# Mechanical Design of a Spatial Mechanism for the Robot Head Configuration in Social Robotics

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**Abstract.** The manuscript presents the mechanical design of the head configuration in the Human Robot Interaction (HRI) used for the message transmission of emotions through nonverbal communications styles. The evolution of this structure results on a natural movement reproduction for the implementation of non-verbal communication strategies in a normal behavior, achieve the main patterns to evaluate the social interaction with the robotic platform. The mechanical design result from a biomechanical evaluation of the Pitch, Roll, and Yaw trajectories of the human head and neck. The spatial mechanisms, according to the Grübber formula for Spatial Robots, allows 4 degrees of freedom. The spatial chain has universal, prismatic, spiral and revolute joins of the mechanical model-ling. This CAD model permit the 3D print of cardan elements to performance the structure of the mechanisms. The appearance is friendly and the interface reach similar capabilities than a human would have for communication. Finally, human interaction through the head movement gives the opportunity in the future for the evaluation of more parameters of the social robotic interaction between robots-humans and robots-robots.

**Keywords:** Additive manufacturing · Spatial mechanism · Biomechanics · Social robotics · Mechanical design · Structural design

## 1 Introduction

Social robots are used in different places and daily there are habitats for the Human-Robot Interaction (HRI) [1]. The human head is a complex dynamic mechanism to mimic in order to reproduce or communicate emotions. When people talks, they often nod or tilt their heads to reinforce verbal messages and complement social communication. In this sense, Human-Robot Interaction (HRI) seeks to implement head


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movement in Social Robotic which require to interact with humans, by identifying patterns in people on uncontrolled situations like answer, questions, interactive attention for elders and so on [2]. The implemented approach can perform orientation of the head in the trajectories around in the X, Y and Z coordinates axis (movements of Roll, Pitch and Yaw) through servomotors that allows the generation of 4 Degrees of Freedom. As well, a fish-eye camera is housed on the top of the head with an asynchronous motor in order to position and rotate the camera lens controlled through a remote operator. This design is a mobile platform with graphic and text interfaces according the level of thorax or head, consider similar human morphological. The interlocutor through this interfaces is able to see expressions displayed in the screen and read messages from the robot [3].

## 2 The Social Robot Human Interaction

The configuration of the robot structure for the gestural communication is implemented with stimulations of the human robot interaction. This stimulation is based in mimics for the interpretation of affirmative, negative or doubt answers. Through the camera housing in the top side of the head, the observation is registered by a camera to achieve feedback of the social interaction. The message depends of the gestural interpretation by the interlocutor [4] (Fig. 1).


a) b)

**Fig. 1.** MASHI Robot: (a) Robot in SCEWC 2016, (b) Robot selfie in SCEWC 2016

## 3 Methods and Materials

The Method for the conception of the social robot is evolutive according the social expectation. The robot has 3 states until the final head configuration.

The structure evolution is implemented as first with a round base with 2 wheels for the translation. There is a joined bar for the body and subjection of features for the communication and display (Fig. 2).

