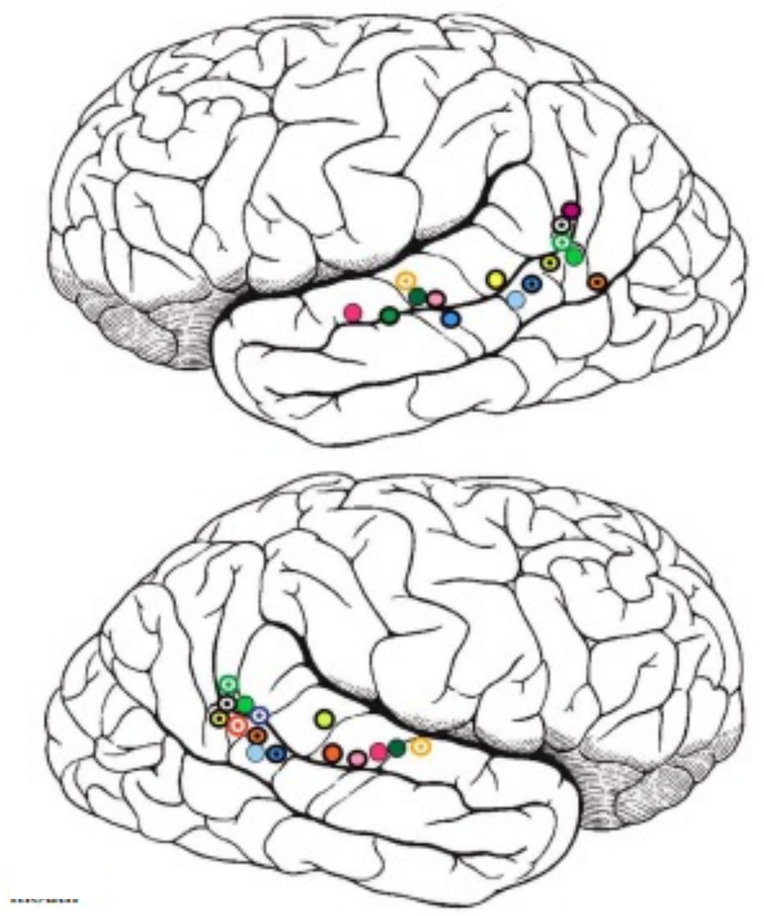
Carnegie Mellon University Africa

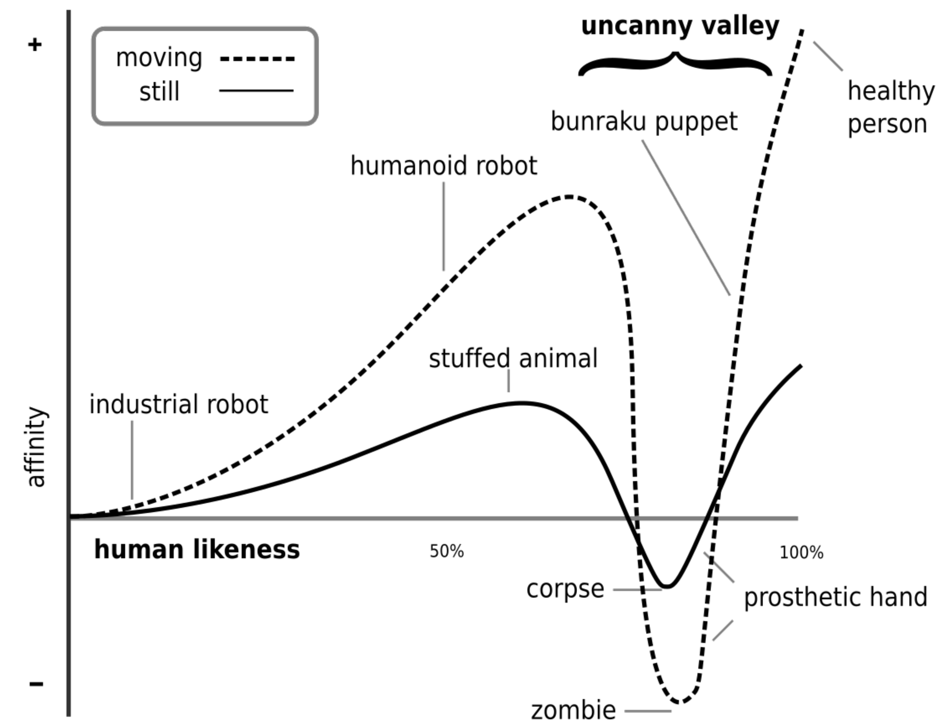
Biological Motion for Gestural Communication by Social Robots

