A Perception Based Metric for Comparing Human Locomotion

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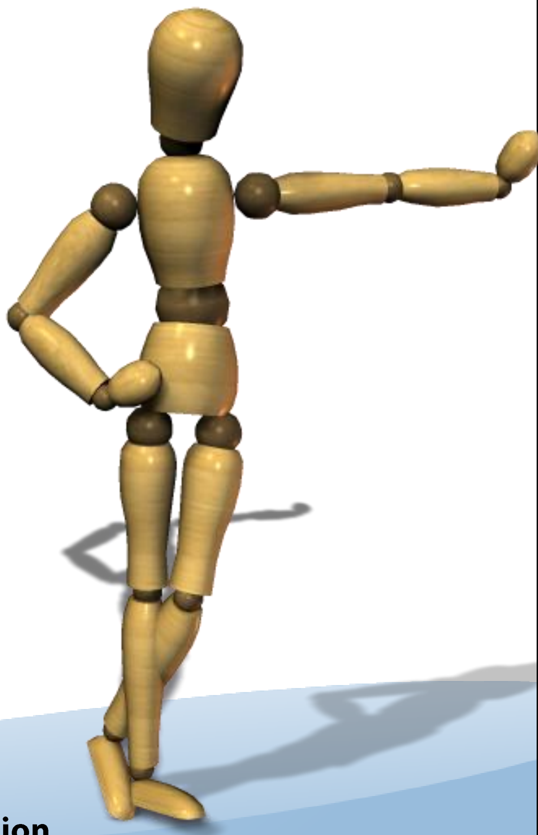
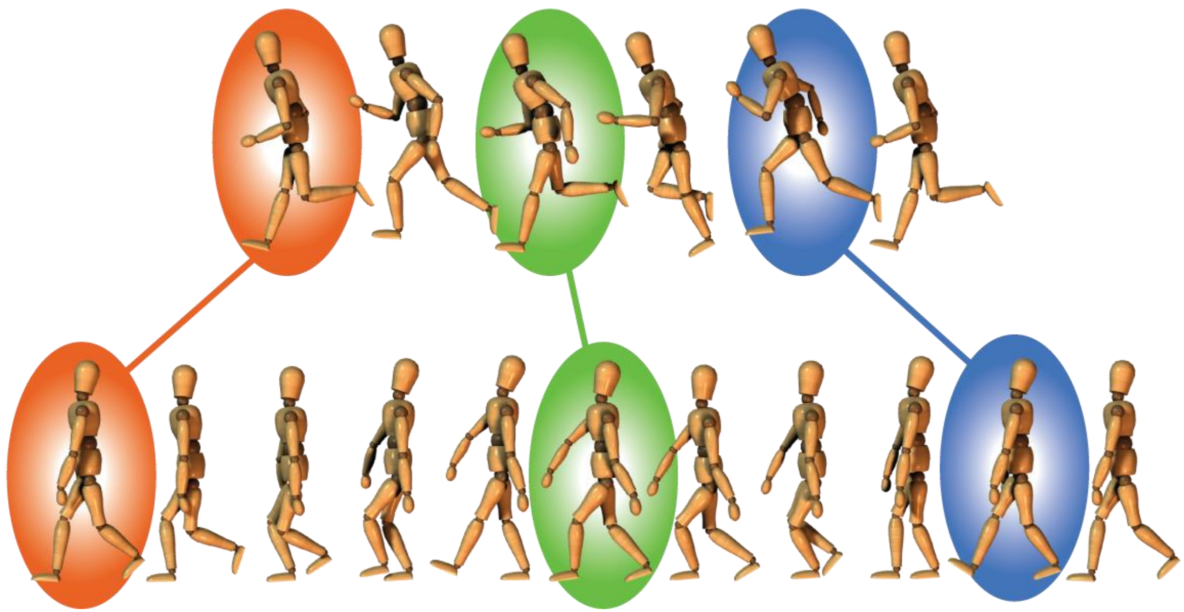
Presentation Outline

- Introduction and a bit of background
- Overview of our work
- Stimuli preparation
- Experiment
- Data analysis
- Metric toolkit
- Results
- Conclusion



Introduction

- Blending animations in games
- Requirement of smooth blends
  - Detecting a good "transition point"

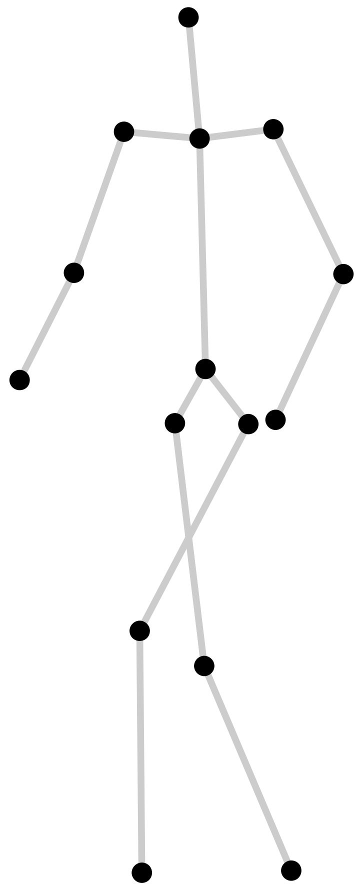


Introduction

- Blending animations in games
- Requirement of smooth blends
  - Detecting a good “transition point”
- Classical methods use non-weighted difference
  - Ad-hoc solution
- We want a **perceptually-based solution**
  - The resulting animation is presented to the user

A bit of background

- **Pointlight walkers**
  - Johansson 1973
    - introducing PL walkers
  - Cutting and Kozlowski 1977
    - Similarity, gender perception
  - Troje 2002
    - Parametric model
  - Giese and Poggio 2003
    - Neurological background
- **Naturalness metrics**
  - Ren et al. 2005
- **Frame similarity metrics**
  - Wang and Bodenheimer 2003
  - Tang et al. 2008



Overview of our work

- **We build** a frame metric **based on perception** (not just an evaluation)
  - Perform a perceptual experiment
  - Create a metric from the results
  - Change parameters of standard metrics to reflect these results
  - Evaluate the output

