FILM AND SOFTWARE PAPER

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Eurhythmy: *Concept and Process*

Eurhythmy means a state of harmony between body and mind. Reflecting this theme, the animation depicts animals, humans and a flock of birds joining together in a surrealistic spiritual dance in a deserted temple courtyard. Adding a sense of religious mystery to the surroundings, the temple, bearing a resemblance to an Islamic mosque, is decorated with symbols from other religions: Egyptian hieroglyphics adorn the walls, and images of angels grace the inside of the temple dome. The observer enters the temple, watches and then becomes part of a ritual dance, one that expresses a mystifying harmony between the physical and spiritual world.

The religious symbols within the architecture might be viewed as symbols of institutionalized religion, where human existence is conceived in terms of a soul which transcends the physical self and the real world. In contrast, the spirituality evoked in primitive dance is acted out in reverence for our identity with ourselves as animals, deeply rooted in our bodies and our connection with the natural environment.

To convey a spiritually uplifting dance, the movement of all of the animals had to be both convincing and expressive. As graduate students at Ohio State University, Michael Girard and Susan Amkraut each carried out research focused on the development of computational models which embody physically motivated qualities of complex animal movements. The animation in *Eurhythmy* was produced exclusively with the software developed during this research.

The human and animal motion was produced using the PODA animation system, written by Michael Girard. PODA implements Girard's research on modelling legged animal motion, incorporating many robotics techniques for body co-ordination, limb kinematics and dynamics.

The multi-legged locomotion of gaits and dance seen in *Eurhythmy* employs inverse-kinematic control of limbs in order to achieve goal-directed leg motions. A supervisory level of control over legged animal locomotion is provided by the animation system. Given the animator's specification of a sequence of gaits and a desired path of motion in the horizontal plane, the locomotion model calculates the co-ordination of the animal's legs in each gait, manages transitions between gaits and determines footholds which are computed to bring each of the legs to a dynamically stable supporting position (see Figure 1).

The translational motion of the animal's centre of mass is accurately simulated during the animal's flight phase as a function of the velocity of the animal's centre of mass at the time of lift-off and the downward gravitational acceleration. Also, the animal's banking angle as it turns is calculated to maintain the

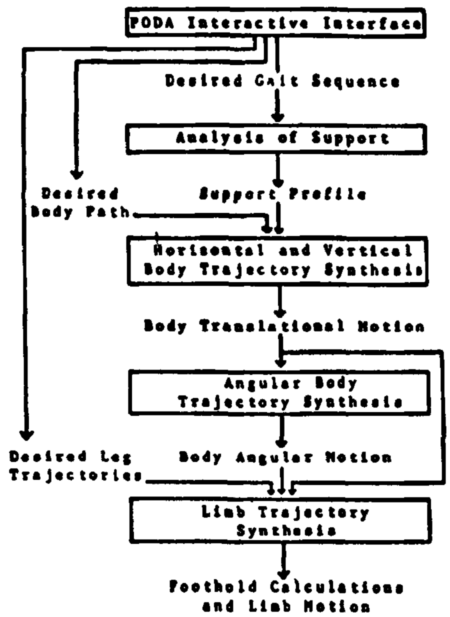

Figure 1. Flow of control of locomotion model. The animator's interactively designed gait sequence, body path, and leg trajectories are gradually synthesized into a coherent animation of the animal's body and limbs

appearance of dynamic stability by taking into account the animal's speed, the curvature of its path, and the gravitational acceleration.

Girard choreographed all the legged animals in *Eurhythmy* using his PODA system. The entry of the animals into the temple was orchestrated to emphasize a counterpoint of gait styles, speeds and rhythms which gradually transform into an orderly formation. Girard's choreography of the human dance which takes place in the second half of *Eurhythmy* intentionally mixes stylistic elements which have roots in both African traditional dance and classical ballet.

The bird motion was created with FLOCK, an animation system which controls the motion of large populations using vector force fields. FLOCK was researched and implemented by Susan Amkraut. FLOCK is a general purpose system which may be used to animate many types of creatures involved in various types of group motion. In FLOCK, the motion of the bodies is controlled through a combination of vector force fields which define dynamic forces in the environment, and each body's individual behavioural response to surrounding force fields (see Figure 2).