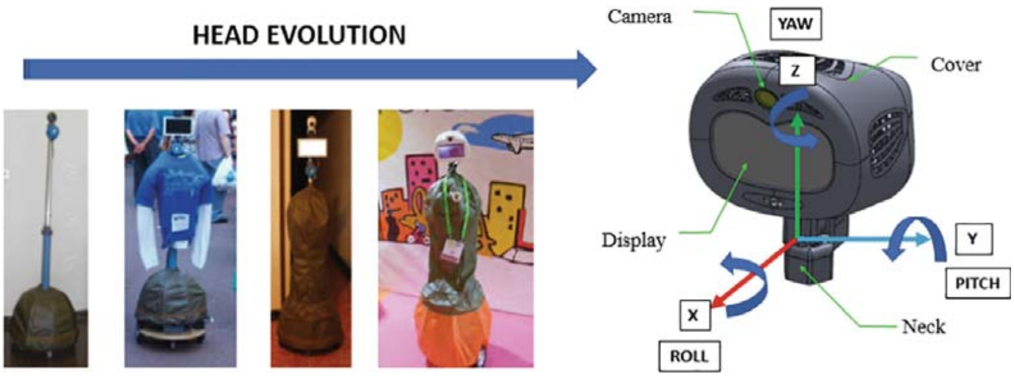


**Fig. 2.** Structure evolution and final head configuration

# 4 The Design Concept

## 4.1 Head Biomechanics

For the head mechanic configuration, the analyses of the head biomechanics begin with the cervical vertebrae [5]. The position of the head is positioned by the 7 cervical vertebrae, linked by cartilages, the movement of the head is flexible and natural with 3 degree of freedom. The rotation of the head has the limits in the gestural position for the answer interpretation: affirmation, negative or possibility doubt answer (Fig. 3).

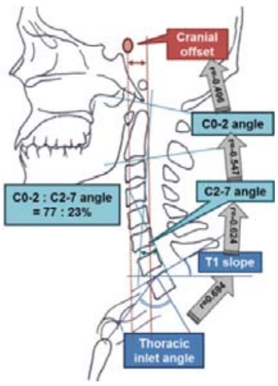


**Fig. 3.** Cervical vertebrae parts. Image modified from [6]

## 4.2 The Neck-Head Mechanism Design

The mechanism of the head and neck is using on the reference of the Cranial Spinal vertebral rotation of the base of the neck and the inertial force that the center of gravity of the head makes [7] (Fig. 4).

The spatial chain mechanism is implementing with 3 servomotors, there is one four linkages in the rare side and two four linkages. All linkages are joined with two lateral slider-crank mechanisms, the element connection in the rare side are the cardan configuration in both sides. The spatial chain has 10 links, 2 virtual links that permit the turn of the display assembled in the front side of the head. Each position allows the interlocution with different muster of interlocution [8].

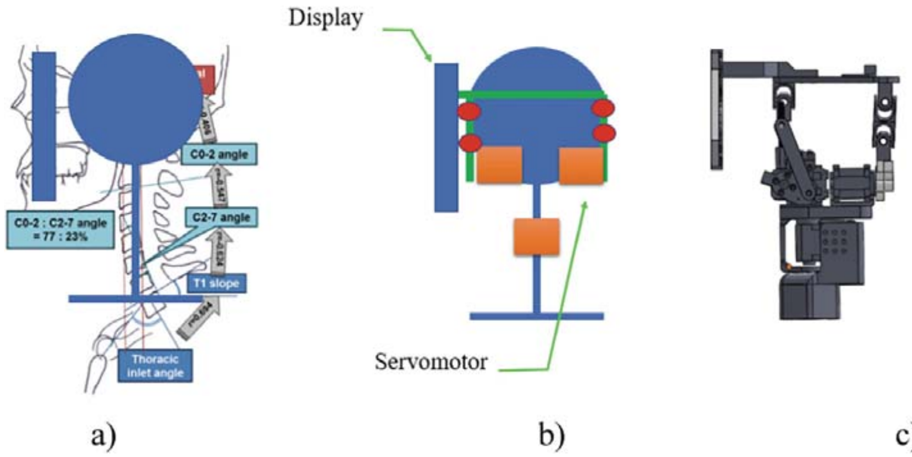


**Fig. 4.** Design of the mechanical mechanism: (a) Geometry definition, (b) structure concept of the links, nodes, servomotors and kinematics spatial chain, and (c) lateral view of the mechanisms implemented with servomotors (without cover).

### 4.3 The Spatial Mechanism

The position of the head around each axis is realized by the servomotors to bring in movement the connectors and links. The limits are the angles of the natural movement of the human neck between 15º in the Roll and Pitch, as well as 50º Yaw angles. The spatial positioning begin with the chain at the Z0′ axis (Fig. 5).