Stimuli Preparation

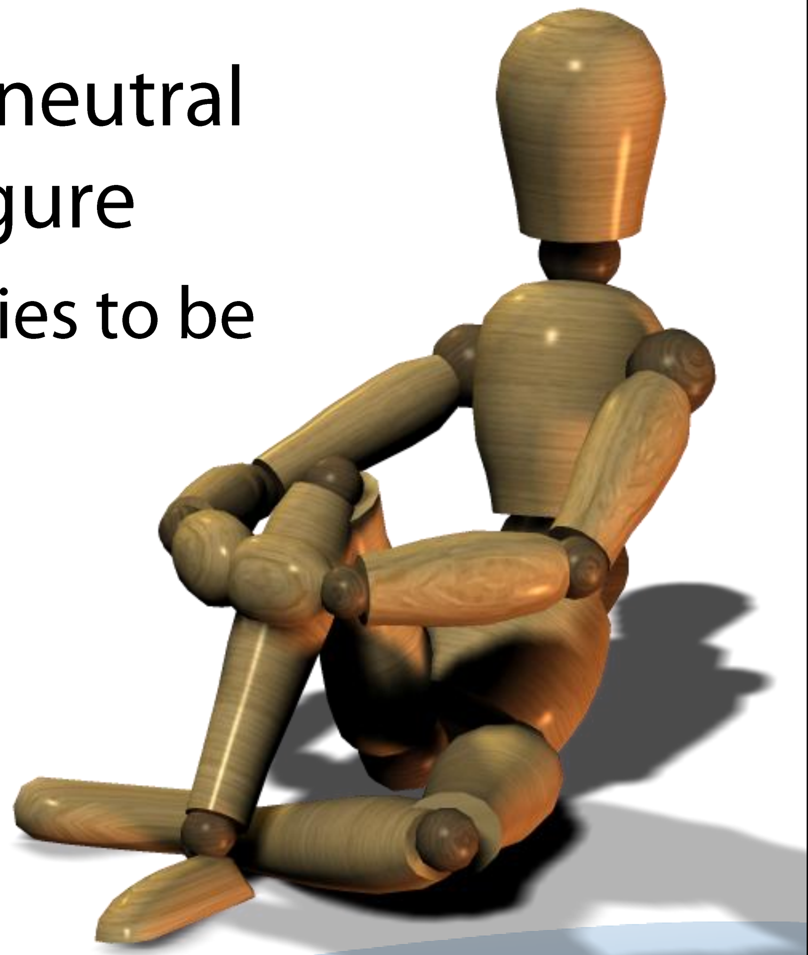
- Motion Capture data
  - Vicon, 13-camera MoCap system
  - 21 walkers (14M, 11F)
  - 42 markers, 100 FPS
- Retargetted to a common character
- Period detection + blending = periodic locomotion clips

Perceptual Experiment (1/4)

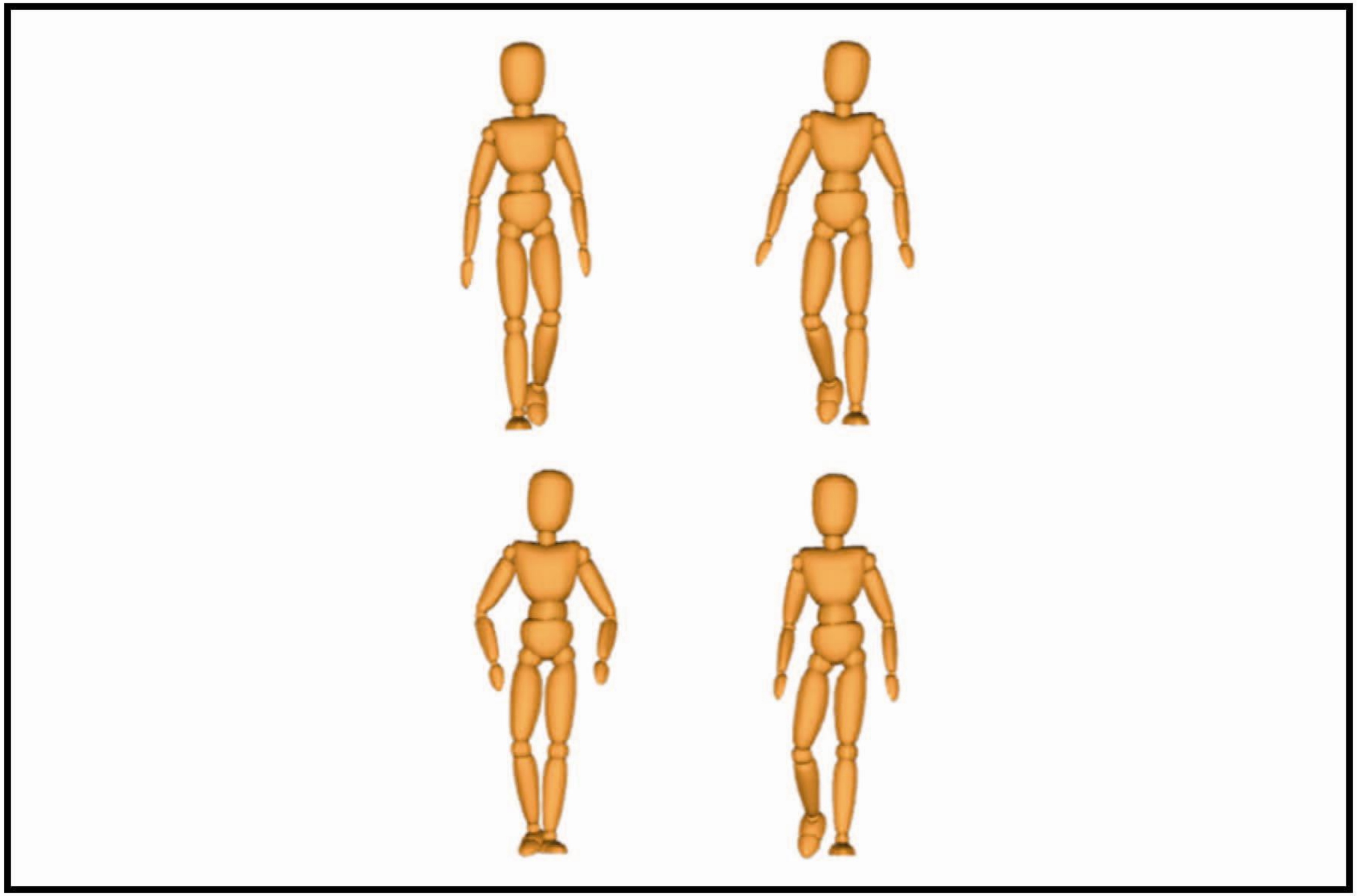
- A matrix of 4 motions is displayed (randomly chosen out of 21)
- Users asked to select two most similar motions
- Time limit 10 seconds
- 63 trials per participant

Perceptual experiment (2/4)

- Motion displayed on a neutral wooden mannequin figure
  - Shown in previous studies to be gender neutral *McDonnell et al. 2009*



Perceptual experiment (3/4)



Perceptual experiment (4/4)

- 29 participants (18 male, 11 female)
- Recorded the four displayed motions + selected pair
- Converted into a relative difference:
  - 0 ~ similar and 1 ~ very different motions

