Scientific Bulletin of the
"Politehnica" University of Timisoara
Transactions on Mechanics Special Issue

The 11th International Conference on
Vibration Engineering
Timisoara, Romania, September 27 - 30, 2005

MODELING THE HUMAN HAND AS AUTOMATIC SYSTEM

Doina DRAGULESCU
Affiliation: Politehnica University of Timisoara, Romania
Tel.: +40-256-403637,Email: ddrag@cmpicsu.utt.ro

Loredana M. UNGUREANU
Affiliation: Politehnica University of Timisoara, Romania
Tel.: +40-256-403249, Email: loredanau@aut.utt.ro

ABSTRACT

This article presents a model of the human hand, developed using SimMechanics, which can be successfully used to implement a good prosthesis. The model is an anatomical one, having the same elements and the same motions, submitted to the constraints of the natural hand. The paper presents how the natural model was translated into a SimMechanics system, how the constraints of the natural motion were applied to this system, and illustrates the trajectories of the fingertips and few snapshots of extension and flexion motions of the hand.

KEYWORDS: Automatic system, hand control, prosthesis

1 INTRODUCTION

The human hand is a very good example of how to implement a complex system capable to realize various tasks using a combination of mechanisms, sensors and control functions. A lot of research was done trying to imitate this fascinating natural system, but the existing prosthesis doesn't satisfy the patients, primary due to the lack of degree of freedom (DoFs). This problem is generated mainly because most of the existing artificial hands do not reproduce exactly the anatomy and the physiology of the natural hand.

Despite the huge research done among the World aiming the development of a innovative human hand prosthesis, studies have been shown that a great number of human hand prosthesis users do not currently use their prosthesis (between 30% and 50% [1]). To convince the patients to use such prosthesis, some criteria must be fulfilled [7]: cosmetic appeal, comfort, and control.

In order to obtain a good cosmetic appearance for the prosthesis, it is desirable to design a hand as anatomically as possible. Following this trend, the paper presents a model of the palm&fingers system based on the anatomical one and studies its motion.

The human hand is highly articulated and to model the articulation of fingers the kinematic model has to be done. This model consists of chains containing bodies connected through joints (Figure 1 [2]). The first body is the palm and links together the wrist and the proximal phalange of each finger, which is the second body of each kinematic chain. The wrist allows the rotation of the hand with respect to the arm, meaning three degree of freedom for the system [6].

Each of the 4 central fingers has 4 DoFs. The metacarpophalangeal (MCP) joint allows two kind of motions (two DoFs) to the proximal phalange of a finger: adduction/abduction (in the palm plane), and flexion and extension (with respect to the palm). The proximal interphalangeal (PIP) joint connects the proximal and medial phalanges and has one DoF. The distal interphalangeal (DIP) joint connects the medial and distal phalanges and has, also, only one DoF.

The thumb has a different structure and has 5 DoFs, one for the interphalangeal (IP) joint, and two for each of the thumb MCP joint and trapeziometacarpal (TM) joint, both due to flexion and abduction motions. The thumb is, also, able to move in opposition with other fingers. So, the whole system has 24 DoFs.

The hand can't make arbitrary gestures because the motion is submitted to some constraints. Each joint is characterized by a specific geometry and by a minimum and maximum angle [3]. Also, another constraint is introduced by the naturalness of the hand [6]. For example, to flex or to extend the finger, all the phalanges are moving in the same time and to catch an object each phalange is moving separately [7].

