Design and Motion Capabilities of an Emotion-Expressive Robot EmoSan

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Content

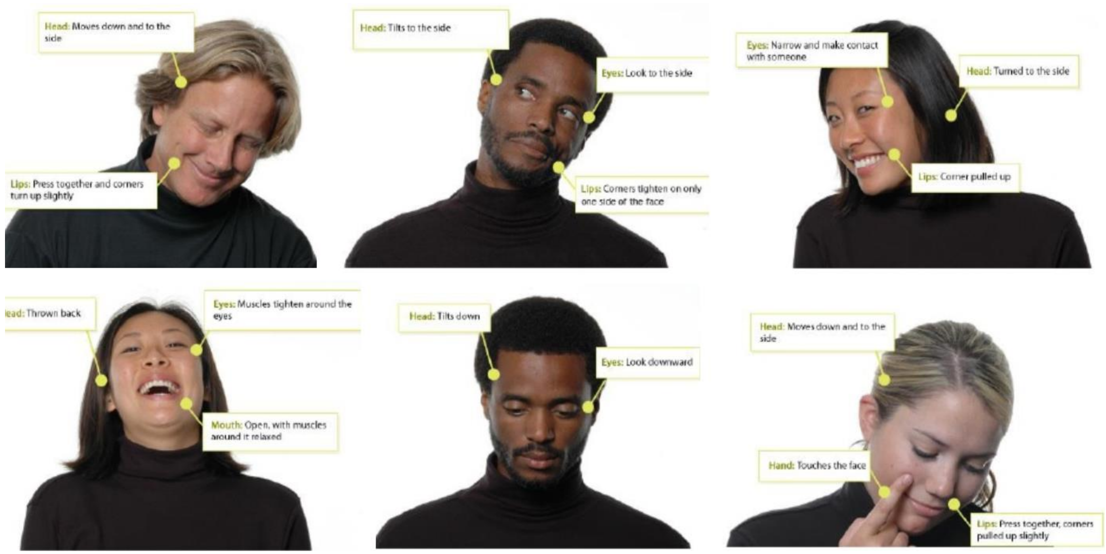
- Purpose of the Project;
- Emotional Expressive Robots;
- Working Space of the Human Head – Comparison;
- Mechanical Design;
- Kinematics Model;
- Capability of the Robot to Reproduce the Movements of the Human Head;
- Workspace of the Robot;
- Electrical Circuit;
- Conclusions;
- Plans for Future Development;

EmoSan – Goals and Motivation

https://asknao.aldebaran.com/press/robot-aids-in-therapy-for-autistic-children

- a new emotion-expressive robot;
- emotional reactions represented in the head motion;
- based on the Gough-Stewart platform.

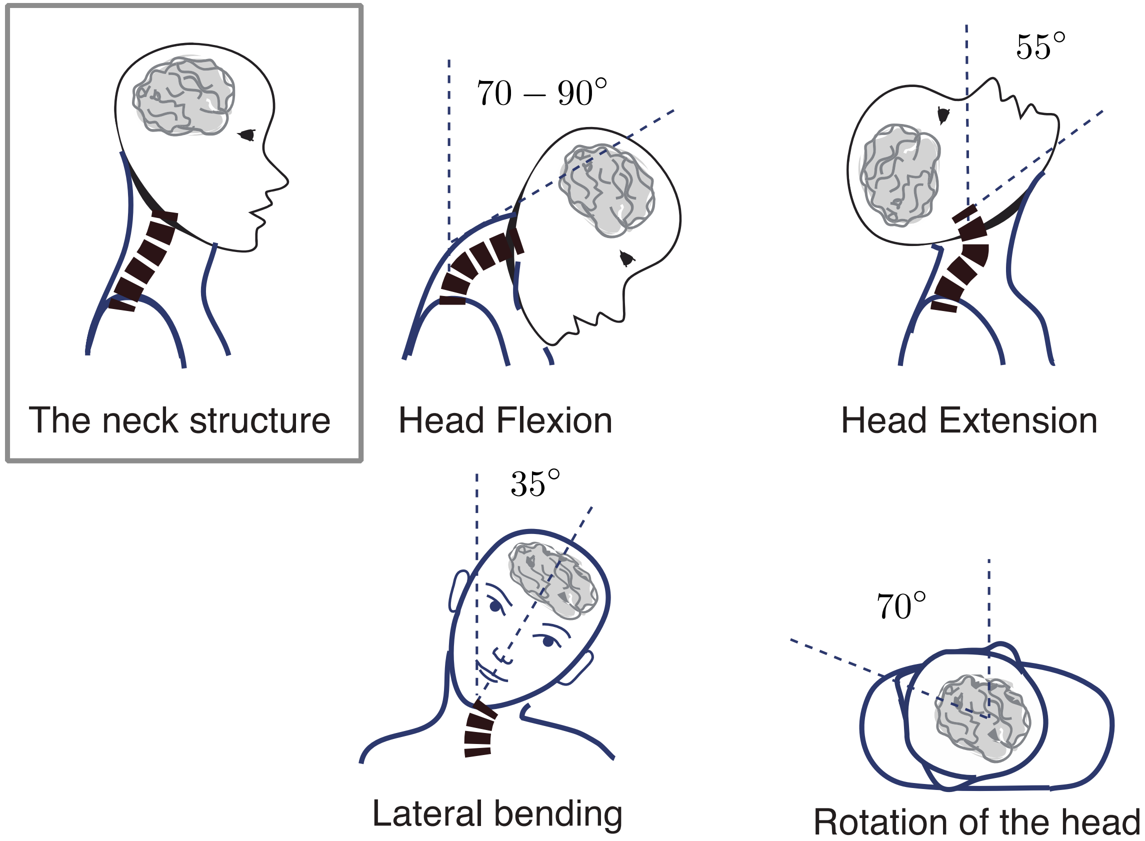
How the Emotions Could be Expressed?



By movements of the head

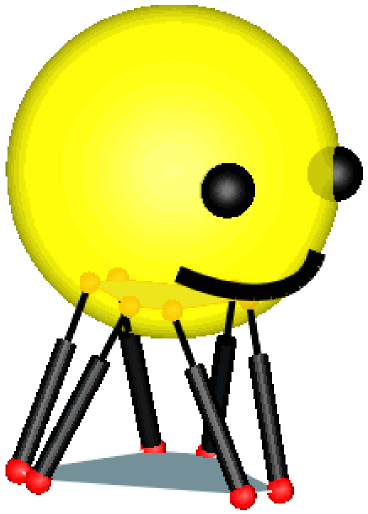
By facial expressions

Human head movement achievability



Allowable angles of movement and working space of the head

The Robot Design (1)



A computer simulation model of the robot`s movements

Why Using Gough-Stewart platform?

- Advantages:

✓Compact;

✓Easy for Control;

✓Well Defined Kinematics Theory;

✓Representing 6 DOF.

- Disadvantages:

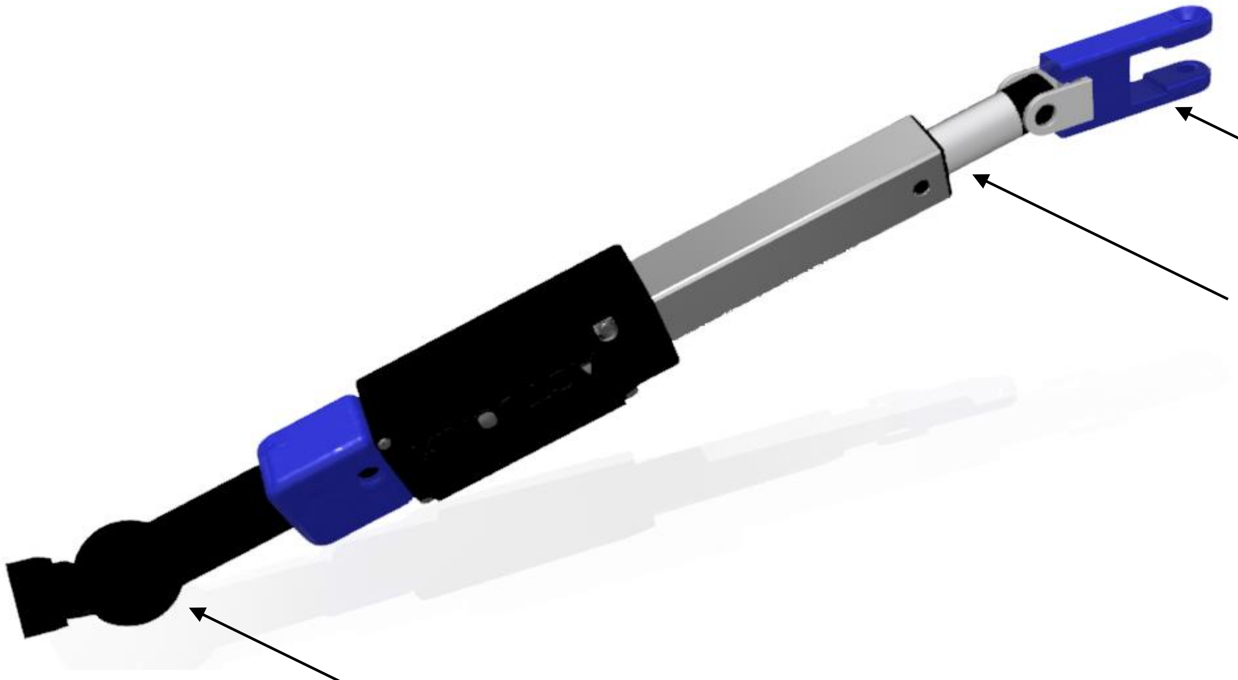
➢ Difficult for Manufacturing;