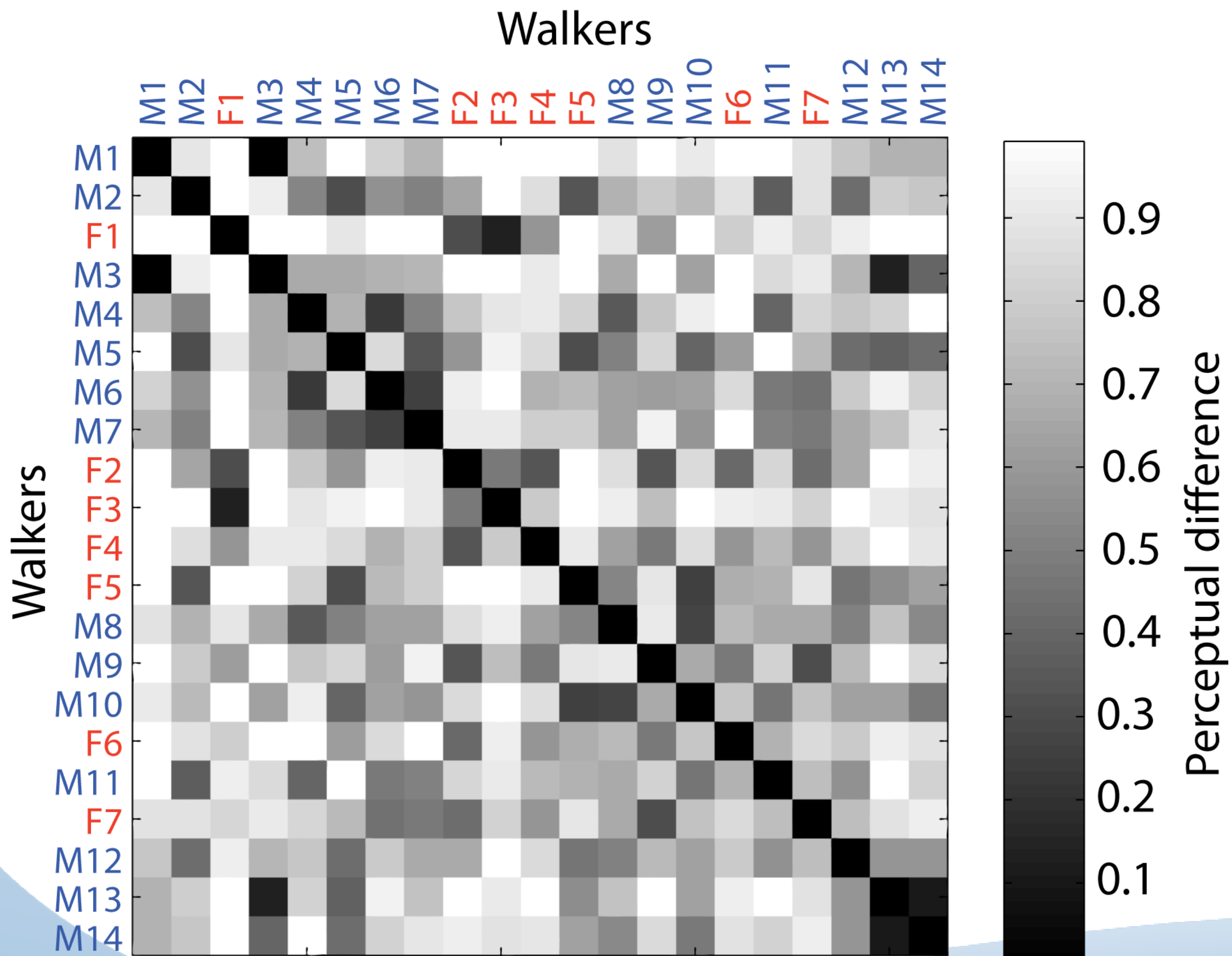
$$\text{difference} = \frac{\text{\# of times a pair was } \textbf{\textit{not}} \text{ perceived similar}}{\text{\# of times a pair shown}}$$

Data analysis (1/6)

- The motion difference converted into a table:

	M1	M2	F1	M3	M4	M5	M6	F2	F3	F4	F5	M7	M8	M9	M10	F6	M11	F7	M12	M13	M14
M1	0.00	0.90	1.00	0.00	0.74	1.00	0.83	0.71	1.00	1.00	1.00	1.00	0.89	1.00	0.91	1.00	1.00	0.88	0.78	0.69	0.69
M2	0.90	0.00	1.00	0.93	0.52	0.31	0.57	0.51	0.65	1.00	0.87	0.34	0.69	0.79	0.72	0.89	0.36	0.88	0.42	0.80	0.78
F1	1.00	1.00	0.00	1.00	1.00	0.90	1.00	1.00	0.31	0.13	0.58	1.00	0.90	0.61	1.00	0.81	0.93	0.84	0.93	1.00	1.00
M3	0.00	0.93	1.00	0.00	0.67	0.67	0.70	0.71	1.00	1.00	0.92	1.00	0.67	1.00	0.63	1.00	0.85	0.91	0.71	0.13	0.39
M4	0.74	0.52	1.00	0.67	0.00	0.69	0.22	0.51	0.78	0.90	0.91	0.83	0.36	0.78	0.93	1.00	0.40	0.84	0.78	0.82	1.00
M5	1.00	0.31	0.90	0.67	0.69	0.00	0.84	0.34	0.58	0.94	0.85	0.32	0.51	0.84	0.40	0.61	1.00	0.72	0.42	0.38	0.42
M6	0.83	0.57	1.00	0.70	0.22	0.84	0.00	0.26	0.93	1.00	0.69	0.73	0.63	0.61	0.63	0.84	0.48	0.44	0.79	0.94	0.81
F2	0.71	0.51	1.00	0.71	0.51	0.34	0.26	0.00	0.92	0.91	0.80	0.80	0.63	0.94	0.59	1.00	0.51	0.48	0.67	0.76	0.90
F3	1.00	0.65	0.31	1.00	0.78	0.58	0.93	0.92	0.00	0.48	0.34	1.00	0.87	0.33	0.84	0.41	0.84	0.42	0.67	1.00	0.93
F4	1.00	1.00	0.13	1.00	0.90	0.94	1.00	0.91	0.48	0.00	0.79	1.00	0.93	0.74	1.00	0.92	0.91	0.83	1.00	0.92	0.89
F5	1.00	0.87	0.58	0.92	0.91	0.85	0.69	0.80	0.34	0.79	0.00	0.91	0.63	0.48	0.87	0.59	0.72	0.58	0.86	1.00	0.90
M7	1.00	0.34	1.00	1.00	0.83	0.32	0.73	0.80	1.00	1.00	0.91	0.00	0.52	0.90	0.25	0.67	0.70	0.90	0.45	0.55	0.63
M8	0.89	0.69	0.90	0.67	0.36	0.51	0.63	0.63	0.87	0.93	0.63	0.52	0.00	0.91	0.28	0.72	0.67	0.67	0.51	0.76	0.54
M9	1.00	0.79	0.61	1.00	0.78	0.84	0.61	0.94	0.33	0.74	0.48	0.90	0.91	0.00	0.67	0.48	0.82	0.31	0.73	1.00	0.86
M10	0.91	0.72	1.00	0.63	0.93	0.40	0.63	0.59	0.84	1.00	0.87	0.25	0.28	0.67	0.00	0.77	0.45	0.76	0.63	0.63	0.48
F6	1.00	0.89	0.81	1.00	1.00	0.61	0.84	1.00	0.41	0.92	0.59	0.67	0.72	0.48	0.77	0.00	0.69	0.85	0.80	0.92	0.88
M11	1.00	0.36	0.93	0.85	0.40	1.00	0.48	0.51	0.84	0.91	0.72	0.70	0.67	0.82	0.45	0.69	0.00	0.74	0.57	1.00	0.83
F7	0.88	0.88	0.84	0.91	0.84	0.72	0.44	0.48	0.42	0.83	0.58	0.90	0.67	0.31	0.76	0.85	0.74	0.00	0.74	0.88	0.93
M12	0.78	0.42	0.93	0.71	0.78	0.42	0.79	0.67	0.67	1.00	0.86	0.45	0.51	0.73	0.63	0.80	0.57	0.74	0.00	0.59	0.58
M13	0.69	0.80	1.00	0.13	0.82	0.38	0.94	0.76	1.00	0.92	1.00	0.55	0.76	1.00	0.63	0.92	1.00	0.88	0.59	0.00	0.11
M14	0.69	0.78	1.00	0.39	1.00	0.42	0.81	0.90	0.93	0.89	0.90	0.63	0.54	0.86	0.48	0.88	0.83	0.93	0.58	0.11	0.00