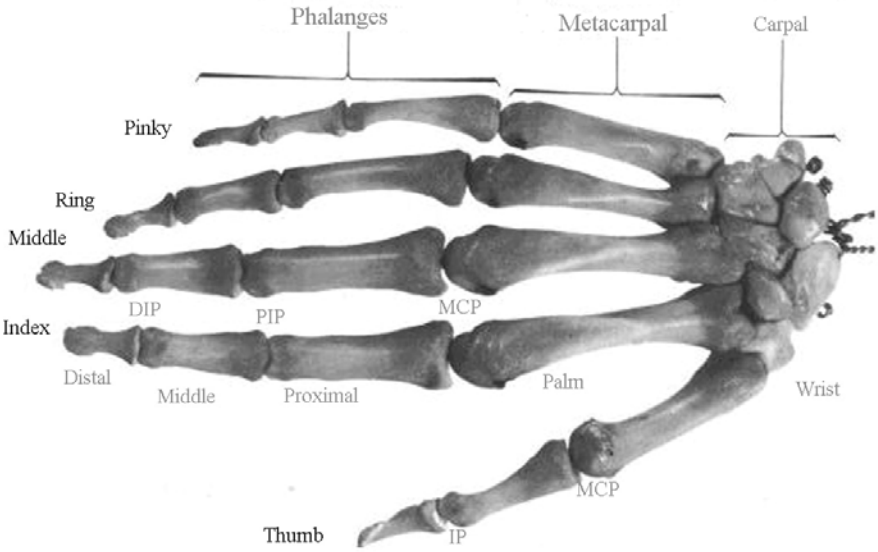


Figure 1. Human Hand skeleton

1.1 MODELING BY SIMULINK

Simulink is a software package which can be used to model, simulate, and analyze dynamic systems. This task can be done in two steps. First, the graphical model of the system to be simulated has to be created. The model depicts the time dependent mathematical relationships among the system's inputs, states, and outputs. Then, using the information entered into the model, Simulink will simulate the behavior of the system over a specified time span.

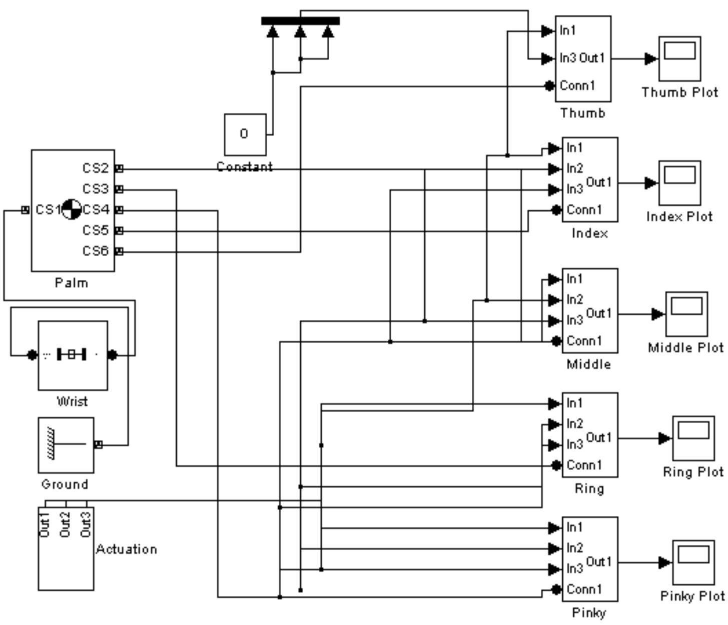


Figure 2. The Simulink model of the hand

The model presented in this paper was created using the SimMechaniks Tools of Simulink, which presumes every system made of bodies with different DoFs, specific positions, orientations and masses. This model (Figure 2) can be used to simulate de flexion and extension motions of the hand, when the wrist motion and the adduction/ab-duction motion are irrelevant.

For this reason, the model respects the following considerations:

- the wrist is modeled by a Weld block which provides no DoFs,
- the MCP joint is modeled using a Revolute block which provides only one DoF (no adduction/abduction motion)
- the PIP and DIP joints are modeled using Revolute blocks, also (Figure 3).
- the palm and the phalanges are modeled using Body blocks, which provide the orientation with respect to the general coordinate system (the Ground block), the length, the mass etc.
- every joint has to be actuated using a Joint Actuator block, which provides the value of the rotation angle.
- the motion of each fingertip is captured using a Position Sensor block and plotted using a Scope block.

