

Classification of User Satisfaction in HRI with Social Signals In-The-Wild

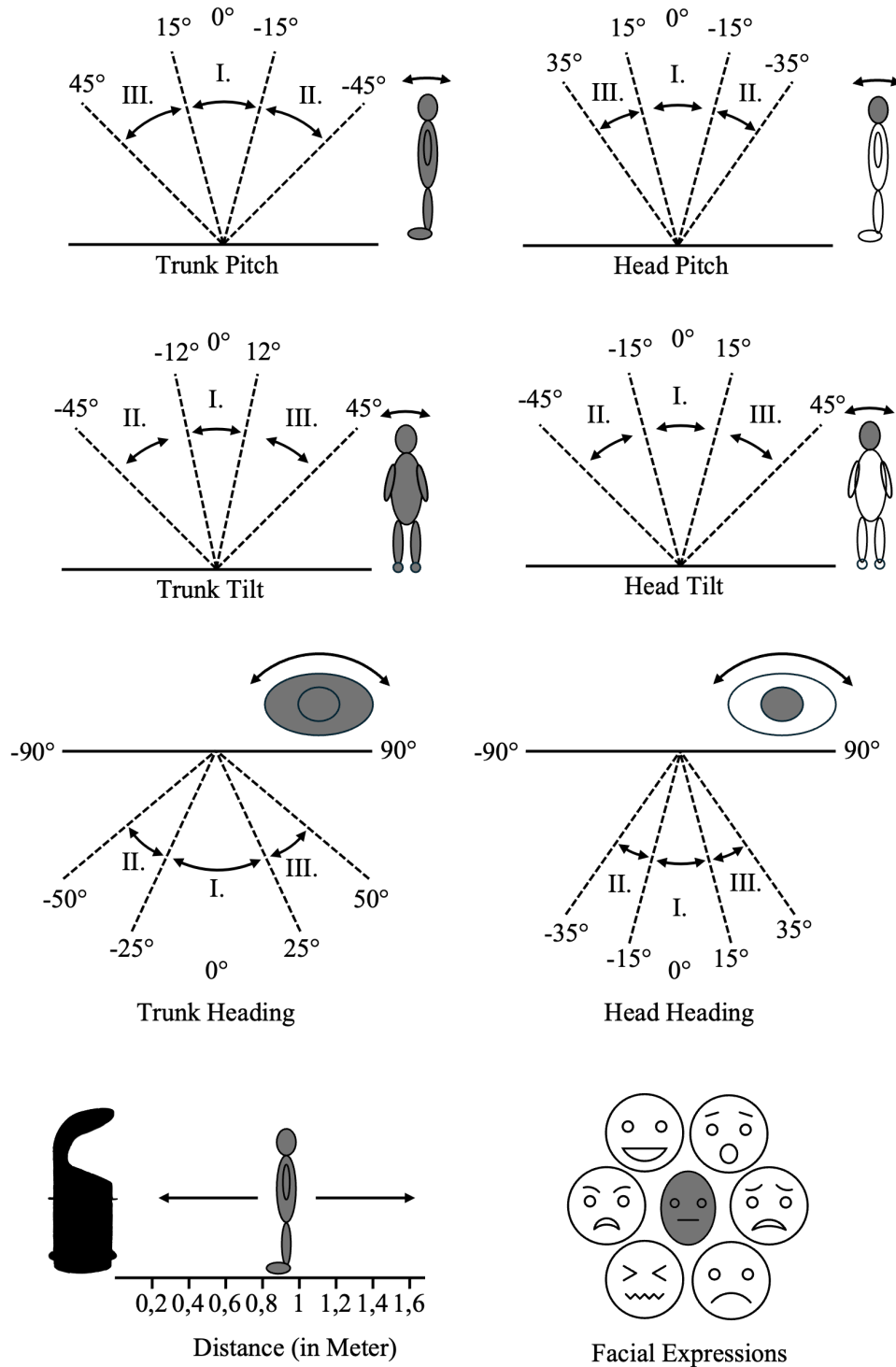
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Appendix A – Figure of the Zones of the Handcrafted Feature Approach



Appendix B – Table of Social Signal Metrics Formulas

All Formulas are derived from the Approach of McColl and Nejat¹ and are reformulated to fit to the body landmarks of MediaPipe.