Data analysis (2/6)



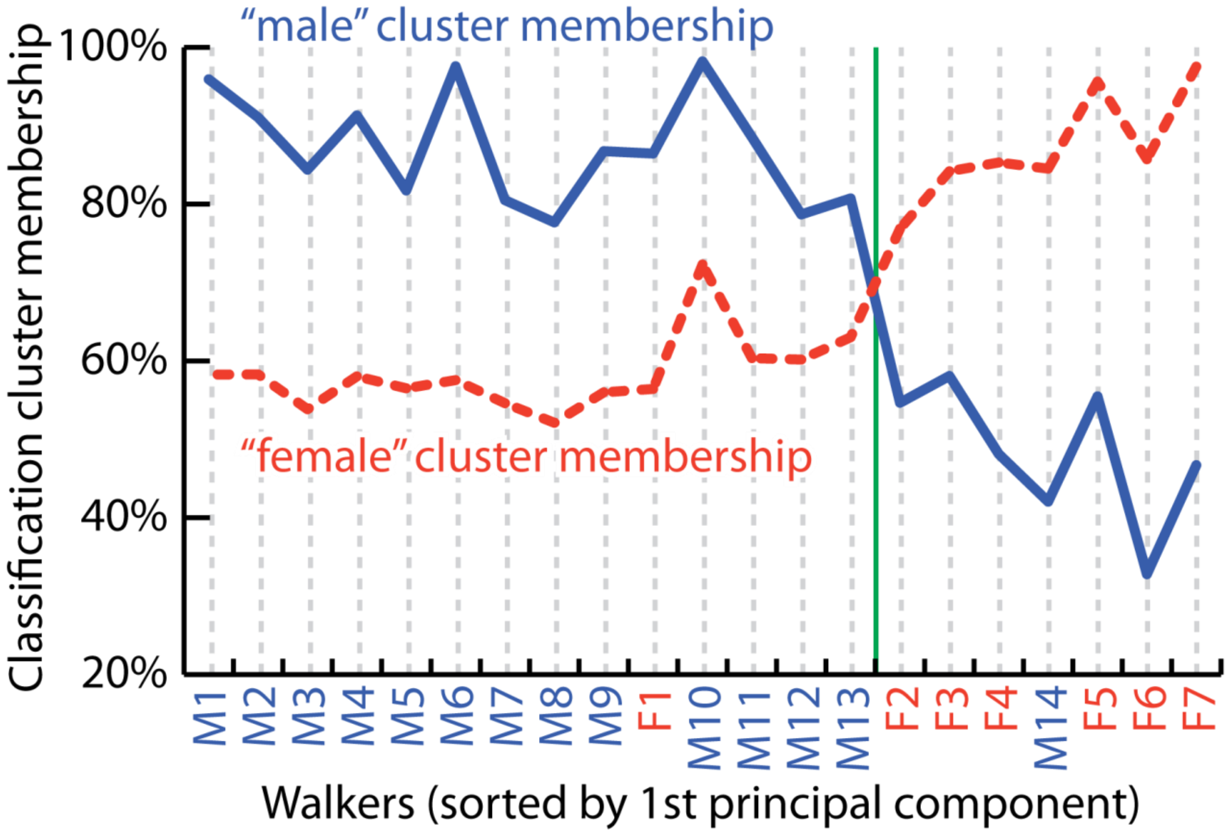
Data analysis (3/6)

- Analysis of this table – is it a metric?
- **Non-negativity** – $d(x,y) \geq 0$
  - By definition of the distance computation
- **Identity** – $d(x,y) = 0$ if and only if $x = y$
  - i.e., zeros on the diagonal
  - Identity requirement, fulfilled implicitly
- **Symmetric** – $d(x,y) = d(y,x)$
  - By definition of the distance function
- **Triangle rule** – $d(x,y) \leq d(x,y) + d(y,z)$
  - Not guaranteed by the process
  - Fulfilled for 98.6% of combinations

Data Analysis (4/6)

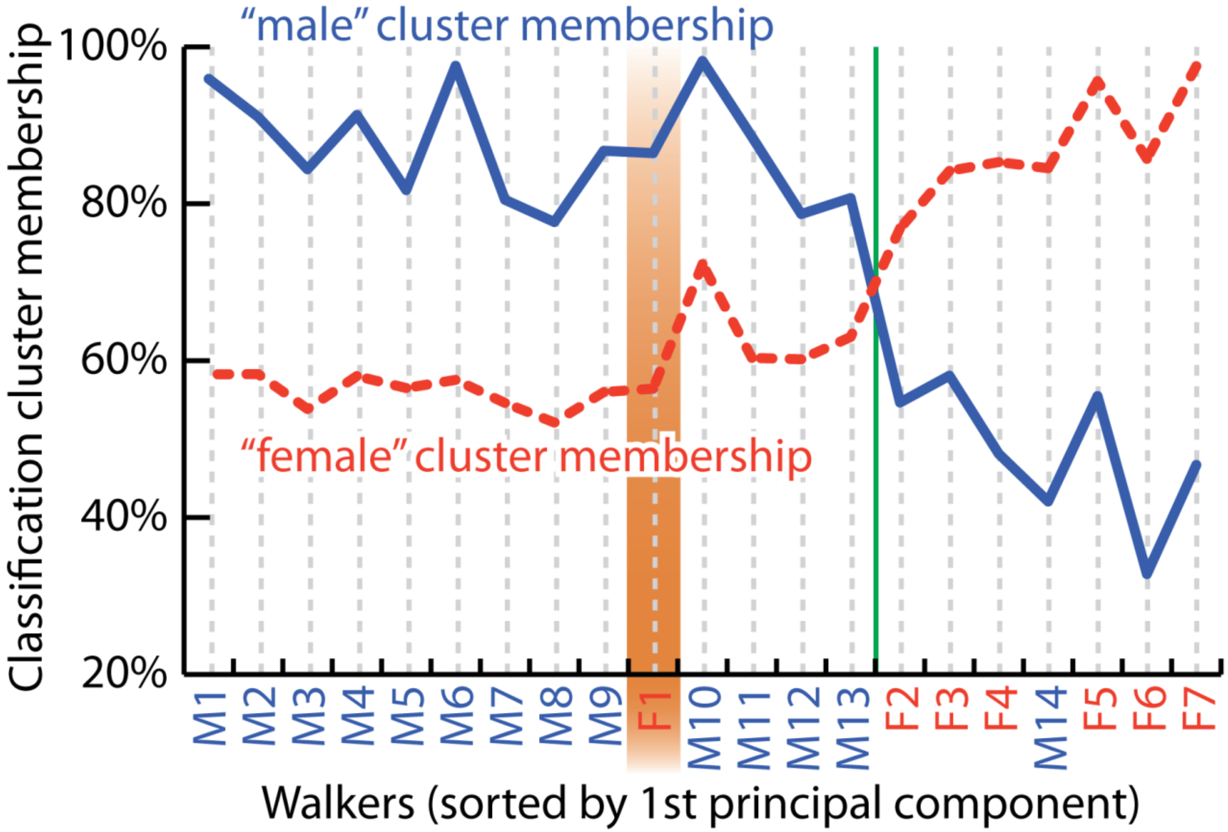
- Further analysis:
  - Interpreting each row/column as an n-dimensional vector (*n = 21* in our case)
  - Principal Component Analysis (PCA) on the data points
  - Projecting on the 1st component
  - K-means clustering of the datapoints