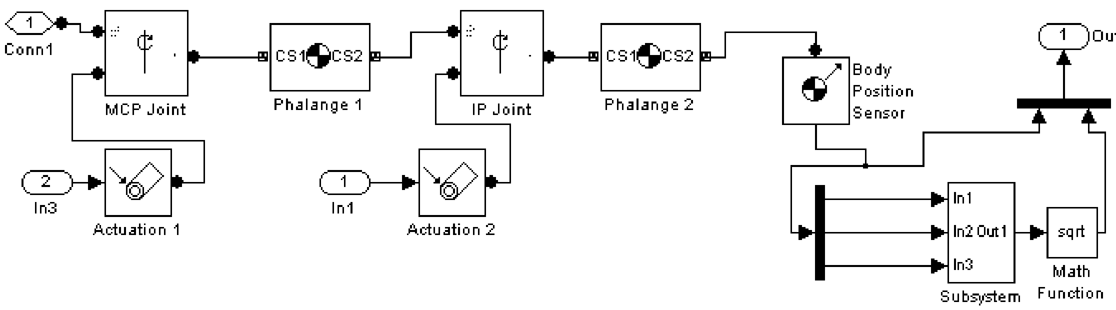


Figure 3. The Simulink model of the thumb

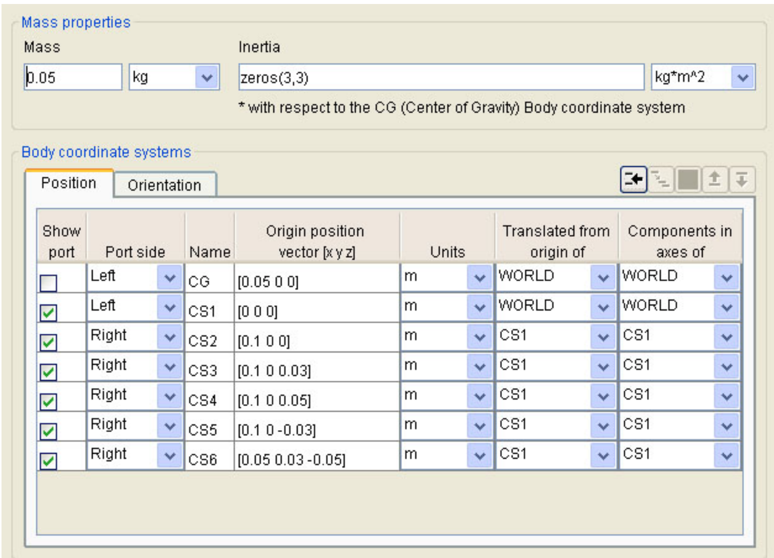


Figure 4. The CS specifications of the Palm body links

Every finger has three phalanges, except the thumb which has only two phalanges. In order to obtain a correct model, one has to express the lengths of the system's components. For the case of this model, the dimensions of a adult normal human hand were considered [6].

The general coordinate system (CS) of the model is attached to the wrist and has the following orientations:

- +Ox points right;
- +Oy points up;
- +Oz points out, perpendicular to the palm plan.

Each body of the model has a CS on its own, which is expressed with respect to the CS of the body placed before it in the model. In this way were specified the lengths of the bodies. For example, the Palm body has six links: one with the wrist, and the others with the MCP joints of the fingers. Each of this links has to have a CS (Figure 4). CS1 of the link with the wrist has the same position and orientation with the general CS (named WORLD). CS2 of the link with the MCP joint of the middle finger has the origin translated with 0.1 m on Ox direction, meaning the palm's length. The CSs of the other central fingers are translated, also, on Oz axis, meaning the distance between fingers. The thumb is translated on Oy axis too.

The motion of the central finger goes around Oz axis in xOy plane, and the motion of the thumb goes around Oy axis in xOz plane. In order to simplify the model, the number of the thumb's DoFs has been reduced. Thus, the only joint which actually moves is the IP joint (the specified motion). The other two joints are blocked at some specific values: the MCP joint at the minimum possible value and the MT joint at the maximum possible value (for the case of extension/flexion motion). Future corrections of the model have to be done in order to fully respect the natural human hand.

2 MOTION STUDY

This model can be used to study the flexion and extension motions of the hand. The considered time span was of 5 s and at each 0.1 s the corresponding values for the joint variables of the movable joints were computed by the Actuation blocks (Figures 2 and 3). After simulations, the curves for the specified motions, with respect to the general coordinate system were obtained. Figure 5 depicts the curves for the flexion motion and Figure 6 depicts the curves in the case of extension motion. It can be seen that the motion is human like.