A global force field may act to direct the flock's pattern of flight. Forces centred on

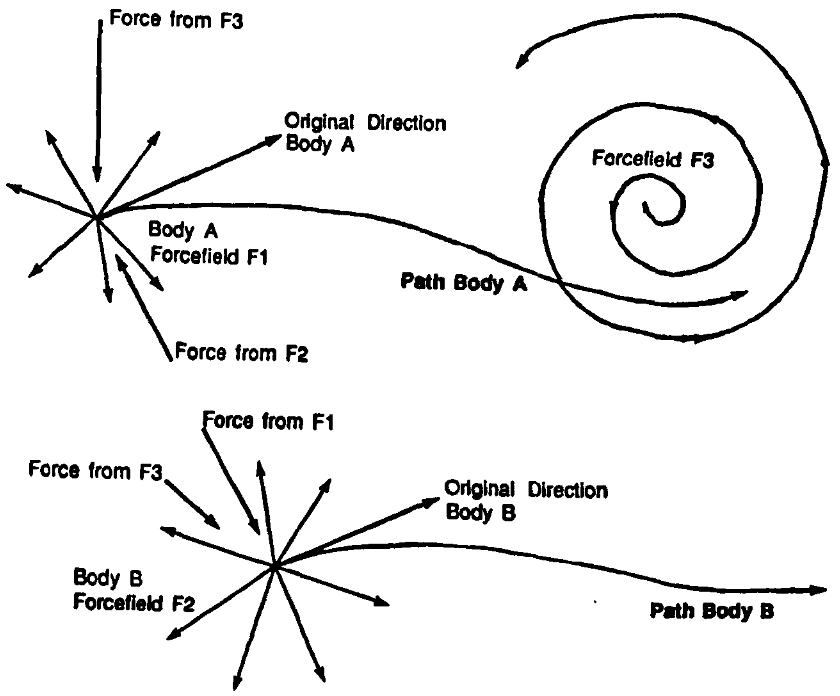

Figure 2. Two bodies reacting to force fields. In this scenario there are two bodies, body A and body B, moving in similar directions. There are three force fields. Force field F1 is a rejective force field, which means that its force emanates outward in all directions. It is positioned at the location of body A every frame. Force field F2 is also a rejector. It is positioned at the location of body B every frame. Force field F3 is a spiral force field, positioned permanently as shown. Body A and body B are originally moving up and to the right. Body A feels the force from F2 pushing it away from body B, and at the same time feels the force from F3, pushing it in a spiral. Body B feels both the force from F1 pushing it away from body A as well as the spiral force of F3. Each frame a new position is computed based on these forces. The depicted paths, approximately, result

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the local co-ordinate system of each body act to prevent collisions from nearby bodies. Linear differential equations are employed in FLOCK to specify force fields which are then numerically integrated to compute each body's trajectory (thereby solving an *n*-body problem). The flow patterns resulting from these linear systems (spirals, sinks, sources, saddles, orbits, etc.) may be generically classified according to the sign of the discriminant and the trace of the linear equation matrix. By selecting force field matrices of a given class, describing how the strength of the force field varies as a function of time and space, and associating the force field with a body, an obstacle, or a position in space, the animator may easily control the overall motion patterns of a large group of bodies.

Behavioural responses to forces are modelled in terms of constraints on an individual body's orientation, direction and speed. For example, large birds have limits on their turning speed, whereas insects are able to change directly suddenly. The flapping/gliding behaviour of each bird and its banking is derived from the bird's angular and vertical velocity.

Susan Amkraut animated the bird flocks in *Eurhythmy* using her FLOCK system. The choreography of the flocks was structured to move gradually from naturalistic flocking patterns to more unnatural ones. In the beginning of *Eurhythmy*, the birds swirl in familiar shifting groups over the temple courtyard. Later in the animation, the entire flock is attracted to a particular plane parallel to and about knee height from the floor. The natural motion of each bird is maintained while the flocking pattern has become unusual, creating a surreal sea of birds in which the humans and animals perform their dance.

