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Kinematic Analysis of the Chickens Lower Limb as Base for Bio-Inspired Robotics

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Abstract

The study of biological and physical systems mainly in animals has allowed to improve and develop new models, based on behavior and movement mechanisms, applied to robotic bio inspired systems and predictive algorithms. In function to improve the system efficiency, giving solution to the central problems in the robots stability and locomotion, for their adaptation in different surfaces of difficult access. Therefore, this work presents the results obtained in the kinematic analysis and stress applied to the lower extremity of the chicken.

Keywords: Bio-inspired robotics, kinematic analysis, Denavit-Hartenberg.

INTRODUCTION

Modern robotics has been applied different kind of strategies, with the aim of guarantee the mechanisms stability during their movement in diverse surfaces, [1] for this purpose, it has been inspired by the coordination and functional animal's movements to adapt in different terrains, [2].

Based on the study of the biological system and movement mechanism in animals, is known as bio inspired systems, with which it has been possible find innovative solutions, which include the dynamic simulation about the evolution level achieved by the species studied, [3], that as response to the difficulty in resolve the movement requirements which cant not be represented by models based on mathematics or physics schemes.

Around the bio inspired system it has been develop various studies in different engineering fields, as the design of optimal networks throw the evolutionary optimization multi-objective, [4], base on the representation of population and chromosomes behavior as evolutionary strategy to the optimization, or well with the use of immunologic principle to the informatics security of the network [5].

The methods and bio inspired algorithms, it has been applied as strategy to develop applications with artificial intelligence, [6], where the design of an intelligent hybrid controller it can be defined by heuristics technics to tune parameters based on animals behavior, as the swarm particle. Furthermore the movement analysis restricted in animals, throw bio inspired robotics it has been studied around the development of mechanisms, which has the capacity to adapt himself in limited spaces for human beings or a conventional robots, [7], [8].

In [9], is described the design and simulation of a bio inspired robot in locomotion system of Tenebrio insects, this work consist in the displacement analysis of the legs insect on different routes and the flat grounds. As result, was obtained the identification of equations and associate parameters with the links movement limits. The simulation allowed to find the movement features, displacement and Tenebrio stability.

In a similar way in [10], was analyzed the legs locomotion of a hexapod robot in the displacement on flat surfaces, by the simulation in Matlab concluding that the simulation platform obtain an stability and control analysis on the robotic mechanism with the practical management of parameters as angles, center of mass and extensions.

In [11], a bio inspired robot was developed in the morphology of a starfish, shaped on elastomers polymers. The work consist on a quadruped robot without sensors and only with five pneumatic actuators with make the move with the appropriate application of pressure about mechanisms limbs.

The present work has the main aim of develop the kinematic analysis of the chicken's lower limb as base for the implementation of Bio-Inspired Robotics in the movement and stability, in the translation on flat surfaces.

METHODS

Low Limb Structure

In Figure 1, is present the mechanical structure of the studied bird low limb, along with their mainly elements which allow to this animal move in different kinds of surfaces.

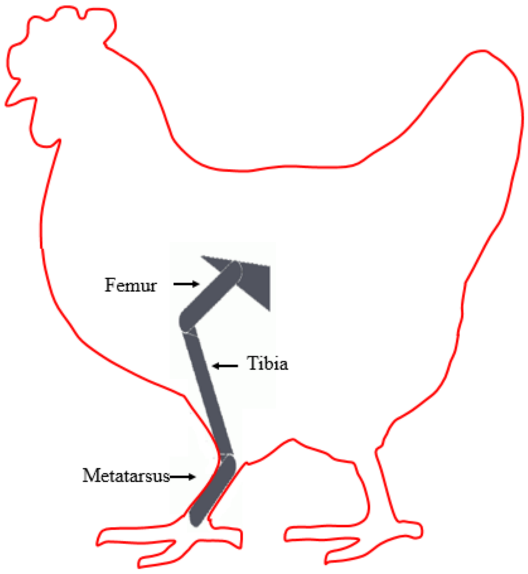

Figure 1. Chickens Low limb structure.

A mechanical model of the limb was designed and simulated, as shown in Figure 2.