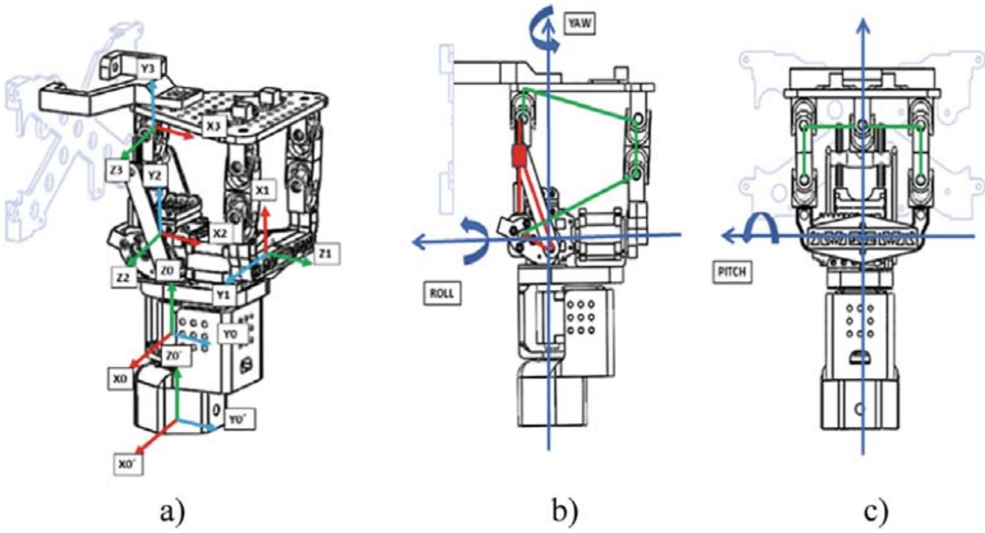


**Fig. 5.** 3D Model: (a) Coordinate axis and chain, (b) & (c) Slider-crank mechanism and spatial chain with the angles roll-pitch-yaw.

## 5 The Additive Manufacturing

The manufacturing of mechanical elements must be considered by the external forces o pressures exposition. The PLA or ABS material characterization define the volume of the part or element for the mechanism assembled. The 3D print of joins for revolute has not a good configuration in the filaments near of the Spheris elements (Figs. 6 and 7).

**Fig. 6.** ABS/PLA 3D printed parts as elements for the material characterization


a) b) c)

**Fig. 7.** 3D printing: (a) Camera assembly (without cover) and servomotor assembly with the spatial chain, (b) Joins of the spatial chain, (c) Base of the head structure [9].

## 6 Results

The results for the structure configuration about the head mechanical design has the following table of joins, connected with servomotors, programed with a set of the servomotors code. The steps corresponding to the angle of each motor as follow (Fig. 8 and Table 1):

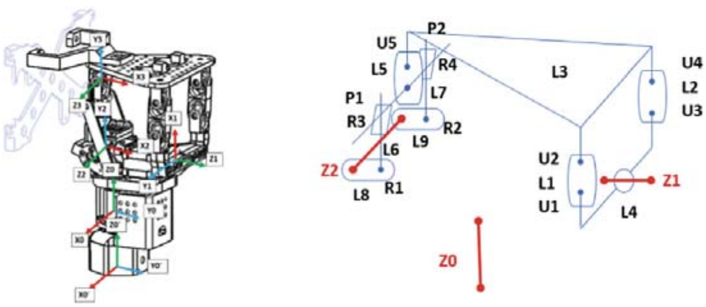


**Fig. 8.** 3D spatial chain (left), joins and nodes of the spatial chain (right)

**Table 1.** Join and nodes with 10 links of the robot head

| Join | Name | Node |
|---|---|---|
| U1…U5 | Universal | 5 |
| P1…P2 | Prismatic | 2 |
| S | Spherical | 0 |
| R1…R4 | Revolute | 4 |

## 7 Conclusions

The social robotic is optimized in the mimic of the head movement trough the kinematic chain. For the configuration of the elements, the geometry and material has an important role. When the 4-bar and slider-crank mechanisms are joined, the spatial chain can be configured. In the implementation of the spatial chain, the mechanism allows the servo-motors to reproduce the position of the human head characterization which implemented in a not controlled ambient, where is permitted as well the communication in the human-robot interaction.

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