Adedayo Akinade and David Vernon
Carnegie Mellon University Africa, Kigali, Rwanda

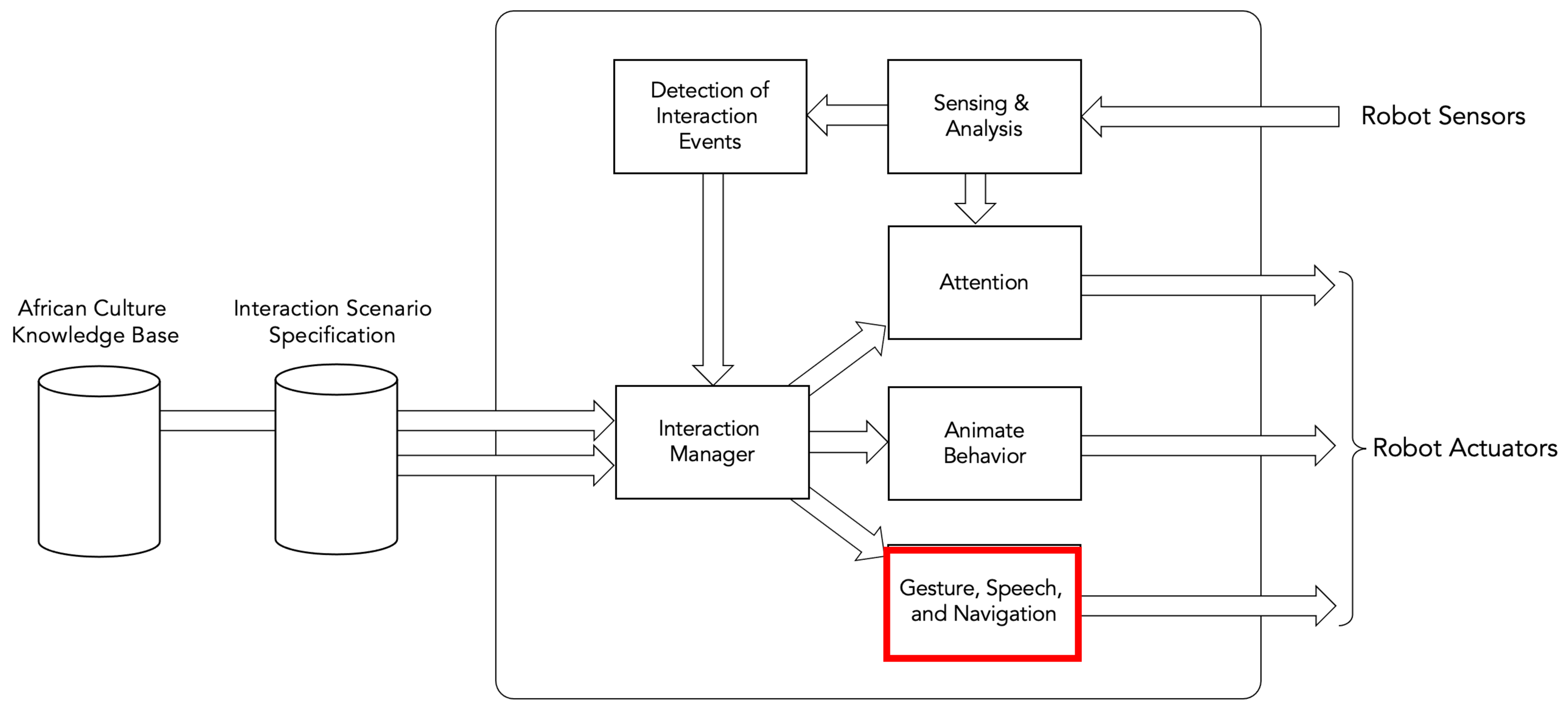
Significance of Biological Motion



Superior Temporal Sulcus activation
(Puce and Perret, 2003)