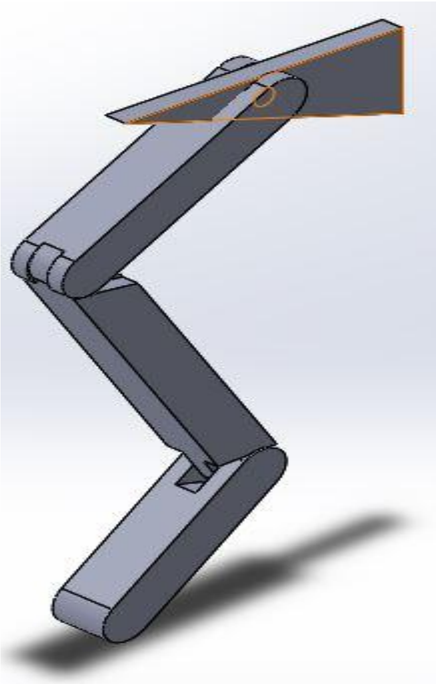

Figure 2. Mechanical model of the lower limb.

Kinematic Analysis

Joint Space Diagram

The graphic representation of references systems taken for the kinematic analysis, is shown in Figure 3. Was taken into a count four joints and three movement links, which represent the femur, tibia and metatarsus.

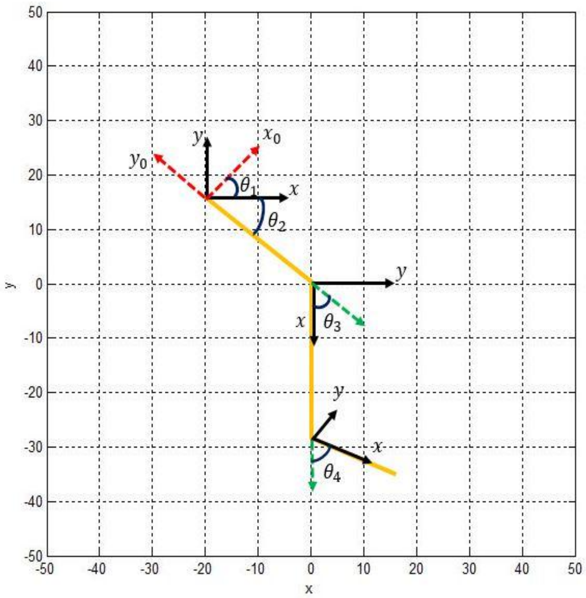

Figure 3. Joint space Diagram.

With the joint analysis in the previous diagram, were established a Denavit-Hartenberg parameters, presented in Table 1.

Table 1. Denavit-Hartenberg Parameters.

	a_{i-1}	a_{i-1}	θ_i	d_i
1	0	0	θ_1	0
2	0	0	θ_2	0
3	0	21	θ_3	0
4	0	41	θ_4	0
5	0	10	0	0

The parameters array by Denavit-Hartenberg were obtained with the frame references previously described. With a model in two dimensions, the torsion angle (α) and the joint distances (d) are equal to zero for all the links. During the analysis was taken into a count ($\theta_1, \theta_2, \theta_3\ y\ \theta_4$) parameters corresponding to joint angles. These angles vary as the flight short bird advances in its march, and with the lengths of the system links.

The array presented in (1), show the transformation Denavit-Hartenberg array, which it is possible model the joint translation and rotation.

$$T = \begin{bmatrix} R_{11} & R_{12} & R_{13} & P_x \\ R_{21} & R_{22} & R_{23} & P_y \\ R_{31} & R_{32} & R_{33} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}$$

$R[3x3]$ Correspond to rotation array, while $P[1x2]$ is the position array. As it was mentioned previously the z axe component is null, due to the intention of this work is model a system in two dimensions.

Each of Denavit-Hartenberg array, was calculated for each link in the system, obtaining a rotation array

(2) of the endpoint in the bird low limb.

$$A_{r_4}^{0} = \begin{bmatrix} \cos(\theta_1+\theta_2+\theta_3+\theta_4) & -\sin(\theta_1+\theta_2+\theta_3+\theta_4) & 0 \\ \sin(\theta_1+\theta_2+\theta_3+\theta_4) & \cos(\theta_1+\theta_2+\theta_3+\theta_4) & 1 \\ 0 & 0 & 0 \end{bmatrix} \quad (2)$$

In (3) the position array is presented for the end of the third link.

$$A_{t_4}^{0} = \begin{bmatrix} a1\cos(\theta_1+\theta_2+\theta_3+\theta_4) + a2\cos(\theta_1+\theta_2+\theta_3) \\ a1\sin(\theta_1+\theta_2+\theta_3+\theta_4) + a2\sin(\theta_1+\theta_2+\theta_3) \\ 0 \end{bmatrix} \quad (3)$$

RESULTS

Given values to references angles $\theta_1, \theta_2, \theta_3\ y\ \theta_4$, the postion ($Px$,$Py$) for each link was obtained during different moments of the bird motion. Table 2, show the joint angles for the four studied movements.