Both PODA and FLOCK are systems which attempt to simulate naturalistic motion. Perhaps the real artistic power of naturalistic computer simulation, apart from its direct connection with experience, is its capacity for altering the premises of reality without violating its logic. *Eurhythmy* does this with birds which gracefully fly in unusual patterns and humans who realistically perform impossible dance steps.

The FLOCK and PODA systems, together with a spline-based camera motion system, formed the foundations of the animation software used to create *Eurhythmy*. All of this software was written in LISP with Flavors and ran on a Symbolics 3670 computer. In contrast to most animation productions, the motion of *Eurhythmy* was designed in three dimensions before the precise camera motion and film language/editing were decided upon. Rather than drawing storyboards, the artists experimented with different camera motions and cuts on the computer, often using bonding box 'stand ins' to speed up the calculation process. Wire-frame tests were computed and then videotaped in real time off the computer screen, edited together and evaluated. Before *Eurhythmy* was rendered in colour, a complete hidden-line wire-frame version of the animation was created by filming each frame directly off the screen onto 16 mm film (see Figure 3).

The camera motion is essential to creating the mystical atmosphere of *Eurhythmy*. The camera guides the viewer through the strange religious event, shaping the viewer's experience. At different times in the film, the camera forces the viewer to become observer or participant, curious or removed.