➢ Need of Combining Rotations and Translations;

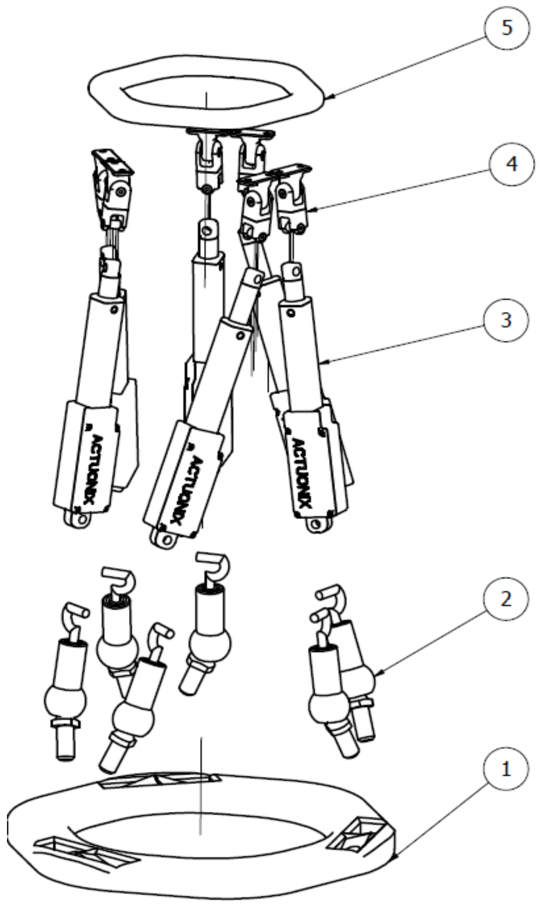
➢ Noise from the Linear Actuators.

The Robot Design (2)

- six identical legs;
- each one having SPU;
- driven prismatic joints;
- 6 DOF.

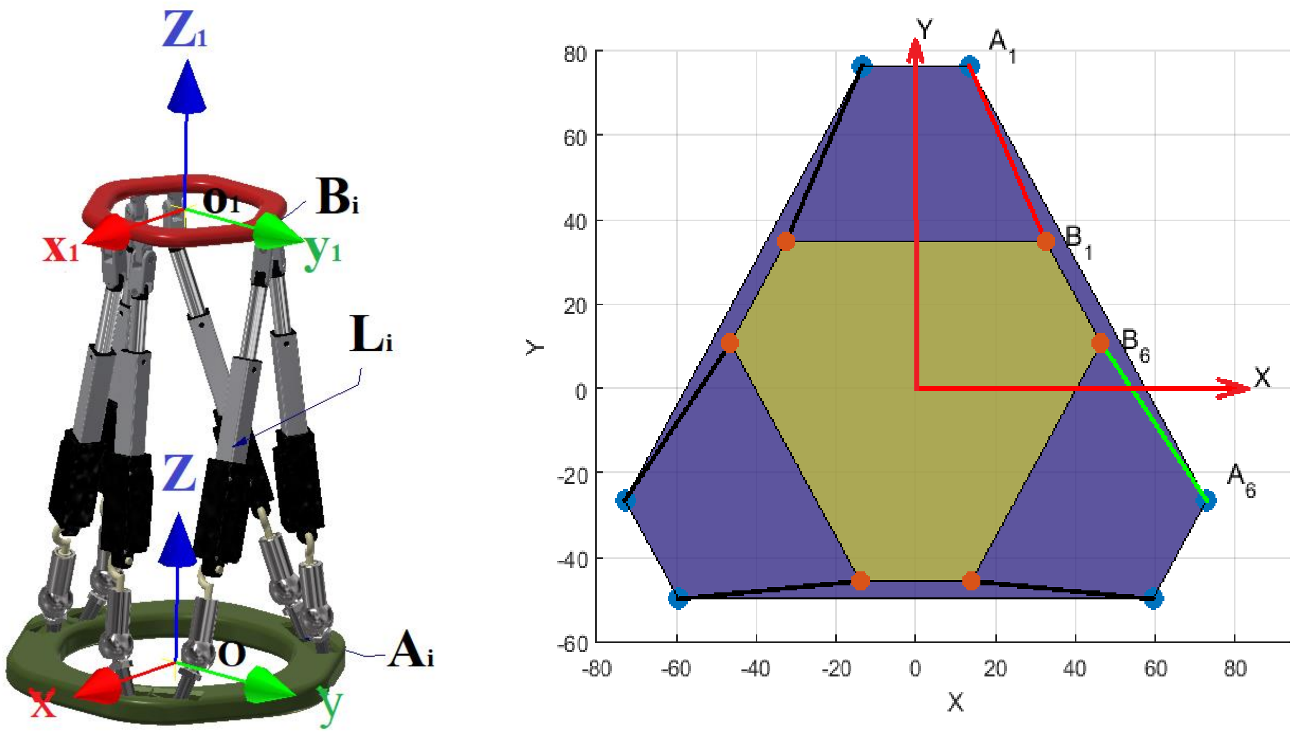


The Robot Design (3)



The robot we have designed consists of the following parts as shown in figure: 1-Bottom platform; 2-Ball joint; 3-Linear actuator; 4-Universal joint; 5-Top platform. Our design consists of six linear actuators (linear motors) with maximum stroke of 50 mm, six ball joints and some 3D printed components as follows: the six universal joints, the top platform and the bottom platform,

Kinematics Model (1)



The arrangement of the coordinate systems

Kinematics Model (2)

The joints A_i and B_i have the following coordinates, given in the OXYZ and $O_1X_1Y_1Z_1$ coordinate systems, respectively:

OXYZ	X	Y	Z
OA_1	13.5	76.4	0
OA_2	-13.5	76.4	0
OA_3	-72.9	-26.5	0
OA_4	-59.4	49.88	0
OA_5	59.4	-49.88	0
OA_6	72.9	-26.5	0

$O_1X_1Y_1Z_1$	X_1	Y_1	Z_1
OB_1	32.53	34.9	0
OB_2	-32.53	34.9	0
OB_3	-46.48	10.72	0
OB_4	-13.96	-45.62	0
OB_5	13.96	-45.62	0
OB_6	46.48	10.72	0

Kinematics Model (3)

The rotation of the moving platform is given by three rotations around the coordinate axes, which are represented by the matrices R_x, R_y and R_z.

$$\mathbf{R}_x = \begin{bmatrix} \cos(\alpha) & -\sin(\alpha) & 0 \\ \sin(\alpha) & \cos(\alpha) & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (1)$$

$$\mathbf{R}_y = \begin{bmatrix} \cos(\beta) & 0 & \sin(\beta) \\ 0 & 1 & 0 \\ -\sin(\beta) & 0 & \cos(\beta) \end{bmatrix} \quad (2)$$

$$\mathbf{R}_z = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\gamma) & \sin(\gamma) \\ 0 & -\sin(\gamma) & \cos(\gamma) \end{bmatrix} \quad (3)$$

Kinematics Model (4)

Then, the matrix describing the rotation of the moving platform around the reference coordinate frame can be written as:

$$\mathbf{R} = \mathbf{R}_z \mathbf{R}_y \mathbf{R}_x \quad (4)$$

The coordinates of the points B_i (i=1..6) can be written with respect to the reference coordinate system OXYZ as:

$$\mathbf{OB}_i = \mathbf{R} \cdot \mathbf{O}_1\mathbf{B}_i + \mathbf{P}, \quad (i = 1..6) \quad (5)$$

where: $\mathbf{P} \equiv \mathbf{OO}_1 = \left[\mathrm{P_x}, \mathrm{P_y}, \mathrm{P_z} \right]^{\mathrm{T}}$ is a position vector of a point O_1 from the moving platform.