Table 2. Joint angles.

	Joint Angles			
Movement	θ_1	θ_2	θ_3	θ_4
1	-63°	-20°	-22°	86°
2	-55°	-19°	-20°	90°
3	-35°	-18°	-39°	110°
4	-22°	-18°	-39°	130°

Table ***3*** show the positions of each link, in the first movement according with the angles present previously

Table 3. First movement positions.

	Px	Py
P_{0-1}	0	0
P_{0-2}	2.5593	-20.8435
P_{0-3}	-8.0523	-60.4464
P_{0-4}	1.4029	-63.7021

The described movement by the joints and positions presented, is illustrated in Figure 4.

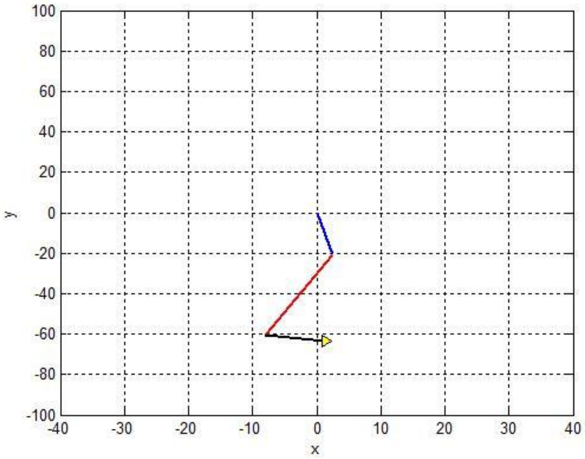

Figure 4. First movement in the march.

The position obtained for the second movement is shown in Table 4.

Table 4. Second movement positions.

	Px	Py
P_{0-1}	0	0
P_{0-2}	5.7884	-20.1865
P_{0-3}	2.9284	-61.0866
P_{0-4}	12.9040	-61.7842

In Figure 5 is present the low limb of the bird in the positions and joints described.

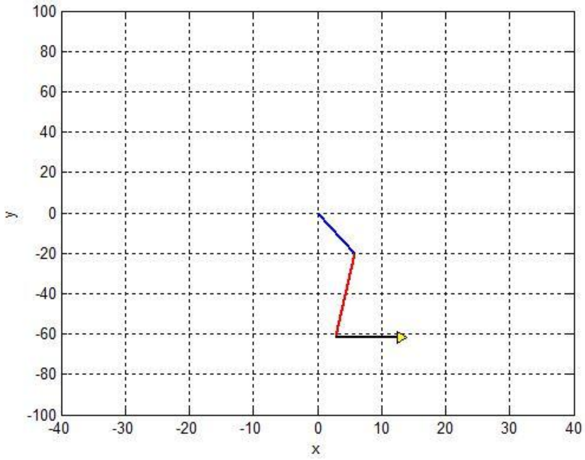

Figure 5. Second movement in the march.

For the third movement were calculated the positions presented in Table 5.

Table 5. Third movement positions.

	Px	Py
P_{0-1}	0	0
P_{0-2}	12.6381	-16.7713
P_{0-3}	11.2072	-57.7464
P_{0-4}	20.7178	-54.6562

Figure 6 show the third movement of the studied bird.

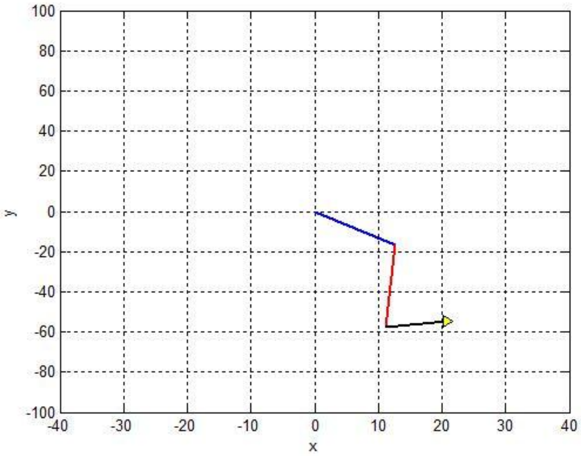

Figure 6. Third movement in the march.

Finally, in Table 6 are show the last positions found for the fourth movement in the march.

Table 6. Last movement positions.

	Px	Py
P_{0-1}	0	0
P_{0-2}	16.0869	-13.4985
P_{0-3}	23.9101	-53.7453
P_{0-4}	30.2033	-45.9738

The last movement is presented in Figure 7 according with the obtained values in the links positions.