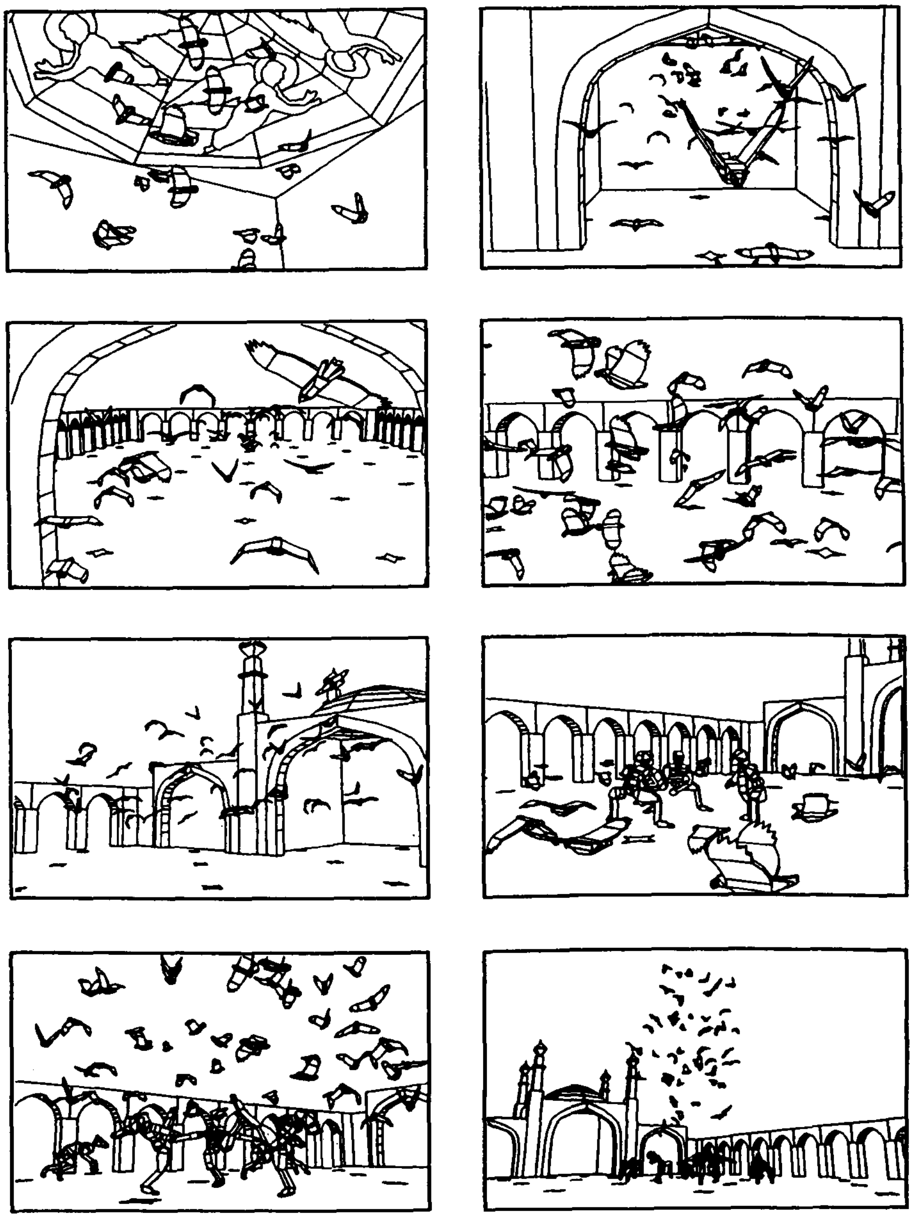

Figure 3. Scenes from the film *Eurhythmy*

Eurhythmy was rendered with an early version of Ohio State University's image-synthesis program, TROUT, written by Scott Dyer of the Ohio Supercomputer Graphics Project. TROUT uses a scan-line *z*buffer visible surface algorithm. Although no texture, bump or environment maps were used, *Eurhythmy* makes extensive use of vertex colouring and polygon colouring to achieve some textural qualities without increasing rendering time. The shadows were generated each frame by a separate program which projected the three-dimensional shapes of the humans, animals and birds onto the courtyard floor, producing two-dimensional shadow shapes which moved over the ground plane. The blurred background of the blue sky and brown ground was a two-dimensional vertical blending of colours. The location of the horizon line upon the screen was based upon the location of the camera, the centre of interest, and ground in three-dimensional space. Rendered on a Convex C1 computer, each frame of *Eurhythmy* was computed in approximately twelve minutes, depending on the complexity of the image.. Some individual frames are shown in Figures 4–7.

Most of the objects in *Eurhythmy* were created using standard polygonal geometric modelling techniques. One exception is the Chinese tile pattern on the temple floor, which was algorithmically generated. Since the masks worn by the dancers are complex structures, they were sculpted lifersize by Girard, Amkraut and Robert Lurye, and then digitized using a 3D space digitizer. The masks were modelled after real masks, which originated from both Africa and North American Indians.

Figure 4. Copyright Eurhythmy 1989: Susan Amkraut and Michael Girard

Figure 5. Copyright Eurhythmy 1989: Susan Amkraut and Michael Girard

Figure 6. Copyright Eurhythmy 1989: Susan Amkraut and Michael Girard

The music for *Eurhythmy* was composed by Michael Girard and Michael Czeiszperger, with the exception of the opening sequence, which was excerpted from the David Hykes performance and composition 'Halleluyah' from his Harmonic Meetings recording. David Hykes employs a style of singing called 'harmonic chant', in which several pure overtones resonate in the vocal tract, creating the impression of several voices.

The original music composed by Girard and Czeiszperger was realized with a midi-controlled Alesis drum machine, a Korg DSS sampler, and various acoustic instruments, such as a digitally-delayed block-flute (played by Girard), and a Chapman Stick (performed by Czeiszperger). To achieve synchronization between the animation and the music, Girard's animation program output the 3D eye-space co-ordinates and the timing of each footstep taken by the legged animals. Czeiszperger wrote software to translate this information into midi format, which was then used to synchronize the Alesis drum machine.

The idea for *Eurhythmy* was first conceived in 1985. The final colour animation was completed in 1989. The four years between *Eurhythmy's* conception and completion were mostly spent on academic research, graduate course work, and the implementation of the PODA and FLOCK systems. As the culmination to Girard and Amkraut's studies at Ohio State University, *Eurhythmy* was born.

EURHYTHMY CREDITS

Film created by
Susan Amkraut and Michael Girard
(Note: Michael Girard and Susan Amkraut contributed equally to *Eurhythmy*, both technically and artistically.)

Animation
Michael Girard: Articulated figure animator
Susan Amkraut: bird flock animator

Software
Michael Girard: PODA, articulated figure animation software
Susan Amkraut: FLOCK, flocking animation software
Scott Dyer: TROUT, rendering software

Hardware
Symbolics 3670 LISP machine: PODA and FLOCK animation systems
Convex C1: TROUT rendering program

Music
Michael Girard and Michael Czeiszperger: Composition
Excerpt from David Hykes and the Harmonic Choir's piece 'Hallelujah'

Produced at
The Advanced Computing Centre for the Arts and Design, Ohio State University

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Calendar of Events

1990

September

2–3 September
Fifth EUROGRAPHICS Workshop on Graphics Hardware, Montreux, Switzerland. Contact: Prof W. Straßer, WSI/GRIS Universität Tübingen, Auf der Morgenstelle 10, C9 D-7400 Tübingen, FRG. Tel.: (49)7071 296356. Telefax: (49)7071 295400. email: igsr001@dtuzdv5a.bitnet.