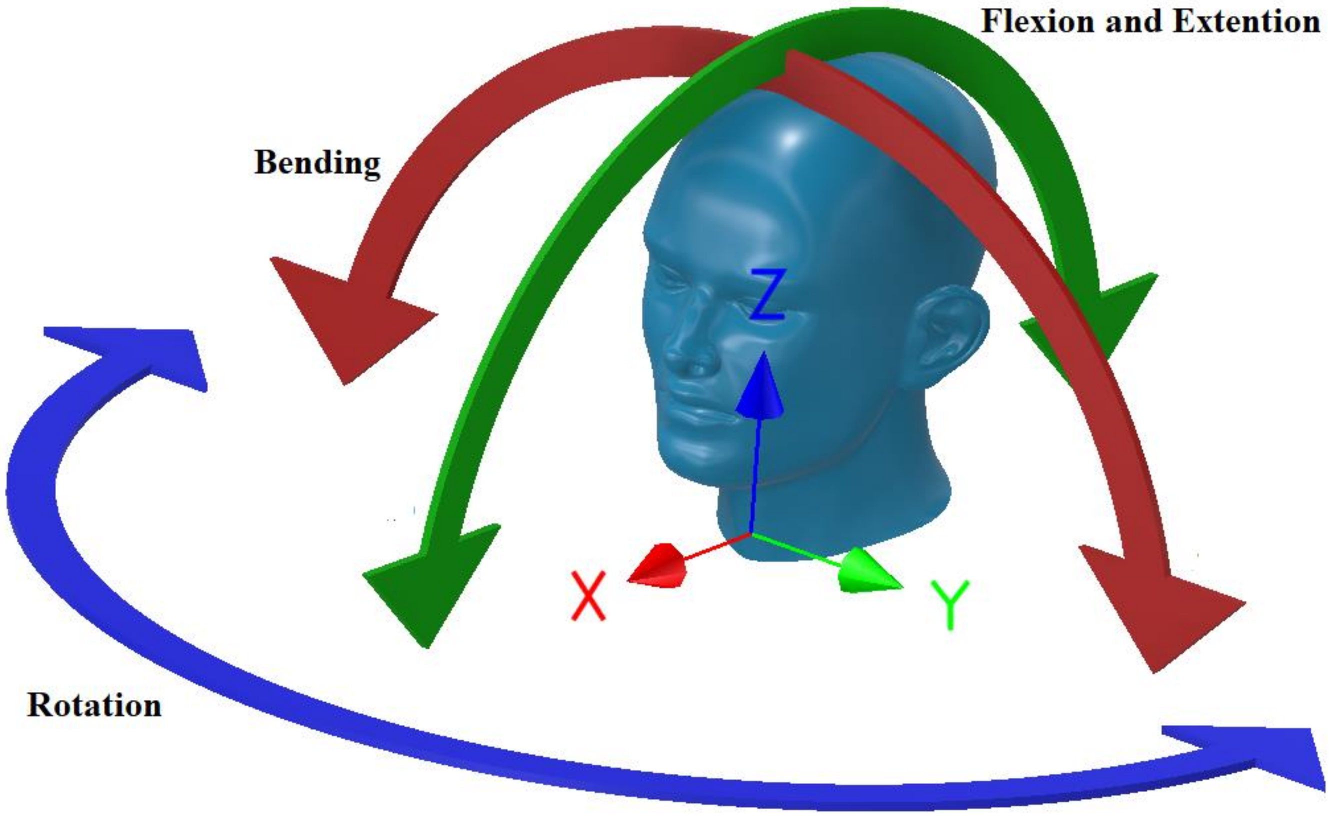
Then the leg lengths can be obtained as:

$$L_i = \left\| \mathbf{OB}_i - \mathbf{OA}_i \right\|, \quad (i = 1..6) \quad (6)$$

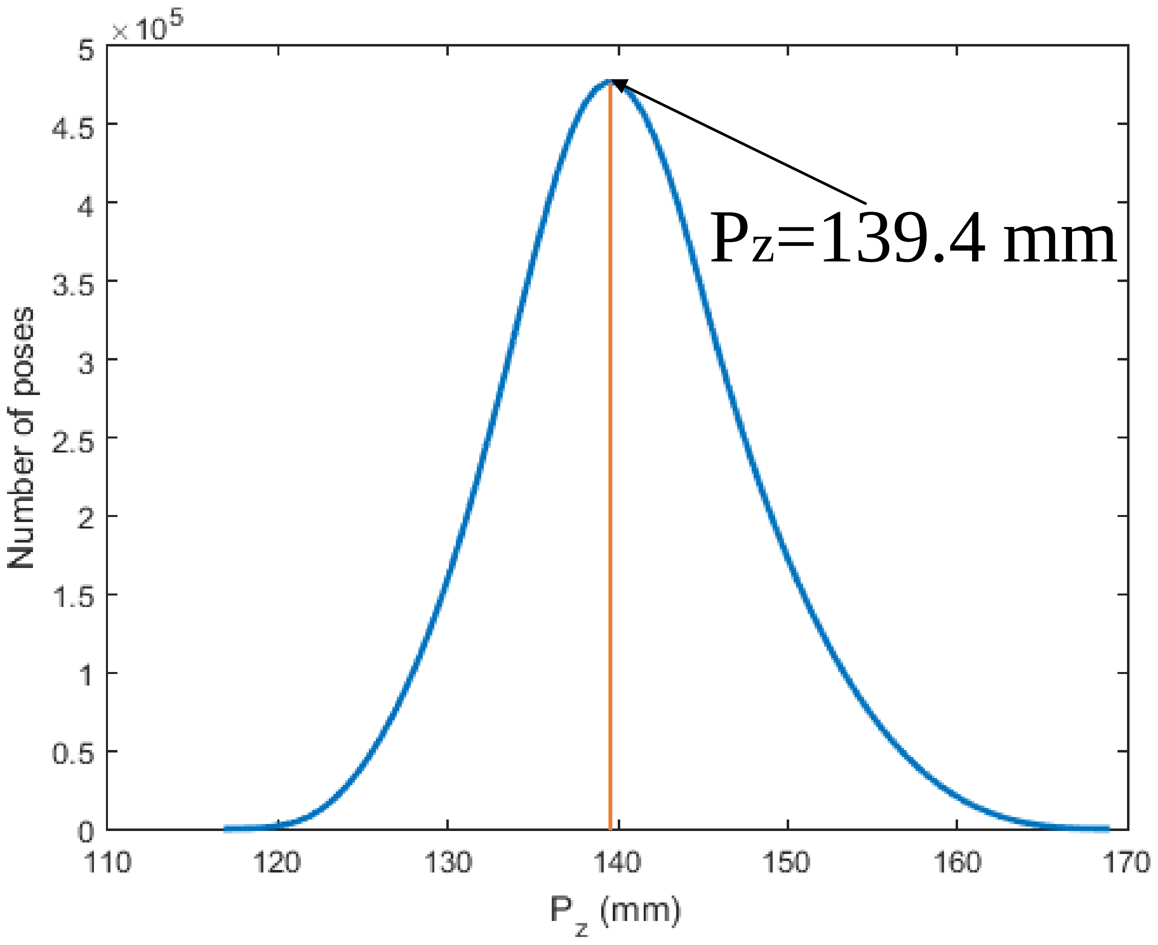
Capability of the Robot to Reproduce the Movements of the Human Head

Flexion	**70° ÷ 90°**
Extension	**55°**
Bending	**±35°**
Rotation	**±70°**

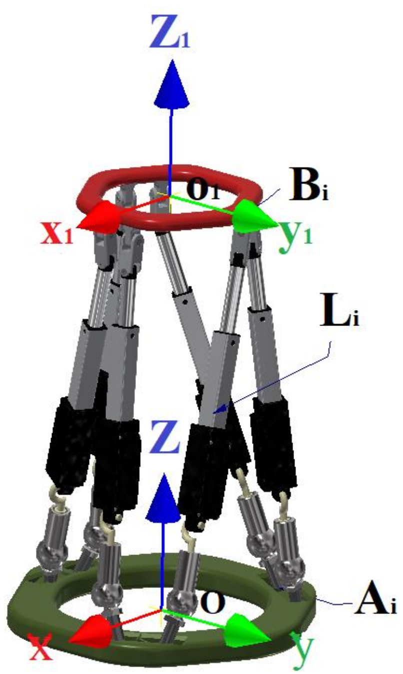
Average Values of the Human Head Capability



Rotation Workspace of the Robot (1)