Data analysis (5/6)



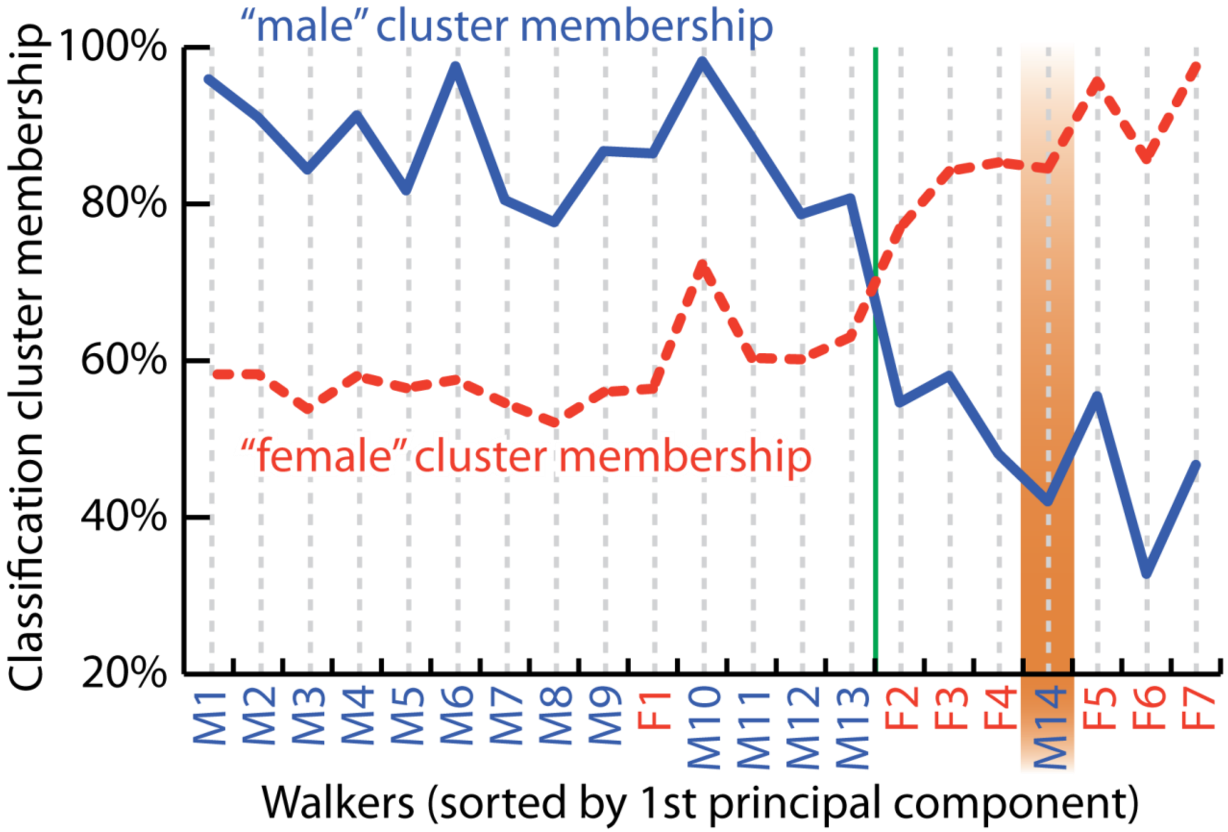
- **Direct relation between gender and first principal component!**

Data analysis (5/6)