3–7 September
EUROGRAPHICS '90—Images: Synthesis, Analysis and Interaction, Montreux, Switzerland. Contact: Conference Secretariat, Paleo Arts et Spectacles, Case postale 177, CH-1260 Nyon, Switzerland. Tel.: (41)22 62 13 33. Telex: 419 834. Telefax: (41)22 62 13 34.

3–7 September
ISPRS Commission V Symposium: Close-Range Photogrammetry Meets Machine Vision, Zurich, Switzerland. Co-sponsors: The International Society for Optical Engineering (SPIE), Federation Internationale des Geometres, Commission 6 (FIG), Information Technology Society of the SEV (ITG), Swiss Association of Biomedical Engineering (SGBT), Swiss Society for Photogrammetry (SGPBF), Image Analysis and Remote Sensing. Contact: Symposium of ISPRS Commission V, Institute of Geodesy and Photogrammetry, ETH-Hoenggerberg, 8093 Zurich, Switzerland. Tel.: +41-1-3773051. Telefax: +41-1-3715548. email: chezpp@igpho@ethz.

5–7 September
ASAP 90, International Conference on Application-Specific Array Processors, Princeton, N.J., U.S.A. Cosponsor: Princeton University. Contact: S.Y. Kung, Electrical Engineering Dept., Princeton University, Princeton, NJ 08544, U.S.A. Tel.: (609) 258-3780.

10–12 September
IEEE Conference on Managing Expert System Programs and Projects, Washington, DC, U.S.A. Sponsor: IEEE Computer Society Task Force on Expert Systems. Contact: Jay Liebowitz, Management Sciences Dept., George Washington University, Washington, DC, U.S.A. Tel.: (202) 994-6969.

16–19 September
ICCD 90, IEEE International Conference on Computer Design: VLSI in Computers and Processors, Cambridge, Mass., U.S.A. Contact: Edward M. Middlesworth, Hewlett-Packard, Bldg. 25U, PO Box 10350, Palo Alto, CA 94303-0867, U.S.A. Tel.: (415) 857-5485; or ICCD 90, IEEE Computer Society, 1730 Massachusetts Ave. NW, Washington, DC 20036-193, U.S.A. Tel.: (202) 371-1013.

27–29 September
Computational Intelligence 90, Milano, Italy. Sponsors: F.I.S. Cassa di Rosp. o. PC. Contact: Giorgio Valle, Universita Milano. Dip. Scienze Della Informazione, Via Noretto 20133, Milano, Italy.

October

1–3 October
15th Conference on Local Computer Networking, Minneapolis, Minn., U.S.A. Contact: Marc Cohn, Advanced Development Div., Raychem Corp., 300 Constitution Dr., Menlo Park, CA 94025-1164, U.S.A. Tel.: (415) 361-3902.

1–5 October
InfoJapan 90, International Conference on Information Technology, Tokyo, Japan. Sponsor: IPSJ. Contact: Takuma Yamamoto, Fujitsu, 3-14-1 Hiyoshi, Kohoku-ku, Yokohamashi, Japan.

8–10 October
Frontiers 90, Third Symposium on Frontiers of Massively Parallel Computation, College Park, Md., U.S.A. Cosponsor: NASA Goddard Space Flight Center. Contact: Johanna Weinstein, Frontiers 90, UMIACS, Univ. of Maryland, A.V. Williams Bldg., College Park, MD 20742, U.S.A. Tel.: (301) 454-1808.

9–11 October
Ninth Symposium on Reliable Distributed Systems, Huntsville, Ala, U.S.A. Contact: Raif M. Yanney, TRW, MS DH2/2328, 1 Space Park, Redondo Beach, CA 90278, U.S.A. Tel.: (213) 764-6033.

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