time frame for averaging is variable, the smoothing algorithm is also effective in applying more slowly changing functions to parameters that do not always respond well to abrupt changes, such as tempo and signal processing. These techniques are often used with the total motion parameter, a value representing the sum of all active regions (all activity within the video field). This type of sensing proves to be responsive and "error proof," since the dancers are not required to be in a specific spot on stage, only to move in a general way. Continuous data is also controlled via a gating function that allows one value to pass every X milliseconds. This reduces the number of calculations required by the computer, while setting a tempo for the algorithms that generate music.

4. Sound Design and Response Mechanisms

The Kurzweil K2500 signal processing architecture offers a sophisticated platform for sound design, since samples can be altered in real time via continuous controller messages. In several sections of the works, physical gestures have an obvious and immediate impact on the quality of timbre by mapping VNS values to control DSP functions, such as filters, low frequency oscillators, and distortion algorithms. Further processing under MIDI control is available from the Ensoniq DP/4 processor. Several techniques may be combined, such as in "Gazelles" from *Songs for the Body Electric*, where location triggers play chords at a maximum rate of two per second, while speed effects a low pass filter and pitch bend.

The various sections of each work are characterized mood, gesture, sound, and response mechanisms. In *Dark Around the Edges* we gravitated towards high impact sound of percussion and machines. We associated these sounds with the force and weight used to move a particular part of the body. Thus, a heavy jump onto one leg has the weight of a large, low sound. Small head movements or flicks of the hand are lighter with less energy, which seem to fit smaller sounds like a small wood block. Whipping, breaking, and tearing sounds appear in particularly strenuous moments. Using speed to crossfade between several related percussive samples adds realism and variety to the resultant sound.

While this approach is too literal and repetitive to be sustained throughout an entire performance, it energizes the performer to produce sound so closely aligned with his efforts.

Linking a single sound to a specific area on stage helps the audience enjoy the show by beginning with a clear and unambiguous example of how the VNS works. The one-to-one approach is extended using prestored sequences and algorithms to generate a different sound, mix, pitch, or a short musical phrase each time a particular region is triggered. This is especially successful when using pitched sounds, since a single area can be retriggered to generate melodies with continuous variation. Variation techniques employ movement data and constrained random values to influence significant musical parameters. Even though the final production was carefully choreographed, the music for each performance varied, as did many subtleties of the dancers' interpretation.

Certain processes, such as transposition, worked well on a continuous basis, with the music moving high and low corresponding to the amount of movement on stage. Continuous changes in tempo were a bit chaotic, and became more predictable when divided to create discreet selections of three or four related speeds. Other processes influenced by overall movement included steadiness of the pulse, amount of dissonance, range of melodies, phrase length, timbre, note density, selection of intervals, melodic contour, and articulation. A smoothing algorithm was often used to average these values to avoid abrupt changes. Motion data averaged over a longer period of time would reflect general types of movement (fast/slow) within a section. This produced interesting delayed processes showing the accumulative results of movement rather than an immediate response.

5. Making Music with Lighting and Video

The fact that the VNS analyzes movement by reading light values poses some interesting analysis problems and must be considered when designing sets, costumes, and lighting for dance. Background color, clothing color, lighting changes, and the proximity of movement to a camera all influence the reading of movement. For example, all other things being equal, if the VNS analyzed the movement of a person wearing white in front of a black curtain, it would result in higher values than a person wearing black moving in front of the same curtain, since there would be greater contrast in light per frame. Quick lighting changes can be registered as tremendous "activity" on stage. These high values quickly reset back to zero as the light remains steady. As for proximity, moving closer to a camera usually results in higher values, since the body occupies more of a region and even small movements cause large changes in the image. Something as trivial as the color or pattern of a shirt could alter the overall reading of the movements. It was important to keep these elements the same from one rehearsal to the next, and to be able to adjust the response software to new spaces and lighting conditions.

In *Dark Around the Edges*, we avoid lighting issues by using a fixed plot which stays the same throughout the show. In *Songs for the Body Electric*, we collaborated with designer Stephen Rueff to create an elaborate series of lighting and video cues to work specifically with the VNS. In general, threshold settings are set so that gradual changes in light or color do not send out location triggers. In "Speaking Stick" however, the lighting board plays music with a group of small spot lights using preprogrammed rhythms. Video projections are also designed to trigger music along with the dancers. In "The Raft," the dancers move at the edge of the stage, outside of the view of the two sensing cameras, while their images (shot from above) are projected onto the back wall along with silhouetted shadows for the VNS. In "Evolution," the sensing area is divided into high and low regions. The dancers slither on the ground in blue light, their speed controlling the distortion and filtering effects of a low rumbling sound, while above their heads, a black and white projection of processed video triggers a high bowed sound.

6. Conclusion

These works explore the imaginative relationships between sound and movement suggesting a new paradigm for dance that links it more intimately than ever with music. The artists involved enjoyed a close collaborative process, addressing some of the inherent artistic and technical challenges posed by this new technology. The VNS, coupled with Max software, proves to be a dependable system in which ideas can be rapidly shaped and carefully refined.

7. References

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