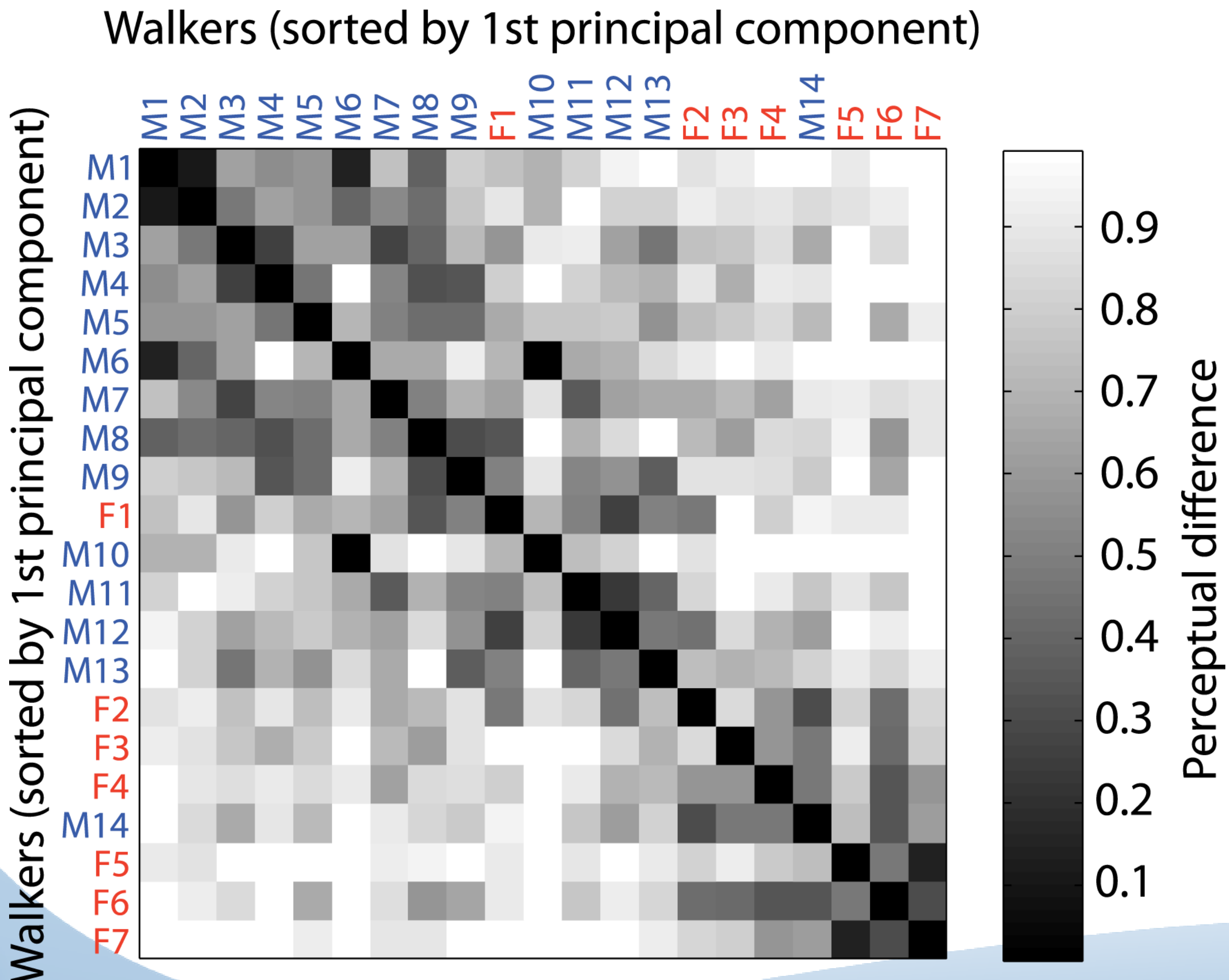
– With exception of F1…

Data analysis (5/6)

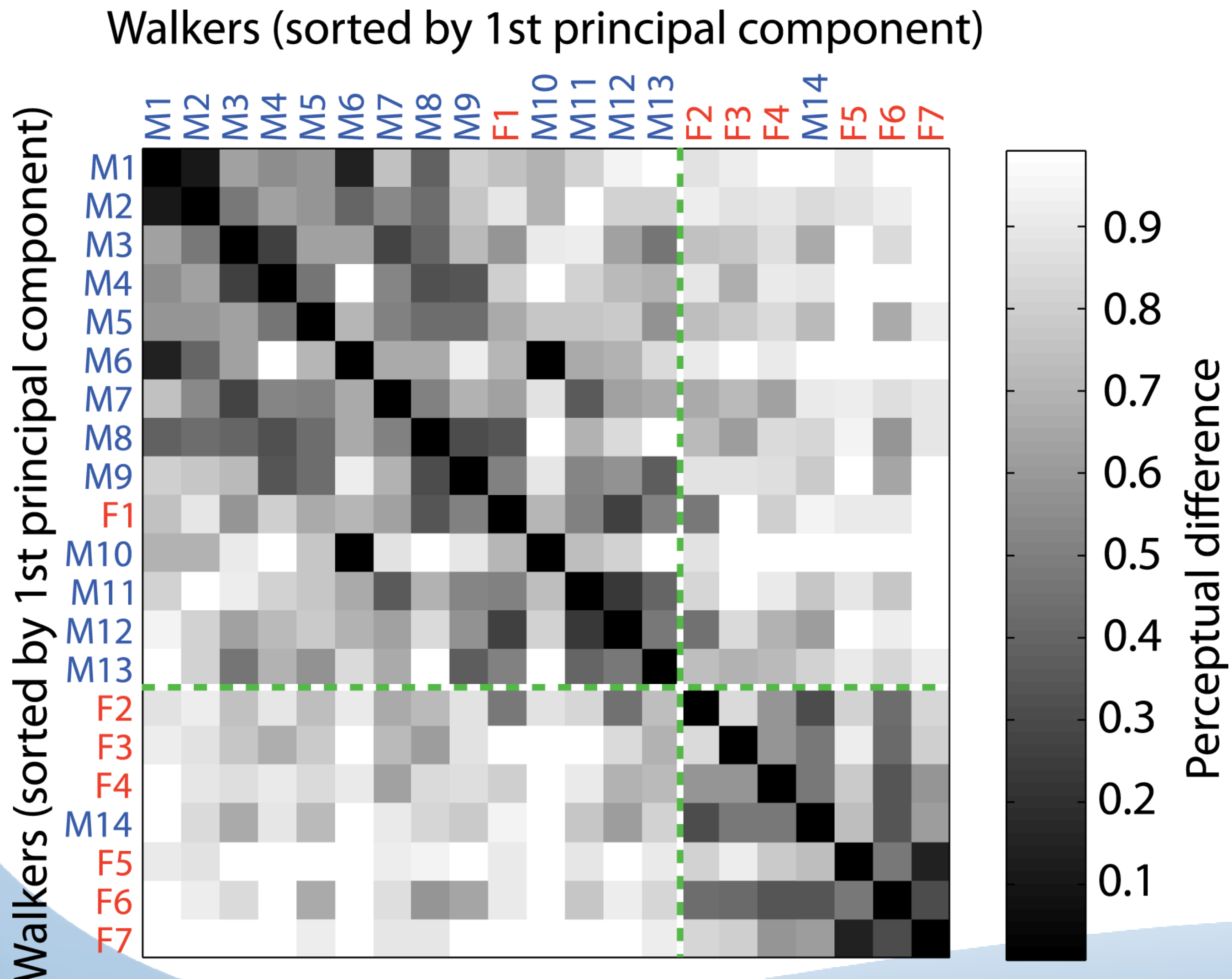


– … and M14

Data analysis (6/6)



Data analysis (6/6)



Metric toolkit

- Generalizing previous results
- Based on Lee et al. (2002) and Kovar et al. (2002)