Feature	Description	Formula
Head's heading	The deviation, by which the head faces away from the robot. Where 0° being the direction of the robot.	$-\frac{\vec{v}_{h1,x}}{ \vec{v}_{h1,x} } \cdot \arccos\left(\frac{\vec{v}_{h1} \cdot -\vec{e}_z}{\ \vec{v}_{h1}\ \cdot \ \vec{e}_z\ }\right) \quad (1)$ <p>\vec{v}_{h1} is the sum of the two normal vectors to the areas enclosed by the eyes' contours after projection into the XZ-Plane.</p>
Head's pitch ⊗ a heading of 0°	The head's attitude relative to the horizon.	$\frac{\vec{v}_{h2,y}}{ \vec{v}_{h2,y} } \cdot \arccos\left(\frac{\vec{v}_{h2} \cdot -\vec{e}_z}{\ \vec{v}_{h2}\ \cdot \ \vec{e}_z\ }\right) \quad (2)$ <p>$\vec{v}_{h2,y}$ is the sum of the two normal vectors to the areas enclosed by the eyes' contours after projection into the YZ-Plane.</p>
Head's tilt ⊗ a heading of 0°	The head's deviation from its upright position along the x-axis.	$-\frac{\vec{v}_{h3,y}}{ \vec{v}_{h3,y} } \cdot \arccos\left(\frac{\vec{v}_{h3} \cdot \vec{e}_x}{\ \vec{v}_{h3}\ \cdot \ \vec{e}_x\ }\right) \quad (3)$ <p>\vec{v}_{h3} is the vector from the inner corner of the right eye to the inner corner of the left eye.</p>
Trunk's heading	The deviation, by which the trunk faces away from the robot. Where 0° being the direction of the robot.	$-\frac{\vec{v}_{t1,x}}{ \vec{v}_{t1,x} } \cdot \arccos\left(\frac{\vec{v}_{t1} \cdot -\vec{e}_z}{\ \vec{v}_{t1}\ \cdot \ \vec{e}_z\ }\right) \quad (4)$ <p>\vec{v}_{t1} is the normal vector of the area enclosed by the trunk's contours after projection into the XZ-Plane.</p>
Trunk's pitch ⊗ a heading of 0°	The trunk's attitude relative to the horizon.	$-\frac{\vec{v}_{t2,z}}{ \vec{v}_{t2,z} } \cdot \arccos\left(\frac{\vec{v}_{t2} \cdot -\vec{e}_y}{\ \vec{v}_{t2}\ \cdot \ \vec{e}_y\ }\right) \quad (5)$ <p>\vec{v}_{t2} is the vector from the middle point between the hips to the middle point between the shoulders after projection into the YZ-Plane.</p>
Trunk's tilt ⊗ a heading of 0°	The trunk's deviation from its upright position along the x-axis	$-\frac{\vec{v}_{t3,x}}{ \vec{v}_{t3,x} } \cdot \arccos\left(\frac{\vec{v}_{t3} \cdot -\vec{e}_y}{\ \vec{v}_{t3}\ \cdot \ \vec{e}_y\ }\right) \quad (6)$ <p>\vec{v}_{t3} is the vector from the middle point between the hips to the middle point between the shoulders after projection into the XY-Plane.</p>
Arms' opening	Average separation between each hand and the center of the trunk	$\frac{1}{2} (\ L_{15} - P_{tc}\ + \ L_{16} - P_{tc}\) \quad (7)$ <p>L_{15} represents the left hand L_{16} represents the right hand P_{tc} represents the center of the trunk</p>
Expansion	Spatial extension of the body in three dimensions	$width = \max_i (L_{i,x}) - \max_j (L_{j,x}) \quad (8)$
		$height = \max_i (L_{i,y}) - \max_j (L_{j,y}) \quad (9)$
		$depth = \max_i (L_{i,z}) - \max_j (L_{j,z}) \quad (10)$
Vertical head's position	Distance along the y-axis from the head's center to the middle point between the shoulders	$P_{hc,y} - P_{sc,y} \quad (11)$ <p>P_{hc} is the point at the center of the head P_{sc} is the point at the center between the shoulders</p>
Sagittal head's position	Distance along the z-axis from the head's center to the middle point between the shoulders	$P_{hc,z} - P_{sc,z} \quad (12)$ <p>P_{hc} is the point at the center of the head & P_{sc} is the point at the center between the shoulders</p>
Vertical body motion	Average movement of the body along the y-axis	$\frac{1}{S} \sum_{i=1}^S (L_{i,y,n} - L_{i,y,n-1}) \quad (13)$ <p>S is the number of landmarks that make up a pose. n denotes the current frame. $n - 1$ denotes the previous frame.</p>
Sagittal body position	Average movement of the body along the z-axis	$\frac{1}{S} \sum_{i=1}^S (L_{i,z,n} - L_{i,z,n-1}) \quad (14)$ <p>S is the number of landmarks that make up a pose. n denotes the current frame. $n - 1$ denotes the previous frame.</p>
Body speed	Body's motion velocity	$\frac{1}{S} \sum_{i=1}^S \left(\frac{\ L_{i,n} - L_{i,n-1}\ }{t_n - t_{n-1}} \right) \quad (15)$ <p>S is the number of landmarks that make up a pose. n denotes the current frame. $n - 1$ denotes the previous frame.</p>