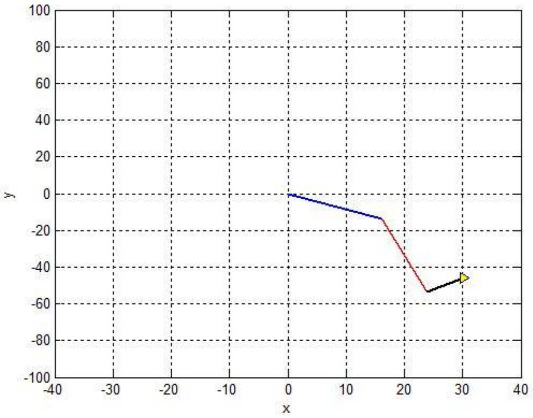

Figure 7. Fourth movement in the march.

Figure 8 represents all the movements in the bird march through a kinematic analysis.

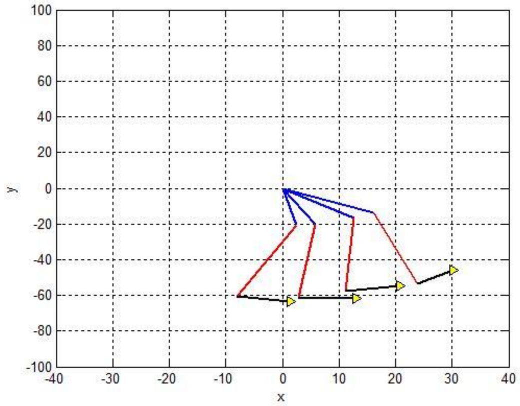

Figure 8. Bird movements in different time instants.

Mechanical study to the bird low limb

To develop this study, it was necessary develop a model of the bird low limb through a 3D design software *SolidWorks*. The model elaborated consist in three mainly parts in the structure of the limb. Femur, tibia and metatarsus. The study includes a torsion, stress and deformation analysis on femur and the bolt related with the unions between joints.

The analysis elaborated was applied a force of $1lb \times in^2$ on one of the bolt faces, obtaining a maximum stress of $577 \times 10^3\ MPa$ and a maximum deformation of $0{,}0039\ mm$. The results of maximum stress achieved in the bolt, is shown in Figure 9.

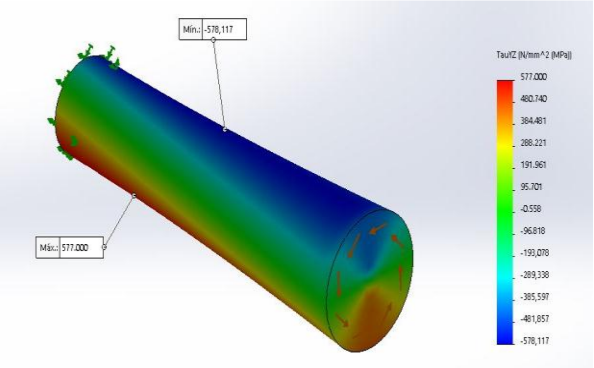

Figure 9. Maximum stress achieved in the bolt.

In Figure 10 is present the results obtained in the study of deformation between joints.

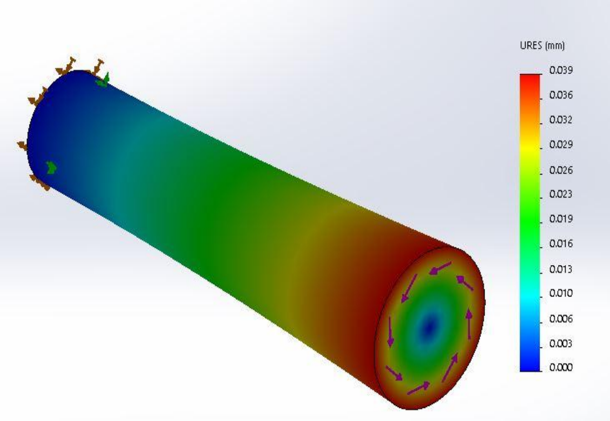

Figure 10. Deformation at the bolt.

Furthermore, in the femur case a force of 1N was applied on an endpoint, where was possible observe the stress and deformation introduced down below in Figure 11 y Figure 12.

The maximum stress achieves in the femur was 657.956,625$N/_{m^2}$.