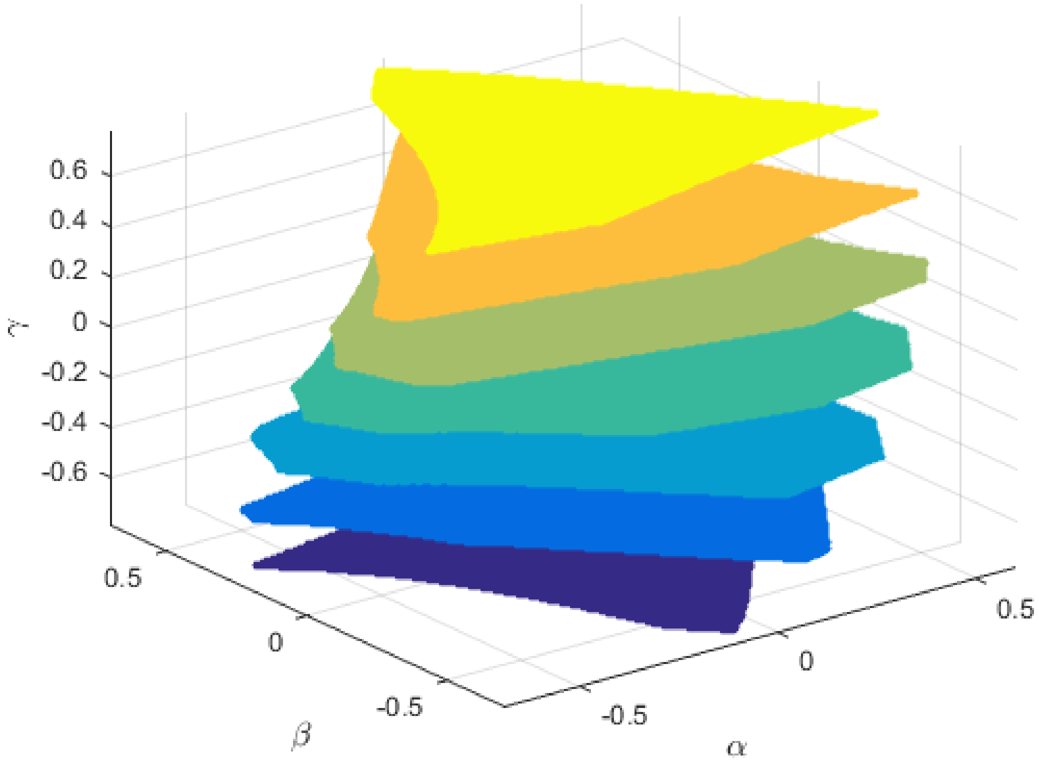


Variation of the range of orientations with respect to the vertical distance P_z



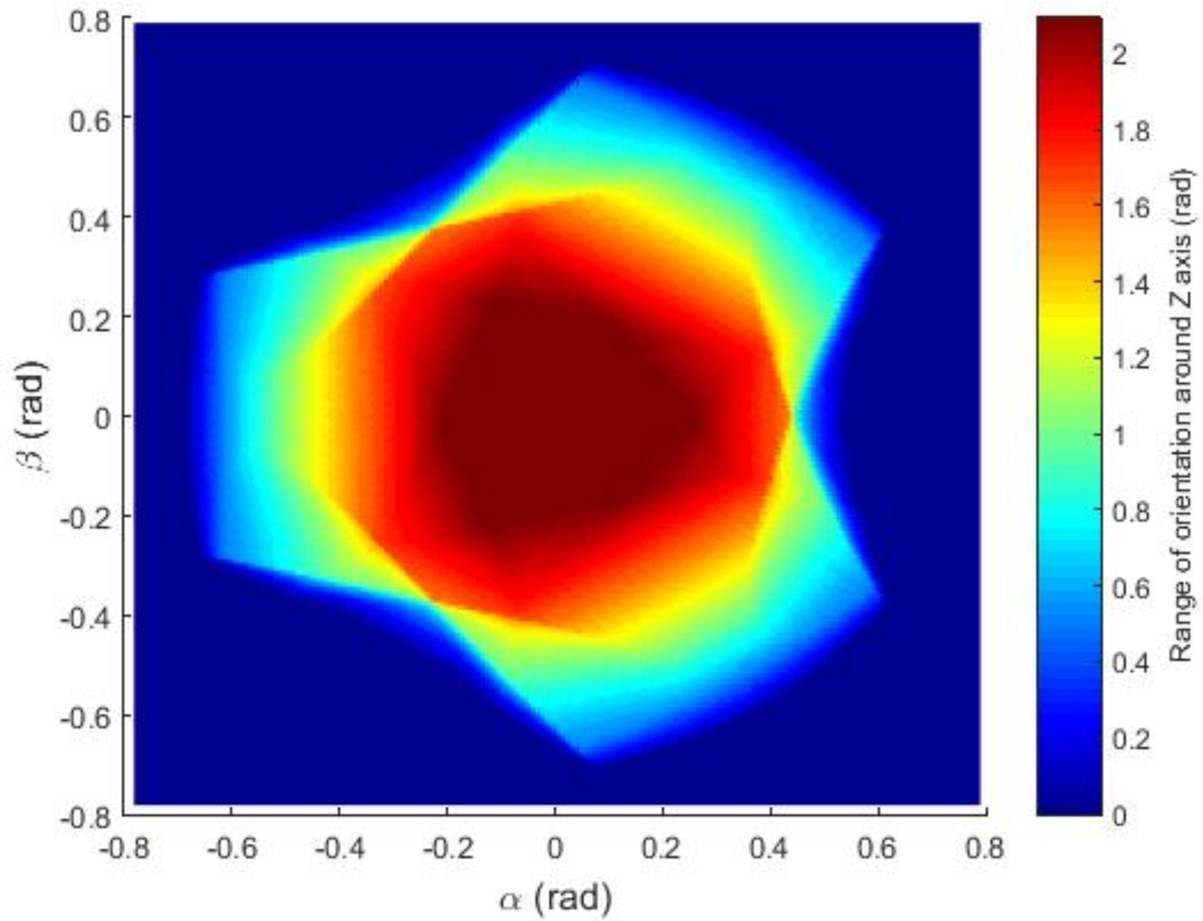
The volume of orientations is represented by the number of poses.

Rotation Workspace of the Robot (2)



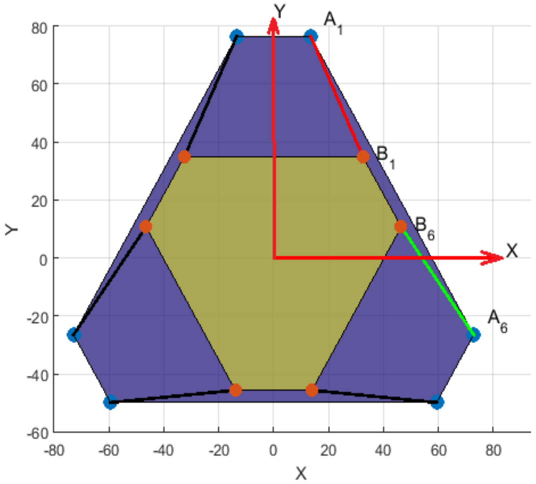
Slices of the orientation workspace in case of fixed position of the moving platform (P=[0, 0, 139.4]).

Rotation Workspace of the Robot (3)

