PROPOSAL OF MODELING, SIMULATION AND IMPLEMENTATION OF ROBOTICS LEG PROSTHESIS

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Abstract: This paper presents a proposal of modeling, simulation and implementation of a robotic biped locomotion system. The initial step is consisted of the determination of the cinematic characteristics and the system performance during walking. Starting from the methodology of the generated kinematics model, several computational programs was elaborated with the purpose of reproducing and manager the space displacement, velocity and acceleration of the articulate system. To validate the developed algorithm, was elaborated a articulate system prototype of robotic leg in which will be implemented and tested the developed methodology.

Key Words: Robotics, Prostheses, biomechanic, automation

1. Introduction

This work has the objective of integrating the knowledge acquired in the areas of anatomy, physiology, biomechanics, neuroanatomy, robotics and automation for the development and implementation of active prostheses "intelligent" of lower limbs, taking in consideration the application in the project of structures, activation systems, transmission systems and sensibility similar to the natural system.

The final goal of this research, that meets in the middle of course, is activating the articulations of the artificial limbs voluntarily through the reception of the patient user's of the prosthesis myoelectric signs, captured of antagonistic superficial muscular groups, having like this the control of the artificial system on the part of the nervous system. These signs after properly filtrates, amplified, and decoded, will control the process of artificial limb march.

Starting from the cinematic model of the system to articulate human and of the dynamic model established for the actuation systems and activation of the human body, every apparatus is being developed in software level for the establishment of the cinematic as dynamic so much control of a knee prosthesis activated by pneumatic actuation that meets now in construction phase. In the task of the development of the project of this articulation a comparative analogy was established with the natural biological system taking in bill anatomical factors, cynesiologics and neurophysiologics, seeking to the maximum, inside of the measure of the possible, the reproduction of the movements and efforts of the natural system to be substituted by the artificial.

Seeking the reproduction of the natural actions, to control the system is being implemented in the control mesh by artificial neural nets and Logical Fuzzy, allowing like this the training and the learning of the artificial system.

In the face of the exposed, the new modeling proposal developed in this work can be used in the bioengineering area as an important approach in the evaluation, programming and project of prostheses, that can apply telemanipulation concepts, task description, learning and programming.

2. Mechanical project of the developed device

Starting from the analytic study and of the development of pneumatic servant-valves with control of variable flow in function of the strangulation or opening of a diaphragm servo controlled, is being built a prototype of articulation of knee anthropomorphic that presents rigidity control, in function of the phase of the march. The prototype has a structure to modulate in way to allow a joining between the different groups of prostheses and developed actuators.

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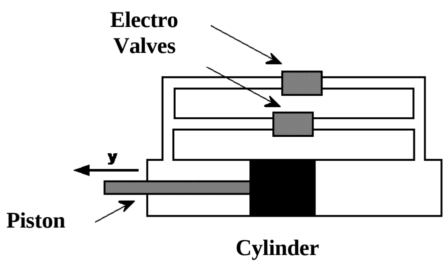
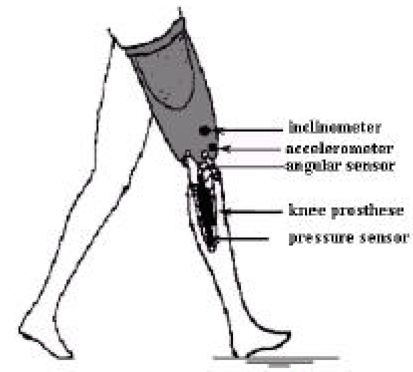
Through the rehearsals accomplished in having supported methodologies will be developed for the establishment of the cinematic and dynamic control of the final prototype of lower limb prosthesis myoelectrically controlled applied in a patient user of the equipment.

The articulation of the knee prosthesis was modeled by a mechanical system endowed with two segments that are tied up for an articulation composed by a mechanism of four bars. This mechanism is endowed with a pneumatic reducer. The device that is being elaborated to be studied initially in a supported, has the equivalent system to the of a pneumatic monkey, playing the reducer part. That is, the valves of the unit of braking (proportional electro valves) allow the adjustment of the rigidity of the artificial articulation starting from the control of the flow of air in the pneumatic circuit. (Figure 1 (a)).