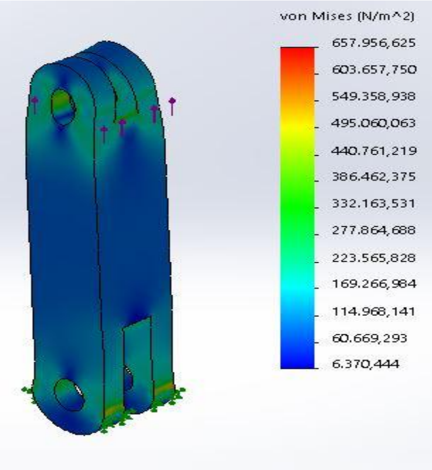

Figure 11. Maximum stress of the femur.

The maximum displacement obtained for the femur was approximately0.002 (mm).

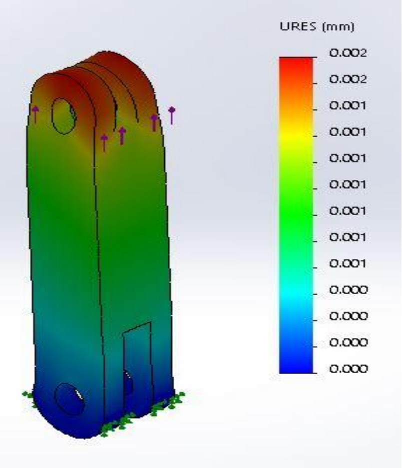

Figure 12. Maximum deformation in the femur.

CONCLUSIONS

The kinematic analysis developed in this work, for the movement of the lower extremity of the short flight bird during displacement, the values of the articulation angles for each link of the locomotion system were calculated and simulated, together with the positions corresponding to different instants of time of the studied bird.

During the study of stress and deformation performed to the bolt, or union between all the pieces of the designed system, a maximum stress of $577 \times 10^3\ MPa$ and a deformation of $0{,}0039\ mm$ was obtained, for a force equivalent to $1lb \times in^2$.

With the study of stress and deformation of the femur, applying a force of 1 N on the upper end of the piece, a maximum deformation of 0.002 (mm) was obtained, and a deformation of 0.001 (mm) over the length of the piece. The stress reached by the femur varies between 6.370.444 $N/_{m^2}$ - 657.956.625 $N/_{m^2}$, this maximum tension tends to be obtained at critical points such as the junction between the femur and the bolt.

REFERENCES

[1] J. Ollervides, N. Pineda, A. Saenz, V. Santibánez y A. Dzul, «Sistema de Control de Locomoción de un Robot Hexápodo Caminante.,» de *Congreso Nacional de Control Automático*, 2013.

[2] R. Campos, V. Matos y C. Santos, «Hexapod locomotion: A nonlinear dynamical systems approach.,» de *IECON 2010-36th Annual Conference on IEEE Industrial Electronics Society*, 2010.

[3] D. Rocha, D. Sarmiento y E. G. Vargas, «Los sistemas bioinspirados y su enfoque en la solución de necesidades en la ingeniería.,» *Redes de Ingeniería,* 2012.

[4] G. Puerta, E. Aguirre y M. A. Alzate, «Effects of topology and mobility in bio-inspired synchronization of mobile ad hoc networks.,» de *Communications (LATINCOM)*, 2010.

[5] G. A. García y O. Salcedo, «Predicción de Fallos en Redes IP empleando Redes Neuronales Artificiales.,» *Polibits,* 2010.

[6] J. Valiente y M. Santos, «Métodos bio-inspirados en el control Pid de un motor.,» de *Actas de las XXXV Jornadas de Automática*, Valencia, 2014.

[7] J. Zhang, J. Wang y W. Chen, «Virtual model optimization and locomotion control of bionic hexapod robot.,» de *Industrial Electronics and Applications (ICIEA)*, 2012.

[8] J. Medina y P. Vélez, «"Soft Robotic": Una nueva generación de robots.,» *Maskana,* 2016.

[9] J. Rodríguez-Calderón, M. F. Ramos-Parra y M. V. Peña-Giraldo, «Simulación de un Robot Hexápodo Bioinspirado en el Tenebrio.,» *Lámpsakos,* 2015.

[10] S. Manoiu-Olaru y M. Nitulescu, «Stability analysis software platform dedicated for a hexapod robot.,» *Advances in Intelligent Control Systems and Computer Science,* 2013.

[11] R. Shepherd, F. Ilievski, W. Choi, S. Morin, A. Stokes, A. Mazzeo y G. Whitesides, «Multigait soft robot.,» *Proceedings of the National Academy of Sciences,* 2011.