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

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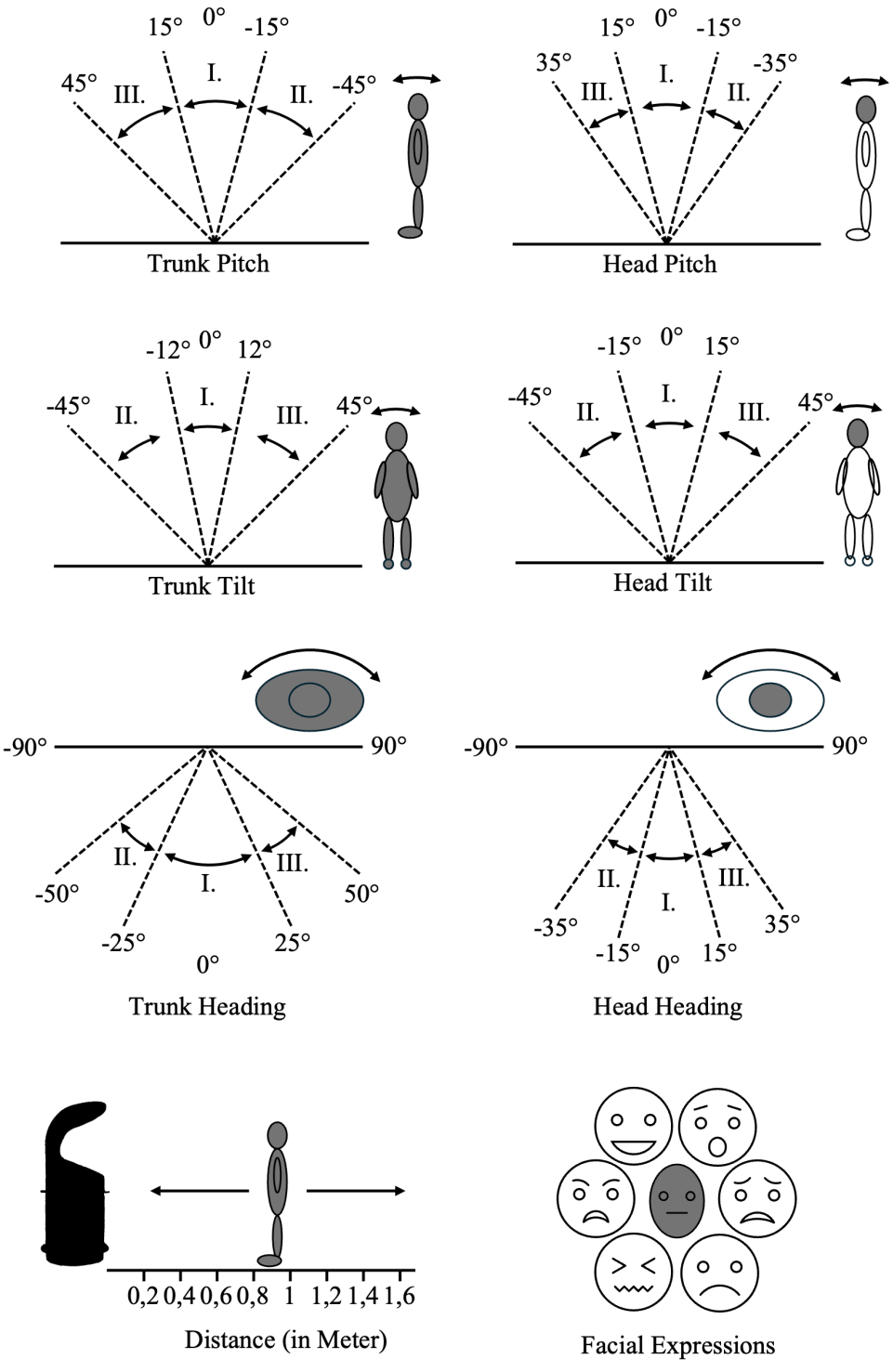
Appendix A – Figure of the Zones of the Handcrafted Feature Approach



Facial Expression Zones: 0 – 0.5 / 0.5 – 0.75 / 0.75 – 1.0 Confidence

Appendix B – Table of Social Signal Metrics Formulas

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

[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.

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__f ft_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