The constraints of the natural motion were fulfilled because:

- the movable joints are actuated using the correct angular value, generated by the blocks named Actuation
- the actuation is made simultaneously for all movable joints for a natural motion.

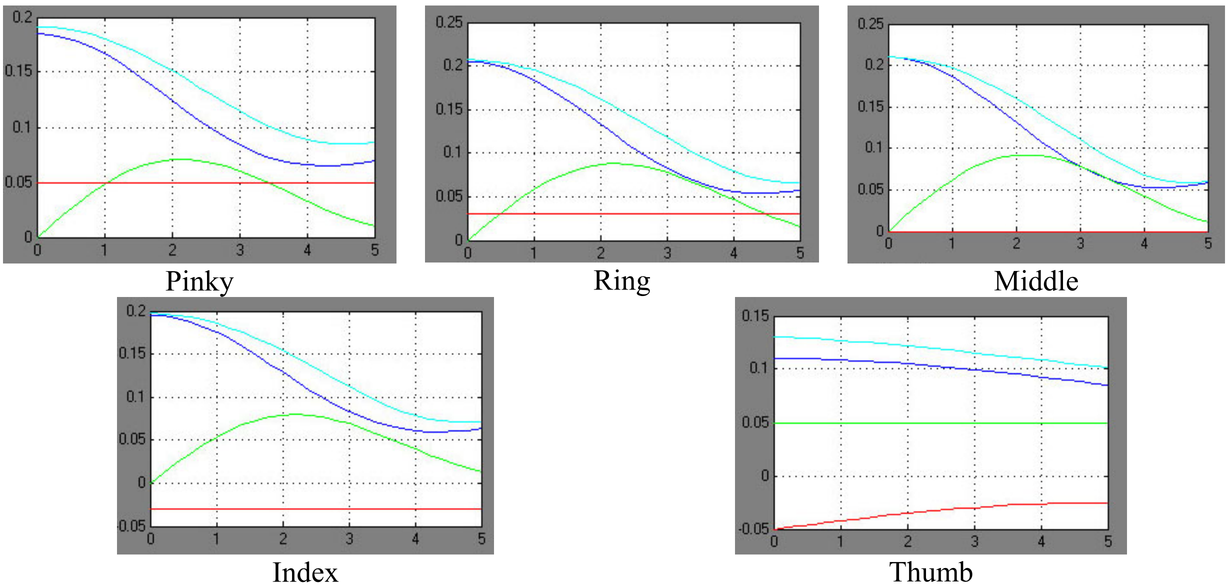