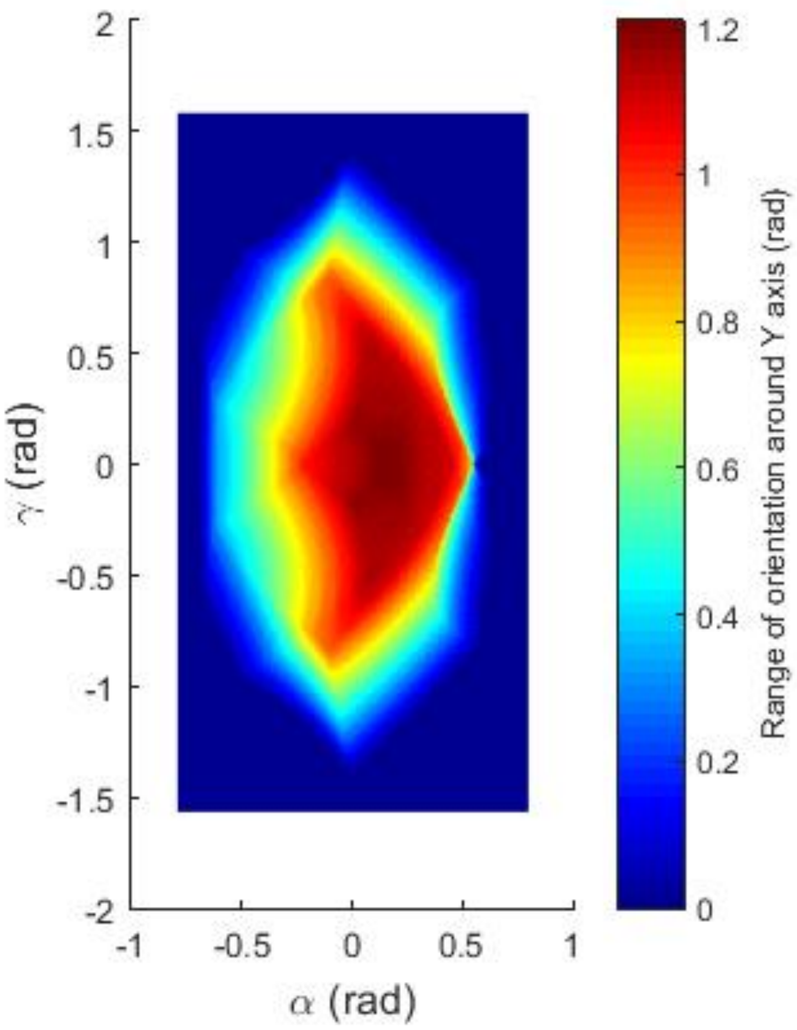


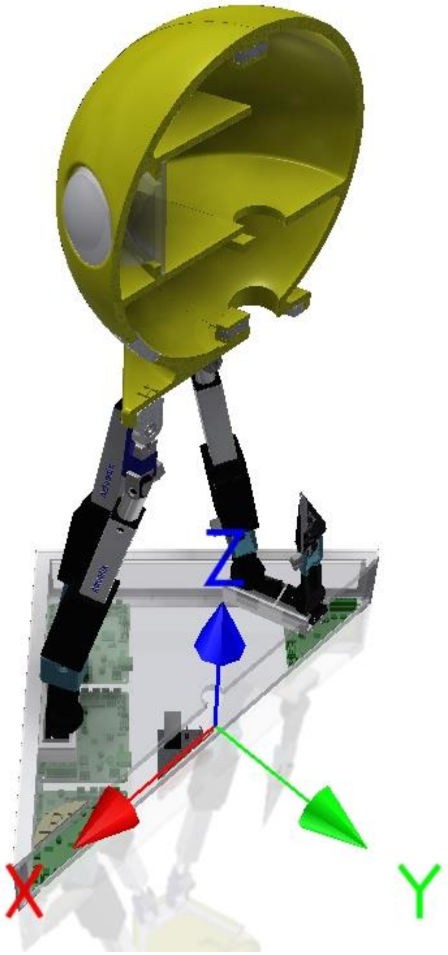
Ranges of the orientation around the Z axis versus the other two angles of orientation.

The value obtained for the maximal range of orientations around the Z-axis is 2.79 rad (for α=0 and β=0).



Rotation Workspace of the Robot (4)

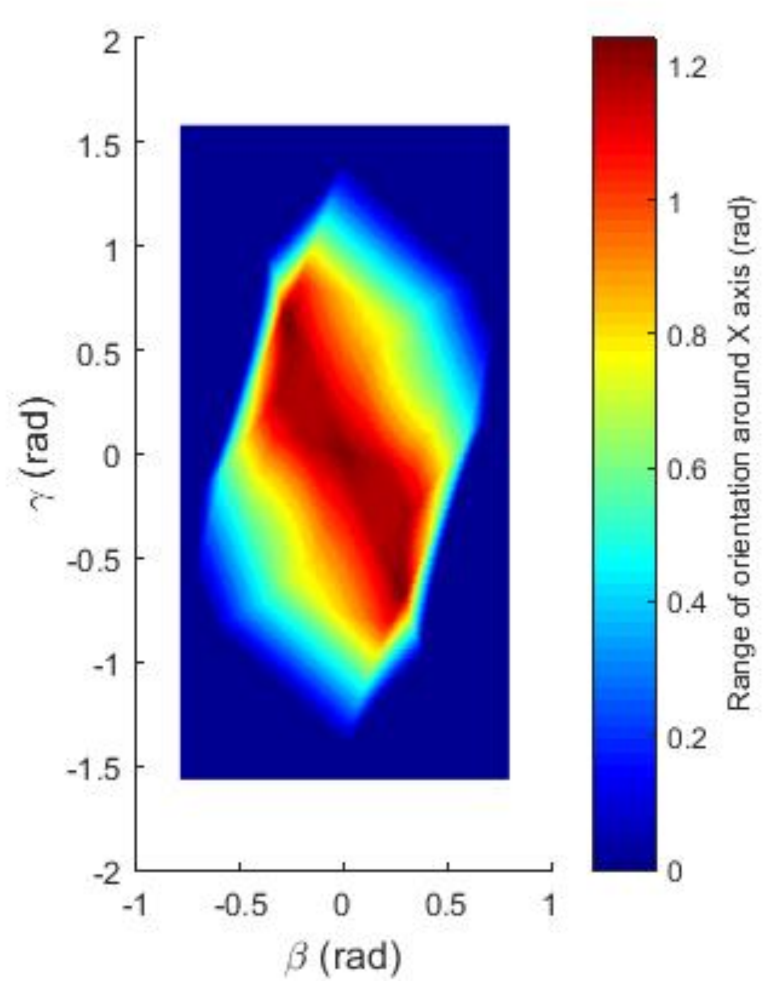


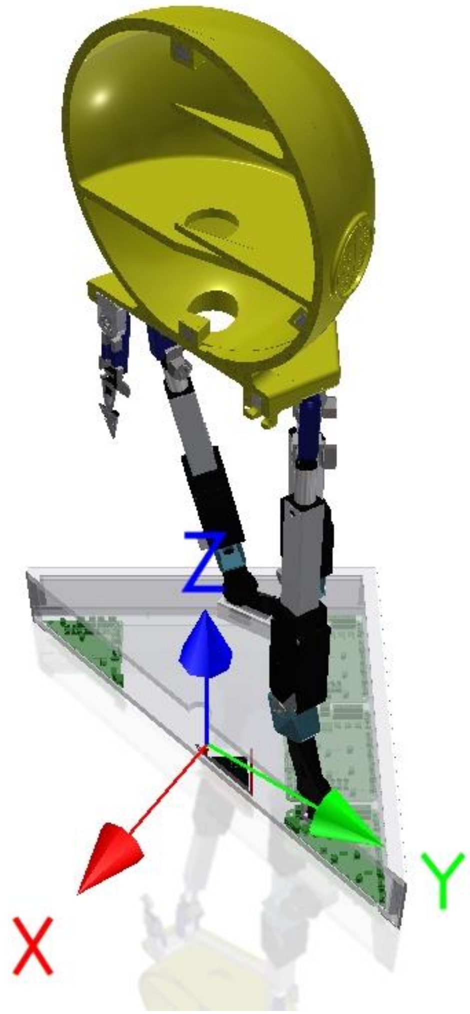


Ranges of the orientation around the Y axis versus the other two angles of orientation.

In this case, the value obtained for the maximal range of orientations around the Y-axis is 1.131 rad (for α=0 and γ =0).

Rotation Workspace of the Robot (5)





Ranges of the orientation around the X axis versus the other two angles of orientation.

Here, the value obtained for the maximal range of orientations around the X-axis is 1.226 rad (for $\beta=0$ and $\gamma=0$).

Comparison between Human Head Movements and EmoSan

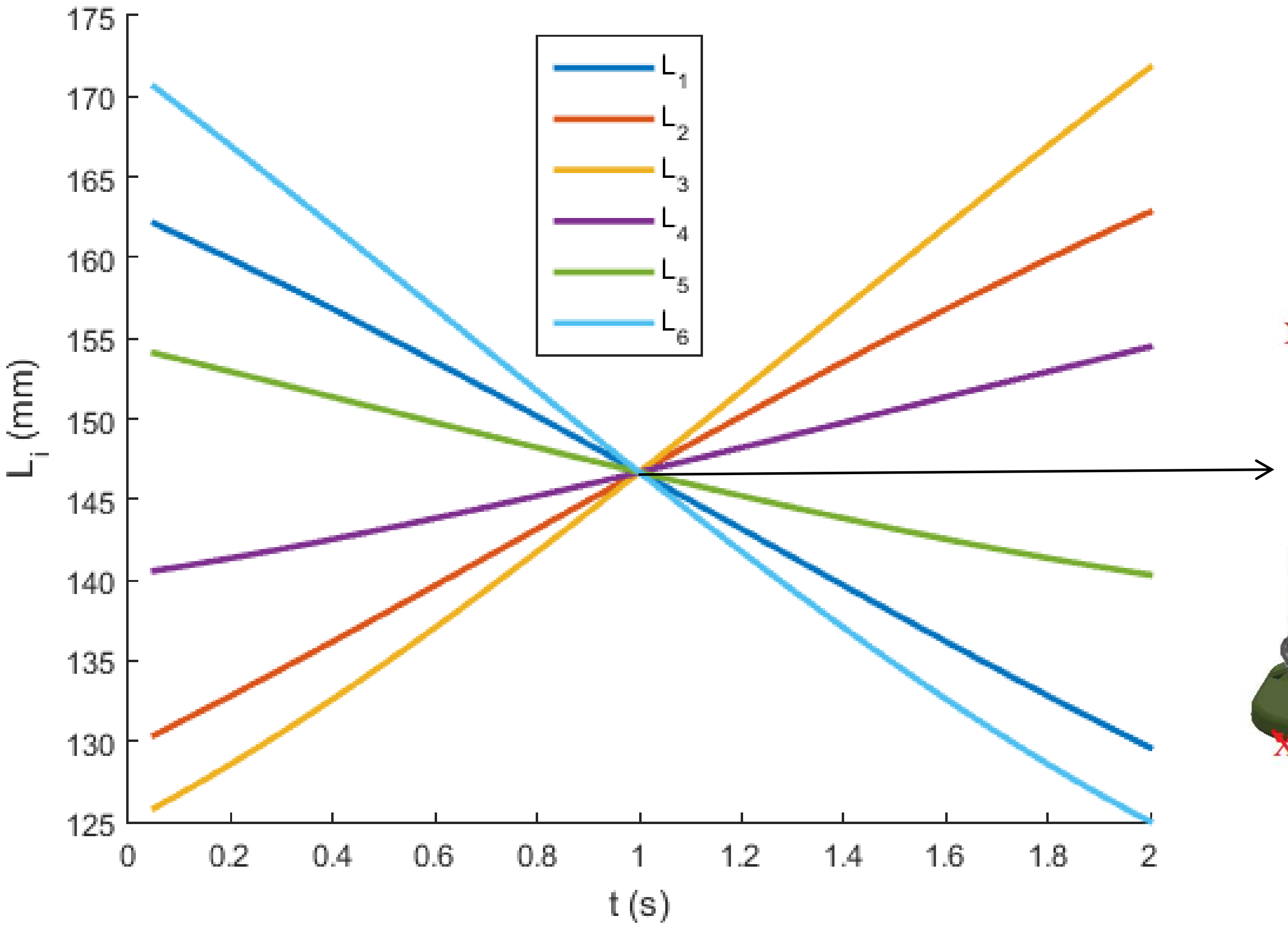
Flexion	**70° ÷ 90°**
Extension	**55°**
Bending	**±35°**
Rotation	**±70°**