(a) Pneumatic circuit and electro valves



(b) disposition of the sensor of the system

Figure 1 –Robotics leg prosthesis

When applied the system in the prosthesis, the rotation of the articulation of the knee generates the movement of translation of the piston. When the angle of flexion of the knee has a certain value, the closing of the electro valves is worked. They control the passage of the flow of air between the two cameras of the cylinder, avoiding the leg as soon as moves excessively due to inertia of the system. The air contained inside of the pistons on that moment increases the elastic energy of the pneumatic system. To avoid a brutal return of the leg, a control of the consumption of air is preceded through the electro valves regulating like this the march of the amputated.

The sensors ones supply the necessary information for the control of the prosthesis. The measure of the width of the articulation requests a magneto-resistive sensor to measure the angular displacement of the knee. An inclinometer supplies the angle between the thigh and the vertical. A coupled accelerometer the junction of the knee supplies the thigh's acceleration and a last one sensor it indicates the pressure in the superior camera. (Figure 1 (b)).

3. Control of the knee prosthesis

At the present time, when a user of knee prosthesis wants to accelerate its march or to run, the artificial limbs behave as a pendulum whose swinging movement is amplified with the increase of the speed of the displacement. This anomaly increases the effort applied in this task notably and it limits the acting of the system, harming the accomplishment of the tasks.

The main defect of this system has the fact that is passive, because, the rigidity law is fixed, not differentiating the change of static phase for the dynamic phase of the march, generating for consequence, a form of walking symmetrical for a step form just.

In opposition to this established philosophy, this work that is in process, has as for objective to accomplish a consistent analytic study on the described prosthesis, implementing to the system so much a cinematic as dynamic control through the use of a micro controller, guaranteeing like this, a control adaptive of the pneumatic electro valves of a anthropomorphic joint of knee prosthesis, in function of the phase and of the speed of the march.

The implementation to be done in this research is related to the establishment of the control of pneumatic knee prosthesis for the case of amputations above the level of this area. The particularity of this work resides in the research of control algorithms and its implementations in a micro controller that adapts the existent prosthesis in function of the phase and of the speed of the march, applying a control action that makes the correction every minute of the trajectory to be processed.

For such intent, initially the study biomechanic of the human march was made, being initially lifted up the temporary, space and cinematic parameters of the inferior limbs. These data constituted the first analyzed base and explored in the intent of the implementation of adapted control algorithms, capable to take in bill the different phases (flexion and extension) and the forms of walking of the march, allowing that the process of the march has characteristics of the natural movement.

4. Analysis of the control of the servant-system

The control of the mechanical system needs the information of the several parameters of the system. In effect, distinguished of a part the intrinsic parameters to the mechanism to command as the inertia, the friction, the reduction, by force of the gravity and of another part, the parameters of the laws that when imposed to the controlled system, determine the wanted behavior. In a general way, a mechanical system can be modeled by an equation non-lineal differential with coefficients non-constants given by the relationship (1):

$$M(q)\ddot{q} + C(q,\dot{q}) + G(q) = \tau \qquad (1)$$

where

- $q, \dot{q}, \ddot{q}$ are respectively the vectorial position, speed and acceleration of the articulation;
- $M(q)$ is the head office of widespread inertia;
- $C(q,\dot{q})$ Figure the vectors of the forces of Coriolis and you centrifuge;
- $G(q)$ Figure the vector of the gravitational forces;
- τ joining to articulate at the level of the knee.

The synthesis of the control implies in the establishment of a temporary function $\tau(t)$. The choice of the function $\tau(t)$ defines properly in this case the type of the command said.

5. Choice of the Command implemented

In this research to be developed, opted for the logical fuzzy as control strategy to be implemented in a dedicated micro controller. The main reasons of the choice are that:

- The model of the prosthesis associated to the leg is complex and doesn't have the physiology of the movement of each case of amputation completely. The controller fuzzy has the capacity to absorb the instabilities in the modeling, using all the properties of the system together.
- The system should react in real time, implying like this the increase of the implementation complexity when it is the problem of the time of calculation.
- With relationship to the hardware, the amount of plates of electronic circuits is flexible, of manners that can come to be reduced and the whole apparatus optimized.
- The data of the obtained measures allow the establishment of linguistic laws to model the behavior of the prosthesis.
- The obtained laws if restore of the laws established by a control fuzzy.
- The control system with architecture fuzzy presents flexibility, allowing future alterations.