Uncanny Valley
(Bartneck et al., 2019)



CSSR4Africa System Architecture

Method

Models of Biological Motion

Minimum Jerk
(Chan et al., 2021)

$$\underbrace{CF = \frac{1}{2}\int_{t_1}^{t_2}\left[\left(\frac{d^3x}{dt^3}\right)^2 + \left(\frac{d^3y}{dt^3}\right)^2\right]dt}_{\text{Cost function being minimized}}$$

Two-thirds Power Law
(Viviani and Flash, 1995)

$$V(t) = K(t)\left(\frac{R(t)}{1+\alpha R(t)}\right)^{\beta}$$

Empirical value $\frac{2}{3}$

Velocity Gain Factor (> 0)

Tangential Velocity

Radius of Curvature

Decoupled Minimum-Jerk
(Huber et al., 2009)

$$r_z(t) = \sum_{k=0}^{5} a_{kz} t^k$$

Trajectory in z-direction

$$r_{xy}(t) = \sum_{k=0}^{5} a_{kxy} t^k$$

Trajectory in xy-direction

Trajectory Generation

Form of trajectory that minimizes jerk

$$\theta(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5$$

Boundary conditions

$$\theta(0) = p_s; \quad \dot{\theta}(0); \quad \ddot{\theta}(0) = 0$$

$$\theta(d) = p_f; \quad \dot{\theta}(d); \quad \ddot{\theta}(d) = 0$$

Joint positions

$$\theta(t) = p_s + k\left[10(t/d)^3 - 15(t/d)^4 + 6(t/d)^5\right]$$

Joint velocities

$$\dot{\theta}(t) = \frac{k}{d}\left[30(t/d)^2 - 60(t/d)^3 + 30(t/d)^4\right]$$

Joint accelerations

$$\ddot{\theta}(t) = \frac{k}{d^2}\left[60(t/d) - 180(t/d)^2 + 120(t/d)^3\right]$$

