Perception and Categorization of Computer Animated Walking Figures

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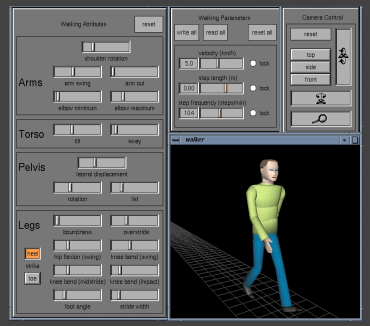
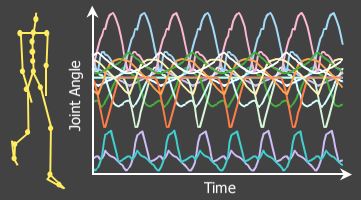
Computer graphics has long benefited from an understanding of human vision. Basic perceptual phenomena such as trichromacy, opponent colors, and color JNDs have enabled the design of graphics hardware and software. More complex stimuli such as human movements are also important for graphics but are not so well understood.

For example, Bruderlin's (1995) walk generator uses twenty-nine parameters to create "human like" walking motions by simulating the joint angle rotations of thirty-six joints (eighty-three rotational angles).





Questions Motivating Our Research:

How should the parameters be adjusted to make the walk appear faster? Younger? Bouncier? Graceful?

Can we find a concise set of descriptive terms to define a "Linguistic Motion Space" which can be used to describe the human motions?

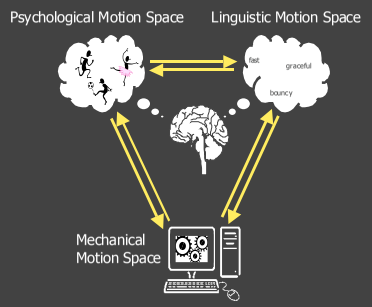
Which parameters are most perceptually salient?

What are the psychophysics of human motion?

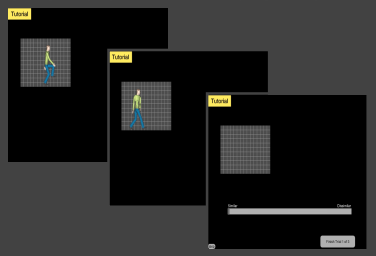
Do experts and novices differ in their ability to reliably distinguish and describe motions?

We are investigating the mapping between the parameters used by a computer to generate animated movements (different gaits of a walking figure), participants' descriptions of movements, and their judgments of the similarity of the movements.

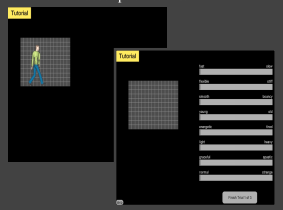
We utilize a conceptual framework relating three motion spaces: a mechanical motion which computer animation programs operate in, a psychological motion space which human encode and organize motions according to their features, and a linguistic motion space that humans use to describe movements using words.



The psychological motion space is defined by the participants' judgments of the similarity of pairs of gaits.



The linguistic motion space is defined by the participants' descriptions of each gait on eight scales labeled with opposite movement description terms.



Stimuli

Motion Parameters → Gaits → Interpolated Gaits (Experiment Two)

Trials

Motion Comparisons (Session One)

Motion Ratings (Session Two)

Responses

Similarities

Ratings (and differences of ratings)

Parameters (and differences of parameters)

Analyses

Correlation

Principal Components Analysis of Ratings

Multidimensional Scaling of Similarities (Experiment Two)

Experiment One:
- 26 gaits, randomly paired
- 6 participants:
  - 5 social dancers (3 females, 2 males)
  - 1 non-dancer (male)

Experiment Two:
- 9 gaits, paired according to schema
- 30 participants:
  - 8 dancers (7 females, 1 male)
  - 17 runners (9 females, 8 males)
  - 5 neither (1 female, 4 males)

Experiment One examined the classification of gaits within the structure of pairs of opposite movement description terms. We found that the focus of attention varied among participants, but that similar stimulus characteristics were salient in determining the classification of gaits:

- fast-slow: step length and knee swing
- flexible-stiff: upper torso and pelvis rotation
- smooth-bouncy: bounciness
- young-old: arm, elbow, and knee swing
- energetic-tired: arm, elbow and knee swing; average torso tilt and knee bend throughout stride
- light-heavy: heel or toe strike
- graceful-spastic: elbow rotation, torso sway, bounciness, and hip swing
- normal-strange: torso sway, bounciness and hip swing

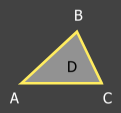
Classification was somewhat consistent across most of our participants with the first two principal components common to a majority of participants and the third and fourth components capturing individual biases.

1st PC of 5 participants (#2, #3, #4, #5, #6)		2nd PC of 5 participants (#1, #2, #3, #4, #6(3rd))	
fast	slow	**fast**	slow
flexible	stiff	**flexible**	stiff
smooth	**bouncy**	**smooth**	bouncy
young	old	**young**	old
energetic	tired	**energetic**	tired
light	heavy	**light**	heavy
graceful	**spastic**	**graceful**	spastic
normal	**strange**	**normal**	strange

Experiment Two explored the metric properties of motion similarity judgments by asking participants to make comparisons between a limited range of movements that were unlikely to span boundaries between multiple linguistic descriptors, but which were perceptually distinct.

Metric Properties:

1. Only self distance is 0
   $D(A,B) > D(A,A) = 0$
2. Distances are symmetric
   $D(A,B) = D(B,A)$
3. Triangle inequality
   $D(A,B) + D(B,C) \geq D(A,C)$



We conclude that similarity judgments do not have all of the metric properties but that their evaluation was similar across participants. Symmetry was the most robust:

1. Self distance often greater than zero, non-self distance often near zero
   $D(A,A) > \square\ D(A,B) < \square$
2. Distances are usually symmetric
   $D(A,B) \approx D(B,A)$
3. Triangle inequality does not hold
   $D(A,B) + D(B,C) < D(A,C)$

We tested for correlations (Pearson's r) between the mechanical motion space (parameters), the psychological motion space (similarity judgments) and the linguistic motion space (descriptions). We present the ranges of participants' strongest correlations for each of these relationships:

	Mechanical versus Linguistic	Mechanical versus Psychological	Psychological versus Linguistic
min	0.48	0.41	0.42
median	0.51	0.52	0.58
max	0.76	0.66	0.68

Observed inter-participant differences suggest that animation systems should be customizable not only for the user's preferences, but for their perceptual abilities and movement categories as well. If our findings are correct, we can predict that this customization might be achieved by altering parameter values associated with the relative weights given to common perceptual cues without the need to add new cues or substantially modify the nature of the cues themselves.

References

Armin Bruderlin. *Procedural Motion Control Techniques for Interactive Animation of Human Figures*. PhD thesis, Simon Fraser University, School of Computing Science, March 1995.

Jason Harrison. *Measuring and Comparing Human Walking Motions for Computer Animation*. PhD thesis, University of British Columbia, Department of Computer Science, December 2001. Available from http://www.cs.ubc.ca/~harrison/Thesis/Doctoral/.

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