6. Implementation of the command system

To apply the strategy of control proposal, algorithms will be developed to make the command of the prosthesis so that its structure will be decomposed in four blocks, that is to say:

- A system for the treatment of the signs;
- A command algorithm;
- A base of reference knowledge;
- A base of knowledge that determines the operation way.

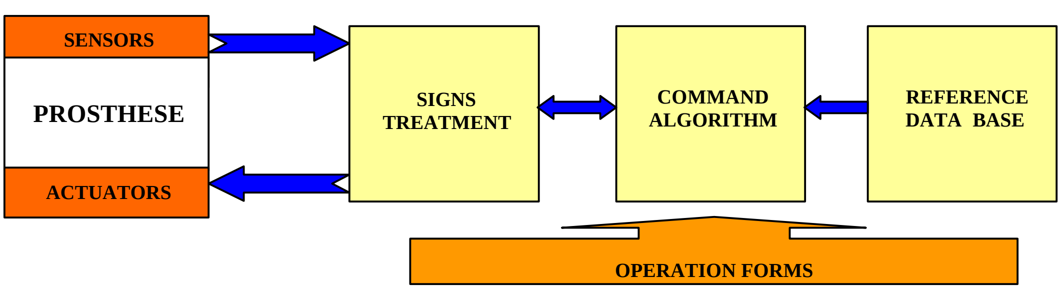


Figure 2– Control system structure

The control of the prosthesis will allow the ascent or gone down of a ramp or of a stairway and of making the march in several rhythms. The parameters of these situations will be introduced in a module neuro-fuzzy that identifies the situation with the aid of sensorial vector and modifies the base of knowledge in the operation way. For the communication between the command part and the sensor ones and actuators is indispensable an electronic adaptation of the levels of the signs.

7. Command algorithm

The control structure used for the controller fuzzy of the prosthesis is presented in the figure 3:

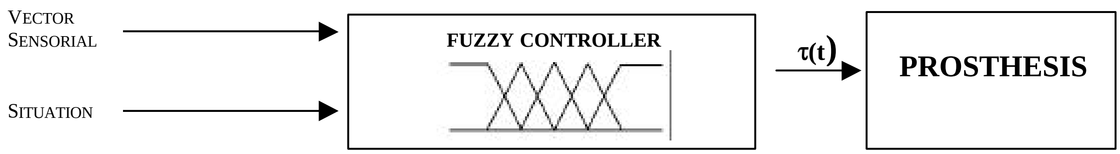


Figure 3 – Structures of fuzzy Control used for the prosthesis

The sensorial vector used in the process of the fuzzyfication will be formed by five components:

1. Angle of the knee and yours derived;
2. Angle of the thigh and its vertical one (inclinometer);
3. The thigh's acceleration (accelerometer);
4. The pressure in the superior camera of the pneumatic system.

To the entrance of the controller fuzzy will be increased a variable that has the function of defining the situation of the course duration.

The controller fuzzy will have as for parameters the functions of pertinence of the variables fuzzy, the aggregation operators and of composition, the base of laws and finally the defuzzyfication method.

It is not a simple task to represent a model of behavior on the form of linguistic laws. To establish a base of convenient laws, will be necessary:

- Preceded him to the analysis in the way of the march starting from experiences, tests and the current modifications starting from the collection of obtained data of measures.
- The reduction of the number of groups auxiliary fuzzy
- the reduction of the laws established by the implementation of the algorithm computational.

Thus, the variables in the entrance and in the exit each one three pertinence functions.

The aggregation of everybody these data makes applying the operator-classified disjunctive of Zadeh, Max (x, y), among the different associated degrees the measures. These operators have the advantage of they be associative.

8. Final conclusions and Future Perspectives

Starting from the results obtained in this research work it intends to reach the following objectives:

- Development of a computational program that allows to simulate the physiology to articulate and the cynesiology of the movements of the superior and lower limbs of the human body;
- To implement the necessary infrastructure in laboratory for the making and implementation of prostheses bio cybernetic of lower limbs,
- To obtain the whole necessary technological apparatus for the project and making of prostheses bio cybernetic with national technology.

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