$$0 \le t \le d$$

Results

Impact Assessment

Non-biological (Control) gestures

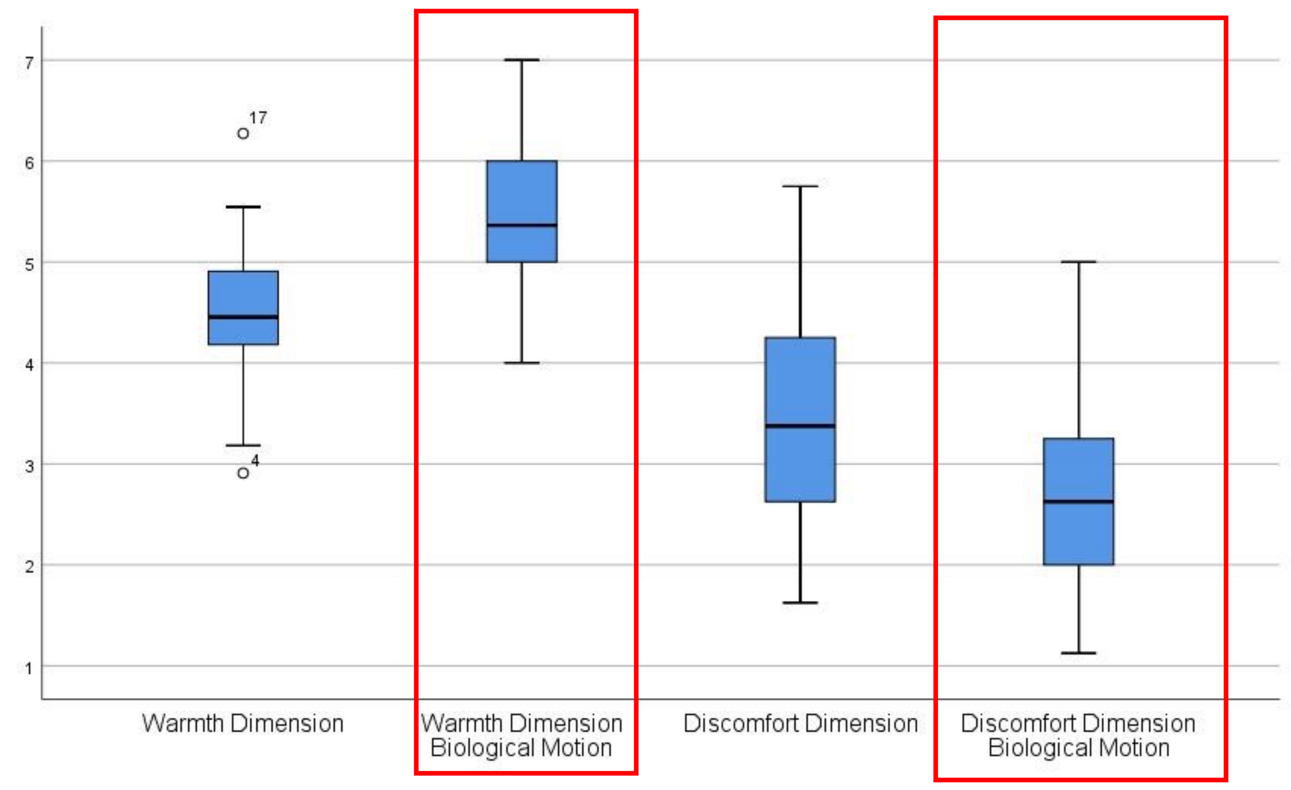
Condition 1

Biological motion profile

Condition 2

Warmth	Discomfort
Organic	Awkward
Sociable	Scary
Emotional	Strange
Compassionate	Awful
Happy	Dangerous
Feeling	Aggressive

RoSAS Assessment Variables
(Carpinella et al., 2017)



References

A. Akinade, Y. Haile, N. Mutangana, C. Tucker, and D. Vernon, “Culturally Competent Social Robots Target Inclusion in Africa”, Science Robotics, 2023.

C. Carpinella, A. Wyman, M. Perez, and S. Stroessner, "The Robotic Social Attributes Scale (RoSAS): Development and Validation", in 12th ACM/IEEE International Conference on Human-Robot Interaction, 2017, pp. 254 – 262.

W. Chan, T. Tran, S. Sheikholeslami, and E. Croft, "An experimental validation and comparison of reaching motion models for unconstrained handovers: towards generating humanlike motions for human-robot handovers", in Proceedings of the 20th IEEE-RAS International Conference on Humanoid Robots, 2020, pp. 356-361.

M. Huber, H. Radrich, C. Wendt, M. Rickert, A. Knoll, T. Brandt, and S. Glasauer, "Evaluation of a novel biologically inspired trajectory generator in human-robot interaction", in 18th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), 2009, pp. 639-644.

C. Bartneck, T. Belpaeme, F. Eyssel, T. Kanda, M. Keijsers, and S. Sabanovic, Human-Robot Interaction: An Introduction, 02 2019.

Puce and D. Perrett, "Electrophysiology and brain imaging of biological motion", in Philosophical Transactions of the Royal Society B: Biological Sciences, 2003, 358(1431), pp. 435 – 445.

P. Viviani, and T. Flash, "Minimum-jerk, two-thirds power law, and isochrony: converging approaches to movement planning", Journal of Experimental Psychology, Human Perception and Performance, 1995, 21(1), pp. 32-53.

This research was carried out in the Culturally Sensitive Social Robotics for Africa project, www.CSSR4Africa.org, as part of the Afretec Network. Afretec is led by Carnegie Mellon University Africa. The network is working in partnership with the Mastercard Foundation.

Carnegie Mellon University Africa