¹ D. McColl und G. Nejat, „Determining the affective body language of older adults during socially assistive HRI“, in *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Chicago, IL, USA: IEEE, Sep. 2014, S. 2633–2638. doi: [10.1109/IROS.2014.6942922](https://doi.org/10.1109/IROS.2014.6942922).

Appendix C – Top Ten Features tsfresh Approach

Feature	Score	P-Value
MainPhase_distance__fft_coefficient__attr_"real"__coeff_51	12,54	0,000955
MainPhase_fe_fear__fft_coefficient__attr_"angle"__coeff_42	17,05	0,000160
MainPhase_width__fft_coefficient__attr_"angle"__coeff_87	15,24	0,000321
MainPhase_head_heading__fft_coefficient__attr_"imag"__coeff_49	14,15	0,000495
MainPhase_vertical_motion__fft_coefficient__attr_"angle"__coeff_51	14,02	0,000522
MainPhase_vertical_head_position__fft_coefficient__attr_"angle"__coeff_4	12,64	0,000917
MainPhase_head_tilt__fft_coefficient__attr_"imag"__coeff_41	14,08	0,000509
MainPhase_distance__fft_coefficient__attr_"real"__coeff_98	12,02	0,001187
MainPhase_fe_surprise__fft_coefficient__attr_"imag"__coeff_35	11,91	0,001243
MainPhase_head_pitch__fft_coefficient__attr_"real"__coeff_95	11,88	0,001258

Appendix D – Top Ten Features catch22 Approach

Feature	Score	P-Value
MainPhase_trunk_tilt_SC_FluctAnal_2_dfa_50_1_2_logi_prop_r1	4,88	0,032472
MainPhase_head_heading_DN_OutlierInclude_p_001_mdrmd	4,59	0,037711
MainPhase_vertical_motion_CO_trev_1_num	4,61	0,037406
MainPhase_width_SB_BinaryStats_diff_longstretch0	5,14	0,028285
MainPhase_height_DN_HistogramMode_10	6,39	0,015111
MainPhase_depth_PD_PeriodicityWang_th0_01	5,17	0,027976
MainPhase_distance_CO_HistogramAMI_even_2_5	5,07	0,029397
MainPhase_distance_SP_Summaries_welch_rect_area_5_1	6,21	0,016523
MainPhase_fe_disgust_SC_FluctAnal_2_rsrangefit_50_1_logi_prop_r1	5,75	0,020762
MainPhase_fe_happiness_DN_OutlierInclude_p_001_mdrmd	5,66	0,021708

Appendix E – Top Ten Features hc features Approach

Feature	Score	P-Value
MainPhase_trunk_heading_Wndw2_Freq_of_Zone_5	5,76	0,020689
MainPhase_trunk_pitch_longest_Period_of_Zone_2	3,93	0,053571
MainPhase_trunk_pitch_shortest_Period_of_Zone_2	4,56	0,038294
MainPhase_head_heading_Wndw1_Freq_of_Zone_5	5,81	0,020201
MainPhase_body_speed_CountZoneChanges	3,80	0,057607
MainPhase_body_speed_shortest_Period_of_Zone_10	4,56	0,038294
MainPhase_body_speed_Wndw1_Freq_of_Zone_8	4,42	0,041328
MainPhase_distance_Wndw5_Freq_of_Zone_3	5,66	0,021801
MainPhase_fe_disgust_Wndw1_Freq_of_Zone_2	4,00	0,051694
MainPhase_fe_neutral_CountZoneChanges	8,96	0,004507