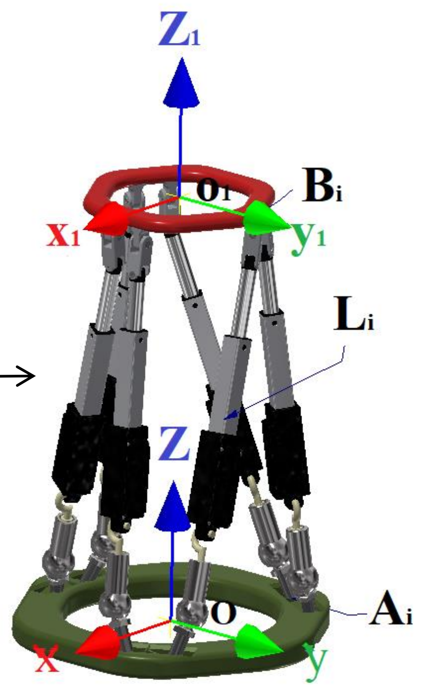
Average Values of the Human Head Capability

Flexion	**39.4°**
Extension	**30.9°**
Bending	**±32.4°**
Rotation	**±80°**

Robot Representation of the Human Head Movements

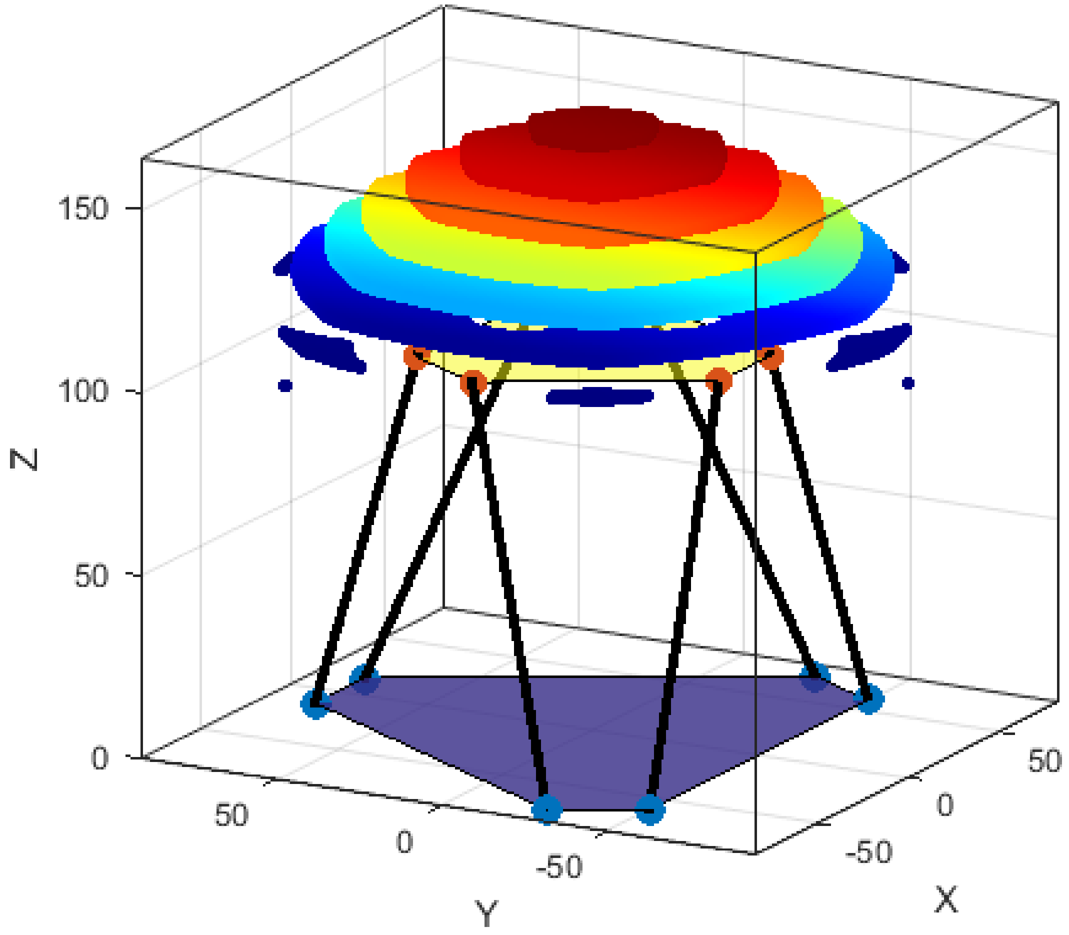
Rotation Workspace of the Robot (6)





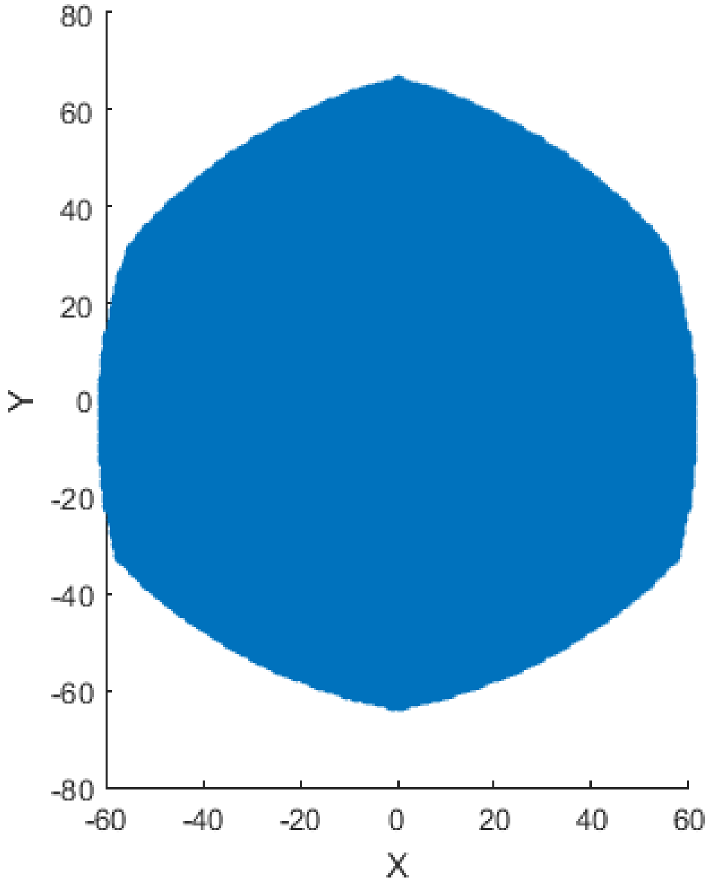
The variation of the leg length in case of rotation around the Y axis from the minimal to maximum values for angle β ([-0.5655 to +0.5655 rad]).

