Verbs and Adverbs:
Multidimensional Motion Interpolation
Using Radial Basis

Charles Rose    Boby Bodenheimer    Michael Cohen
Microsoft Research

Presented by WSHong
Goal

1. Construction of new motions with the interpolation
   a. Real time + Radial basis function

2. Verbs and Adverb
   a. Verbs: The parameterized motions
   b. Adverb: The parameter controlling verbs

3. Verb graphs
   a. Transition from verb to verb
   b. Runtime data structure
   c. The repertoire of expressive behaviors
Overview

- Emotional expression
  - Control behaviors

- Verbs
  - Characterized
  - Interpolation
  - Interpolation
  - Combined
  - Smooth transition

- Adverbs
  - Control

- Example Motions
  - Interpolation

- Verb graph

- IK
  - Radial basis functions
  - Low order polynomials

- Other verbs

Repertoire of expressive behaviors
Related Work

1. Unuma et al.
   • Fourier techniques with interpolation.
2. Amaya et al.
   • Emotion transform
3. Bruderlin and Williams
   • Blending motions, multitarget interpolation
4. Witkin and Popovic
   • Motion warping
5. Wiley and Hahn
   • Linear interpolation, blending motion
6. Hodgins and Pollard
   • Interpolation over the space of control
Verbs and Adverbs

The system:

• Offline authoring system
  – Define verb
  – Construct transitions
  – Verb graph
• Runtime system
  – Invocation of verbs
  – Evaluating figure’s pose
Verbs and Adverbs (Cont.)

- A verb \( M \)

\[
M_i = \{ \theta_{ij}(T), \mathbf{p}_i, K_m : i = 1 \ldots \text{NumExamples}, j = 1 \ldots \text{NumDOF}, m = 0 \ldots \text{NumKeyTimes} \}
\]

\( \mathbf{p}_i \): location in adverb space \( K_m \): Keytimes \( \theta \): DOF function

The restrictions of example motions:

- All examples for a verb are structurally similar:
  - Same starting foot, same step numbers, same arm swing phases & no spurious motions.
- Joint angle consistency
Verbs and Adverbs (Cont.)

- Example motions:

\[ \theta_{ij}(T) = \sum_{k=1}^{\text{NumCP}} b_{ijk} B_k(T) \]

- \( b_{ijk} \): scalar B-spline coefficients or control points
- \( B_k(T) \): B-splines
Verbs and Adverbs (Cont.)

Time warping:
Mapping keytimes $T$ to generic time $t$

\[
t(T) = \left( m - 1 + \frac{T - K_m}{K_{m+1} - K_m} \right) \frac{1}{\text{NumKeyTimes} - 1}
\]

\[
t(K_m) = \frac{m - 1}{\text{NumKeyTimes} - 1}
\]
Inverse kinematics constraints:

- Keytimes also specify constraint periods
  - Heel-strike & toe-off in keytimes
- Use IK to enforce constraints at runtime

\[ J \Delta \theta = \Delta x \]

\( J \): Jacobian
Verbs construction

- Verb space:
  Examples with keytimes and adverb settings
- NumAdverbs:
  The dimension of the space

Standard problem of interpolation:
  Higher dimension and/or few examples cause interpolation difficulties
Verbs construction (Cont.)

- Solution:
  Radial basis function + linear approximation

\[ b_{jk}(\mathbf{p}) = \sum_{i=1}^{\text{NumExamples}} r_{ijk} R_i(\mathbf{p}) + \sum_{l=0}^{\text{NumAdverbs}} a_{jkl} A_l(\mathbf{p}) \]

\[ K_m(\mathbf{p}) = \sum_{i=1}^{\text{NumExamples}} r_{im} R_i(\mathbf{p}) + \sum_{l=0}^{\text{NumAdverbs}} a_{lm} A_l(\mathbf{p}) \]
Verbs Graph

- Combine verbs nodes with smooth transitions
- Duration of the transition: average

\[
\frac{(T(t_{c}^{A}) - T(t_{s}^{A})) + (T(t_{c}^{B}) - T(t_{s}^{B}))}{2}
\]
Verbs Graph (Cont.)

- Blending during correspondence region
Runtime Verb Evaluation

Evaluating DOF

1  $T = \tau - \tau_{offset}$
2
3  For each keytime $m$
4  $K_m = \text{InterKey}(m, p)$  // Eqn. 4
5  Next
6
7  $t = \text{GenericTime}(T, K)$  // Eqn. 1
8
9  For each DOF $j$
10  For each B-spline coefficient $k$
11  $b_{jk} = \text{InterBSCoeff}(j, k, p)$  // Eqn. 3
12  Next
13  $q_t = \mathbf{A}_k b_{jk} \mathbf{B}_k(t)$
14  Next
15  For each kinematic constraint $c$
16  $\text{EnforceConstraint}(c)$  // Eqn. 2
17  Next
Results

Reach high

Reach low

Reach right  Reach left
Conclusion

• Advantages
  – Build new motions from few examples motions
  – Able to compute them at runtime
  – The repertoire of expressive behaviors using verb graph

• Drawbacks
  – RBF introduce noise
  – The animator has to determine key times
Q & A
Thank you!