Figure 5. The trajectories of the fingertips in flexion motion of the hand

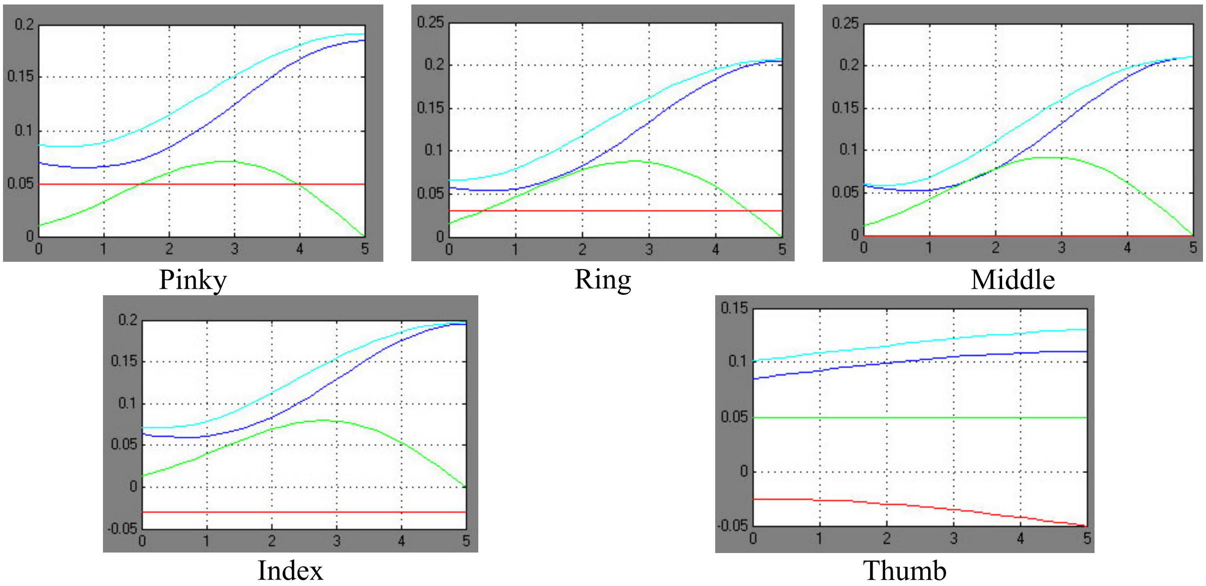


Figure 6. The trajectories of the fingertips in extension motion of the hand

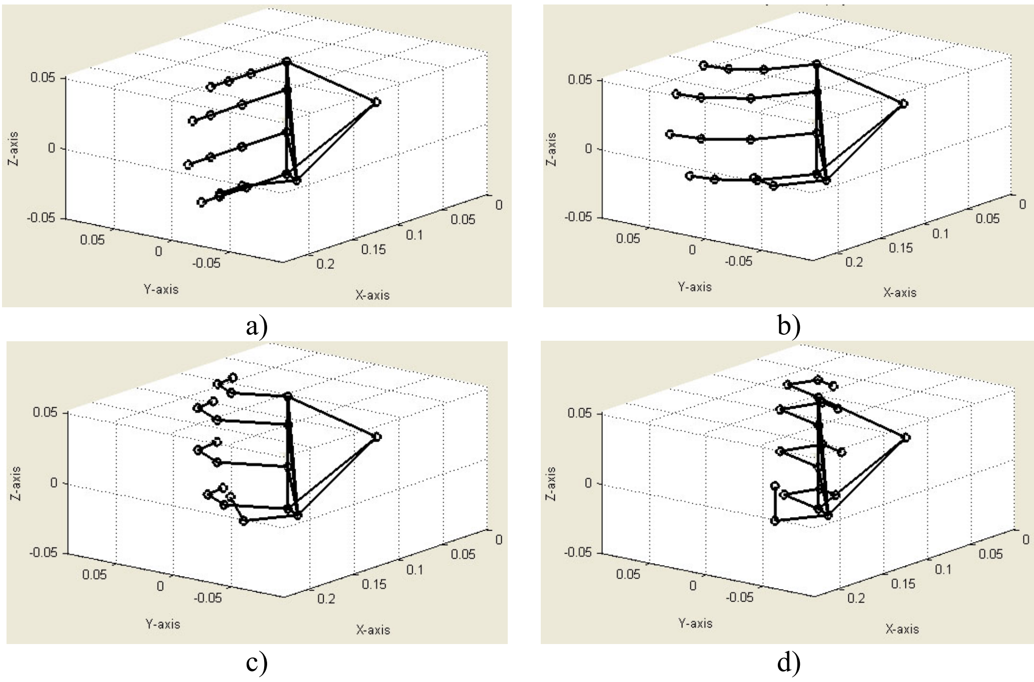
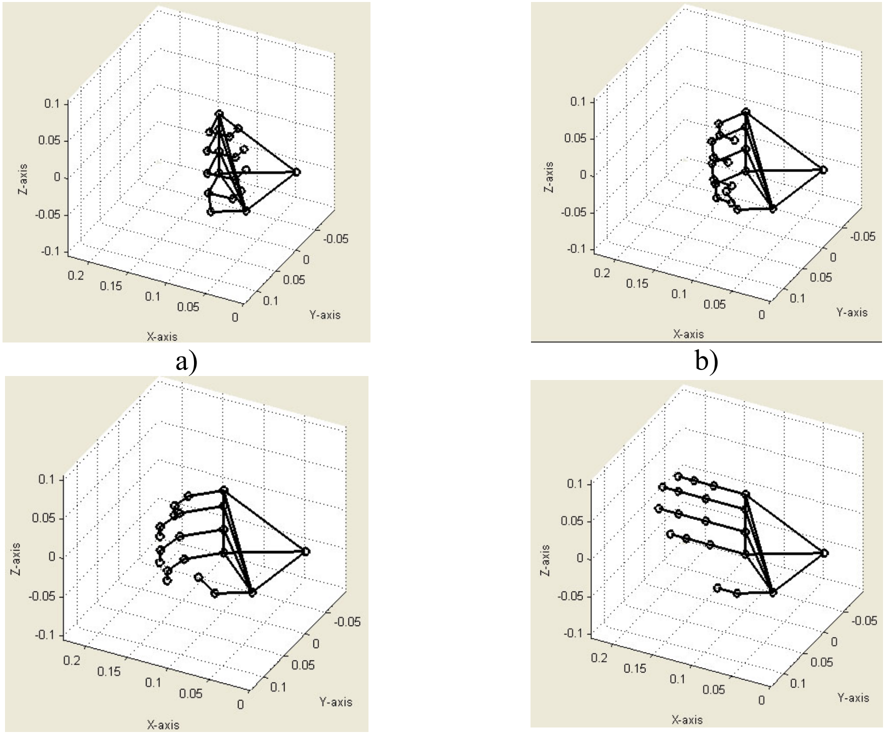