Translation Workspace of the Robot (1)



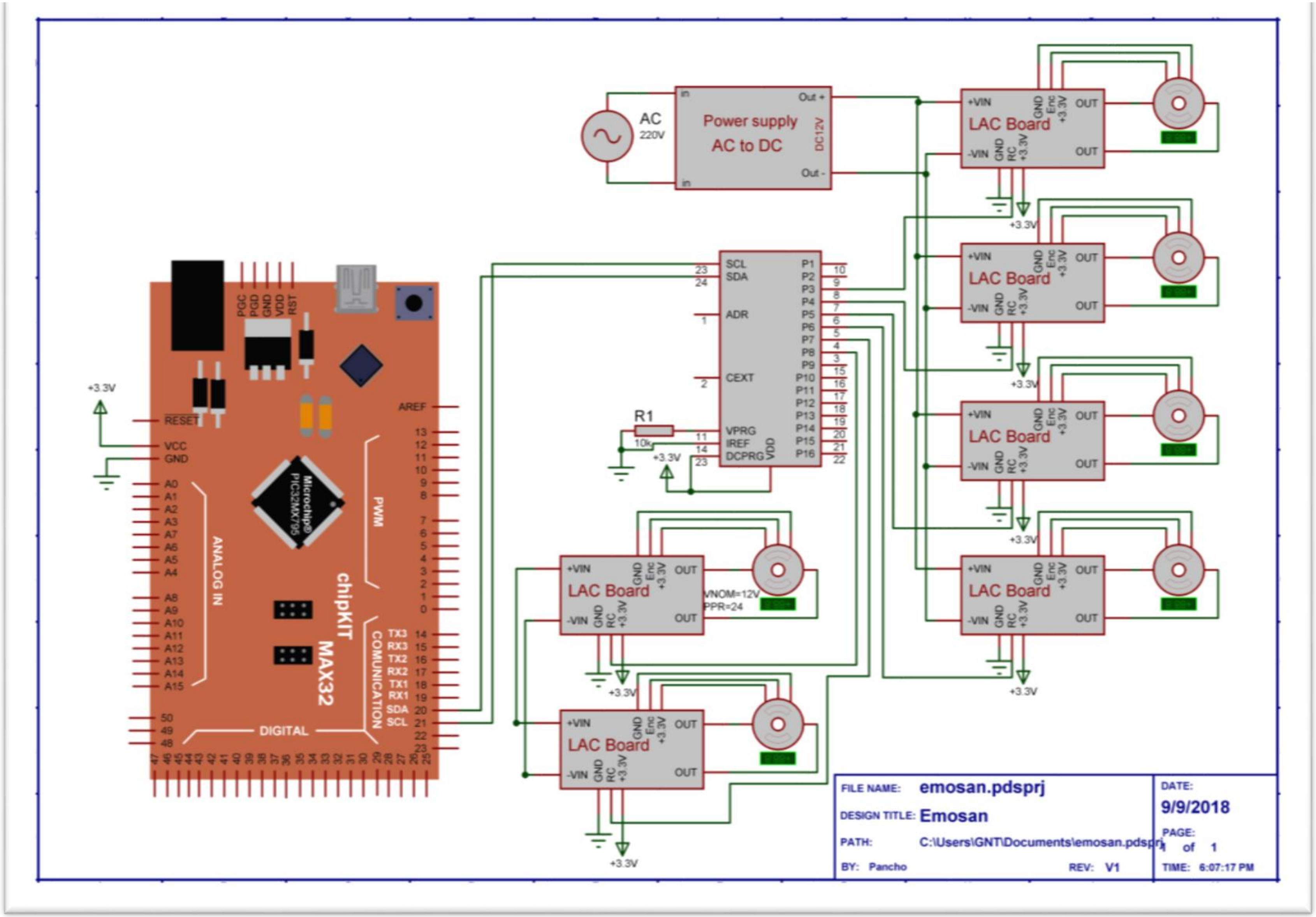
Slices of the translation workspace with constant orientation (α=0, β=0 and γ=0).

Translation Workspace of the Robot (2)

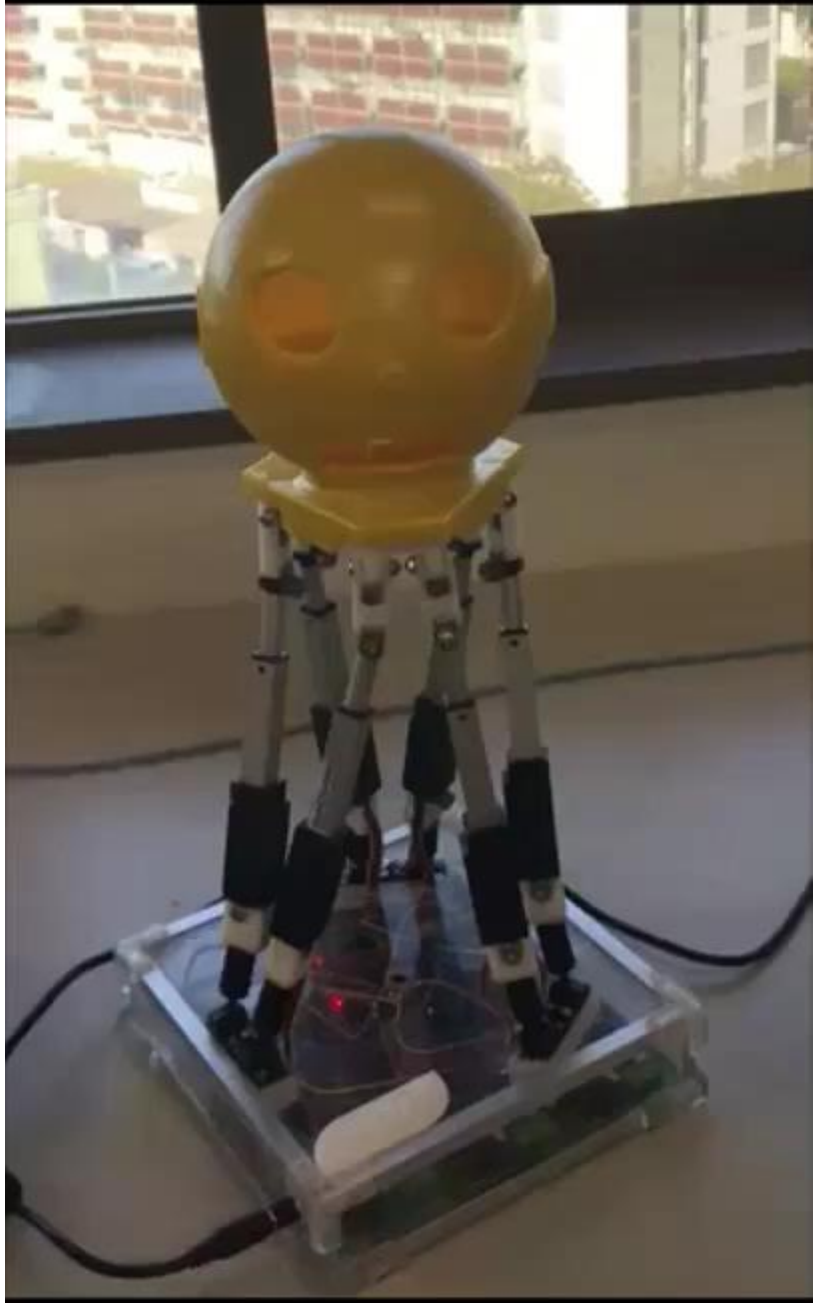


The position workspace for Pz=139.4 mm and a fixed orientation (α=0, β=0 and γ=0).