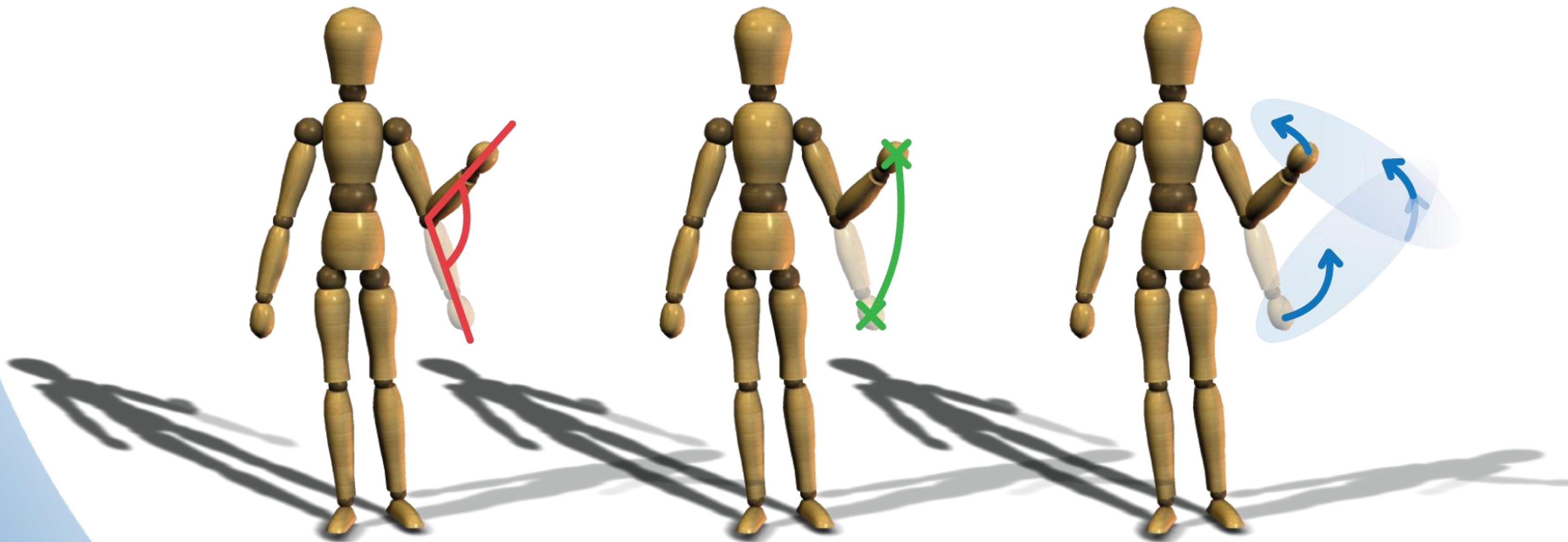
$$d_{angles}(f_i, f_j) = c + \sum_{k=1}^{m} w_k F(q_{i,k} \cdot q_{j,k})$$

$$d_{positions}(f_i, f_j) = c + \sum_{k=1}^{m} w_k F(\|p_{i,k} - p_{j,k}\|)$$

$$d_{velocities}(f_i, f_j) = c + \sum_{k=1}^{m} w_k F(\|v_{i,k} - v_{j,k}\|)$$

What are we looking for?

- To find out **which metric** best fits the perceptual data



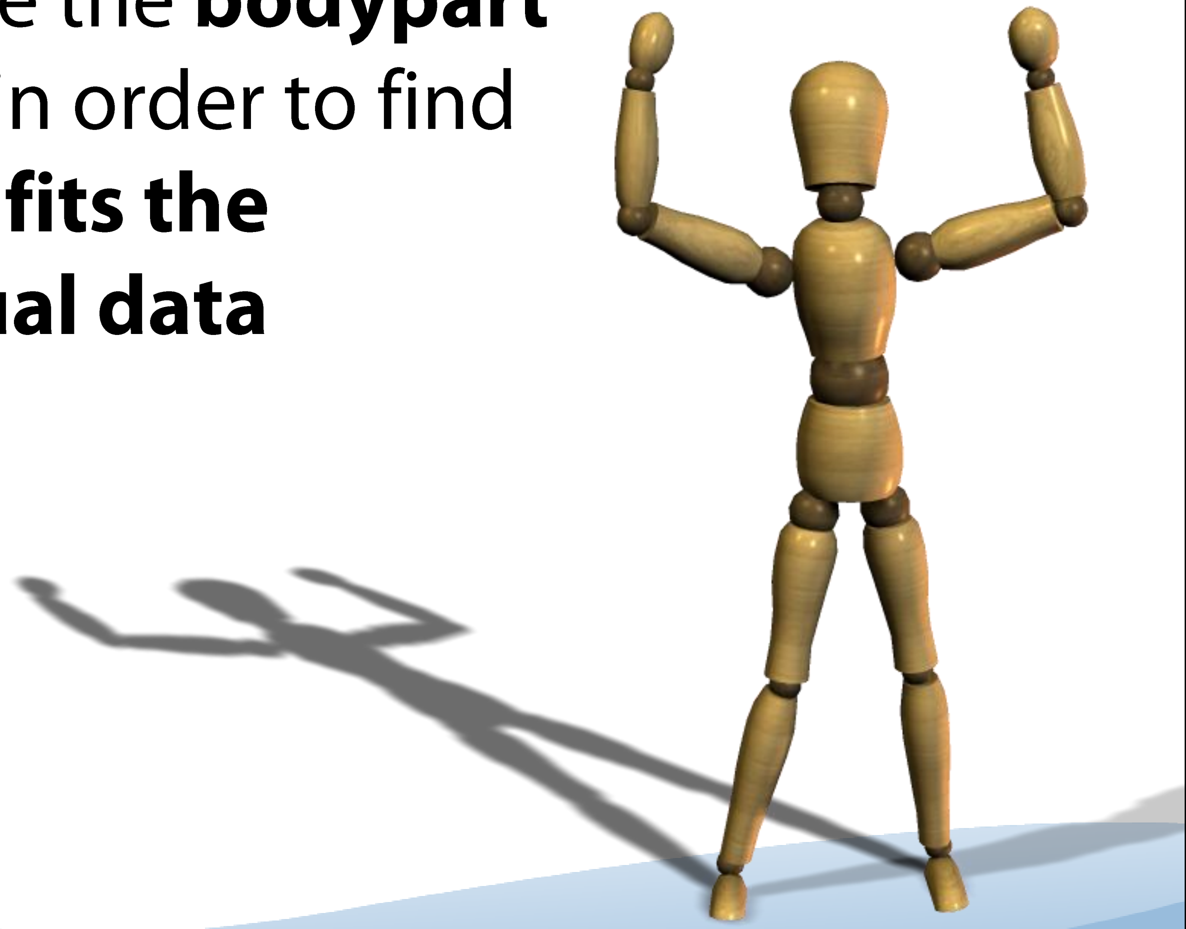
Angular difference

Positional difference

Difference in velocity

What are we looking for?