Figure 7. The flexion motion of the hand

One of the greatest facilities of Simulink is that it can provide graphical visualization of a model. Figure 7 plots four phases from the flexion motion of the hand, between full extension a) and full flexion d). On the other hand, Figure 8 plots some phases from the extension motion, between full flexion a) and full extension d). Each finger tip follows a motion curve, which is the one plotted in Figure 5 (Figure 6 respectively) in the case of flexion (extension) motion.

One can see from these plots that the hand model realized using the SimMecanick Tool of Simulink is an anatomical one, having the same size, submitted to the same motion constraints and having the same motions as the natural model. Nevertheless, the presented system is not identical with the human hand, having some constraints specified earlier in the paper. In future work, these design constraints will be eliminated in order to obtain a anatomical model of the human hand.



a) b) c) d)

Figure 8. The flexion motion of the hand

3 CONCLUSIONS

The human hand is a fascinating system capable to realize various tasks using a combination of mechanisms, sensors and control functions. In order to obtain a prosthesis, which can act as human like as possible, one have to design a correct model. This paper presents such a model, which has the same size and the same motions as the human hand. The model can be successfully used to implement a human hand prosthesis, which, actually, is the goal of the article's authors.

REFERENCES

[1] Dario P., Carrozza M.C., Menciassi A., Micera S., Zecca M. (2002), On the Development of a Cybernetic Hand Prosthesis, Third IARP International Workshop on Humanoid and Human Friendly Robotics, IARP2002, Tsukuba, Japan, Dec 11-12

[2] Folgheraiter M., Gini G. (2000), Blackfingers: an Artificial Hand that Copies Human Hand in Structure, Size, and Functions, Proc. IEEE Humanoids 2000, MIT, Cambridge, Mass, sept. 2000

[3] Lin J., Wu Z., Huang T.S., (2001), Modeling the Constraints of Human Hand Motion, Proc. of 5th Annual Federated Laboratory Symposium, Maryland

[4] Ghinea M., Firețeanu V.. (1998) MATLAB. Calcul numeric, grafică, aplicații, Editura Teora, Bucureşti, ISBN 973-601-275-1

[5] Ungureanu L., (2005) Modelul mâinii umane ca sistem automat, Referat de doctorat, ianuarie 2005, Universitatea „Politehnica“ din Timisoara

[6] Ungureanu L., Dragulescu D., (2005), Modeling a Human Finger as an Automatic System, Proceedings of SACI, May 12–14, 2005, Timisoara, pp. 69–75

[7] Visser H., Herder J., (2000), Force-Directed Design of a Voluntary Closing Hand Prosthesis, Journal of Rehabilitation Research & Development, vol. 37, no. 3, pp. 261–271