Electrical Circuit



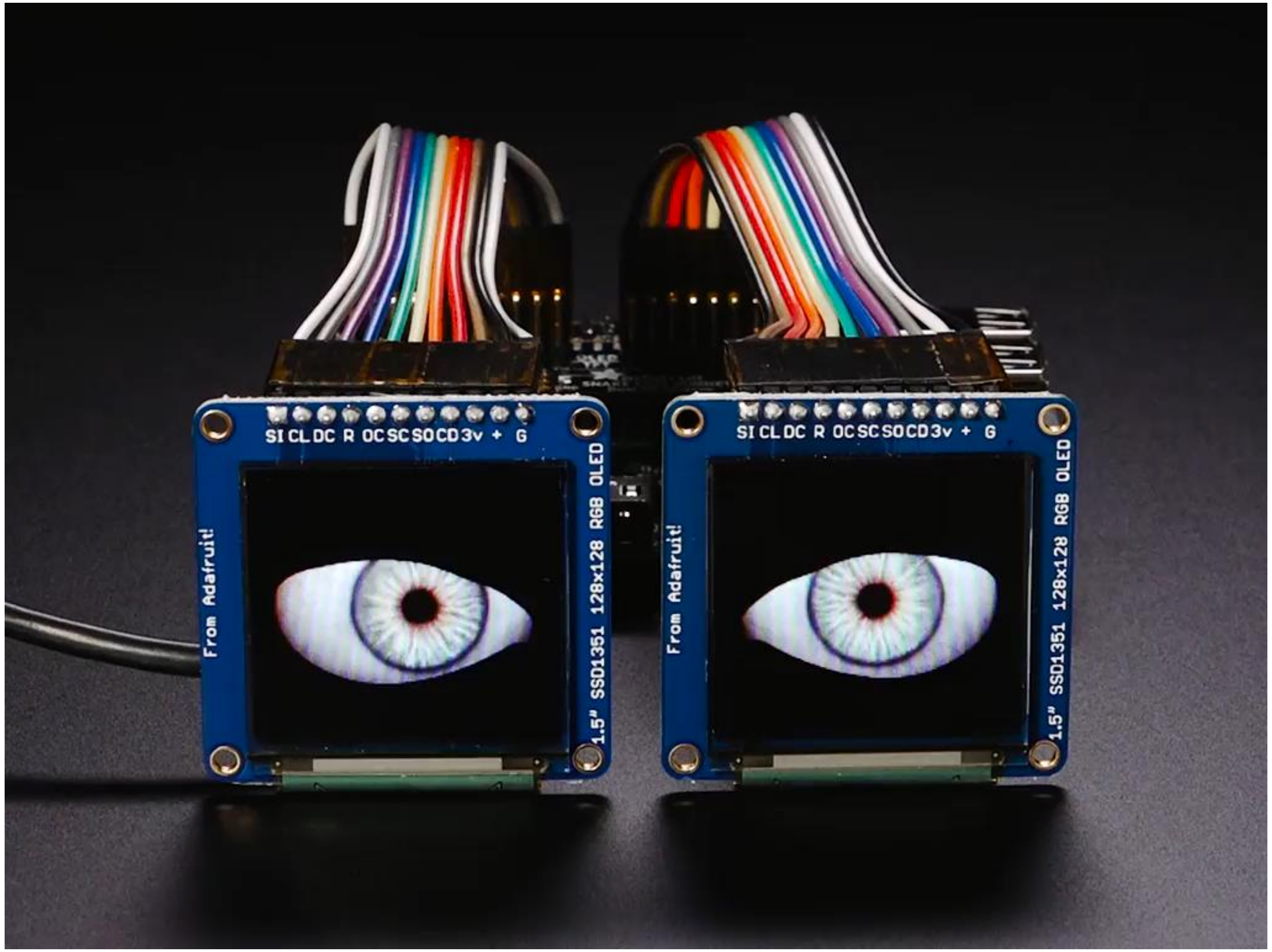
Working Demonstration



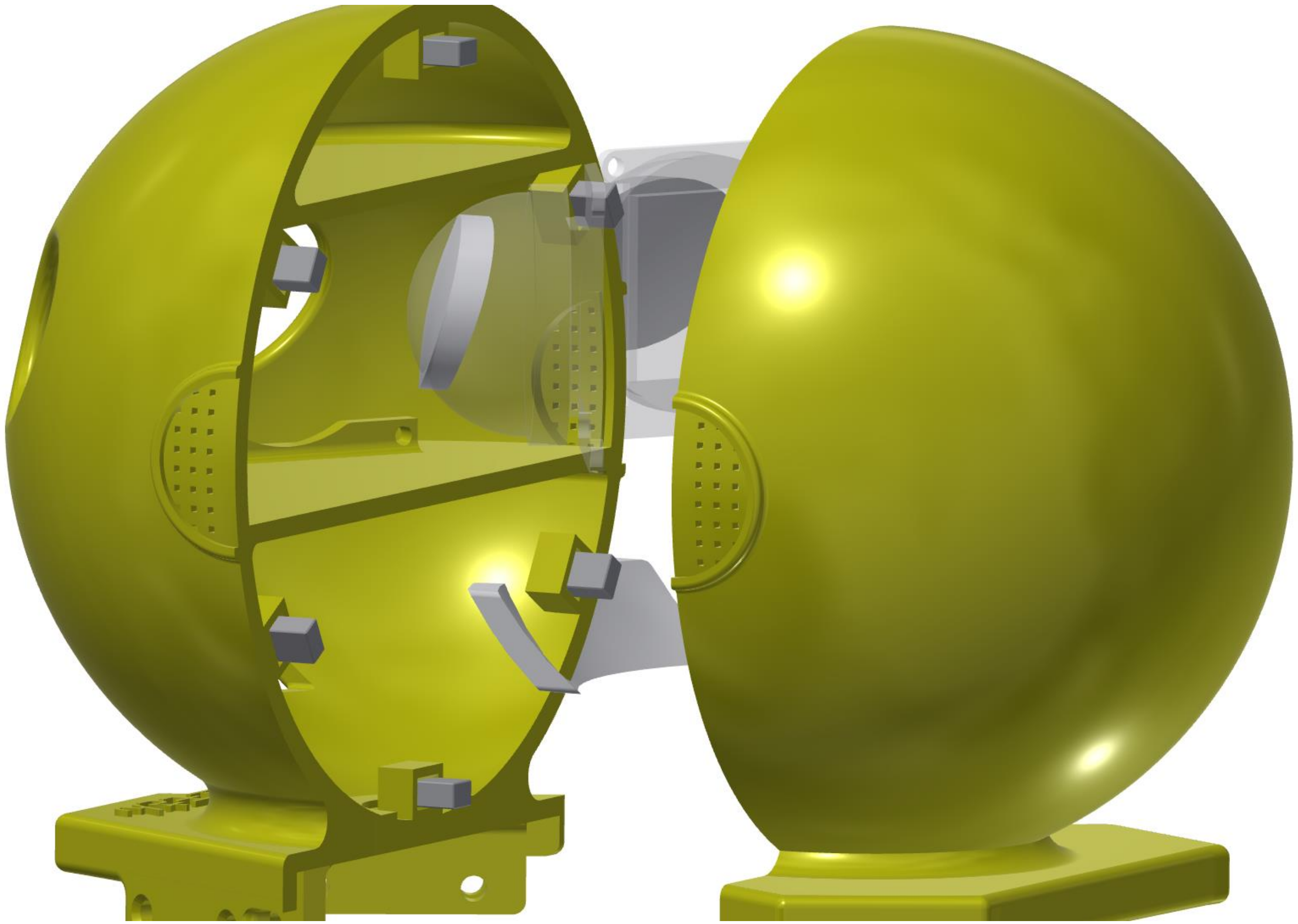
Conclusions

- The emotion-expressive robot proposed in the paper has six degrees of freedom and can reproduce the movements of the human head;
- The design of the robot is based on the Gough-Stewart platform mechanism;
- The analysis of the motion capabilities reveals that the robot could fully reproduce the motion of the human head;
- The robot motion capabilities are revealed through the analysis of the workspace, which is graphically illustrated.

Plans for Future Development (1)



Plans for Future Development (2)



Plans for Future Development (3)

Creating a Control System Based
on Emotiv Device Using EEG Signals

Acknowledgements

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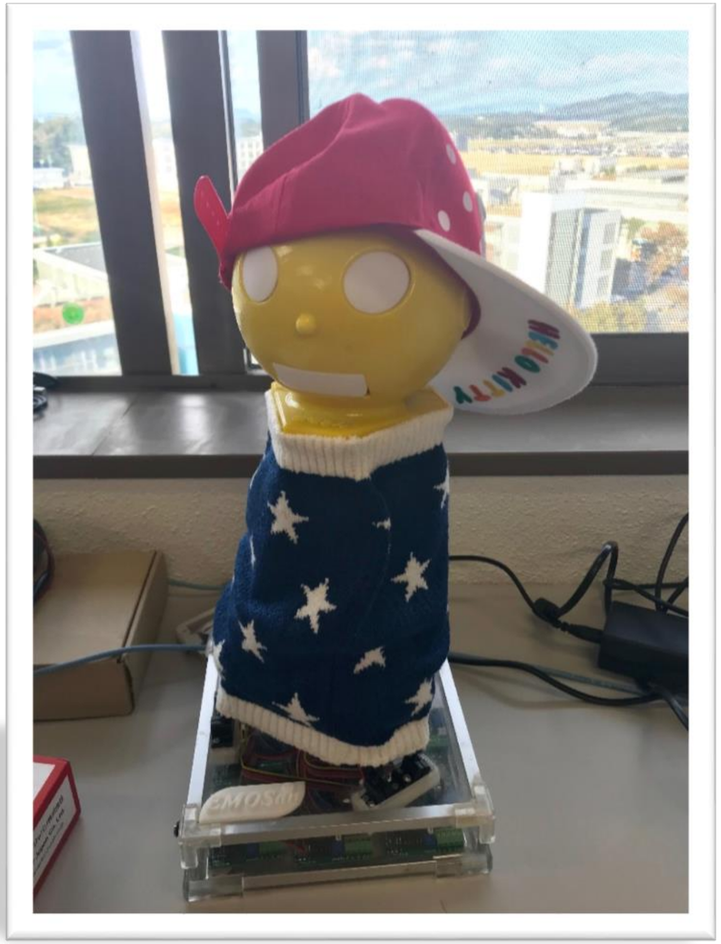
Thank you for your Attention!

"Technology is a useful servant but a dangerous master"

Christian Luis Lange



- Questions;
- Comments.