- To change the **bodypart weights** in order to find out what **fits the perceptual data**



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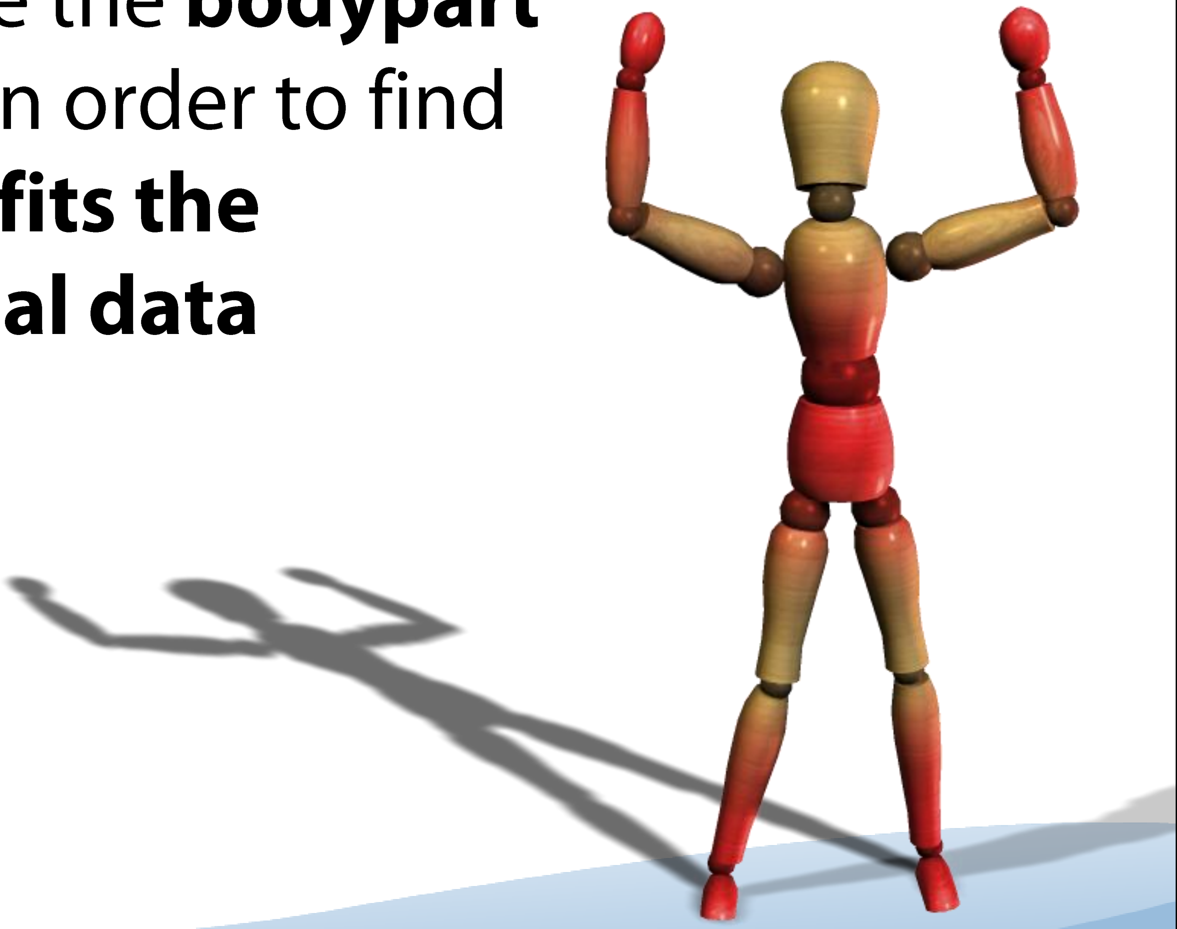
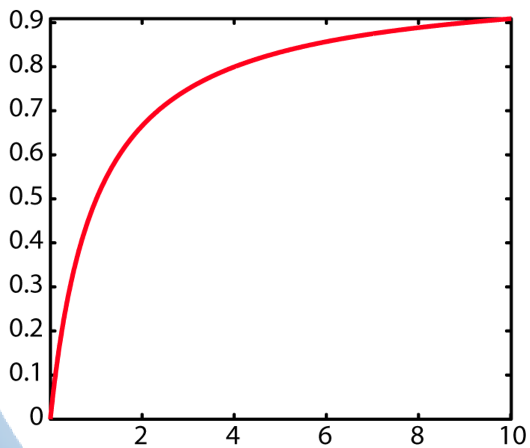
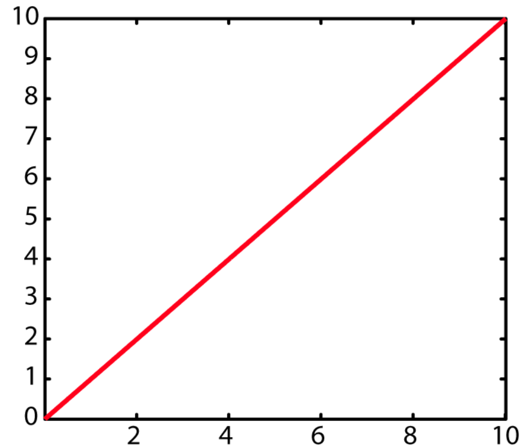


What are we looking for?

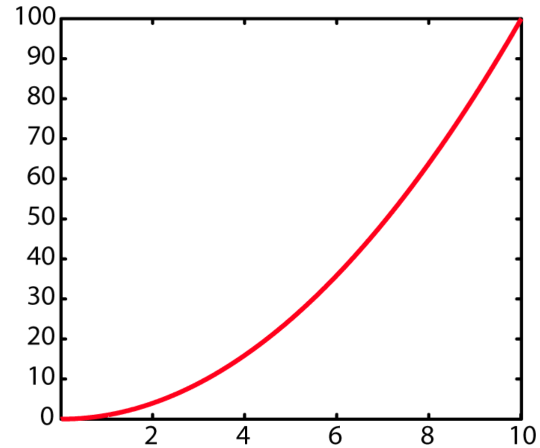
- The **metric function** which fits the data the best



Sigmoid
d / (d + 1)



Linear
(~ Manhattan metric)



Squared Euclidean

Fitting the metrics

- Non-negative least squares fitting
- Using random-start gradient descent
  - 1000 starting points
  - Smooth space = good convergence

Results

		Difference	Constant	Normalization Constant	Head	Clavicle	Upper Arm	Forearm	Hand	Thigh	Calf	Toe
Angles	euclid	23.335	0.508	659.272	0.000	0.000	0.006	0.000		**0.669**	**0.325**	
	manh	18.448	0.324	19.537	0.041	0.003	0.061	0.000		**0.622**	**0.273**	
	sigm	**18.004**	0.312	20.016	0.039	0.008	0.076	0.000		**0.614**	**0.263**	
Positions	euclid	17.117	0.290	206.509	0.062	0.000	**0.551**	**0.181**	0.000	0.000	0.050	**0.156**
	manh	13.423	0.069	9.909	0.020	0.000	**0.362**	**0.429**	0.000	0.000	0.000	**0.189**
	sigm	**13.264**	0.059	10.375	0.015	0.000	**0.344**	**0.455**	0.000	0.000	0.000	**0.184**
Velocities	euclid	25.779	0.431	1914.283	0.000	0.000	0.000	0.000	**0.605**	0.000	**0.298**	**0.098**
	manh	22.039	0.193	36.885	0.000	0.000	0.000	0.000	**0.551**	0.000	**0.298**	**0.151**
	sigm	**21.993**	0.189	36.532	0.000	0.000	0.000	0.000	**0.564**	0.000	**0.306**	**0.157**

- Sigmoid function + global positions lead to the best fit
- Not all joints required for the comparison

Conclusion + future work

- It **WORKS**!
- Only for locomotion
  - Different styles / types of locomotion
  - Other motions
- Different functions
- Different metric types

Questions?