Modeling a Human Finger as an Automatic System

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Abstract: The study of the human hand can offer interesting solutions for the human hand prosthesis development or in fields like computer animation or gesture recognition. The model presented in this paper is an anatomical one, having the same elements and the same motions. The model is developed using SimMechanics and is submitted to the constraints of the natural model.

Keywords: Prosthesis, automatic system, hand control

1 Introduction

This paper presents a model of the palm-finger system based on the anatomical one and studies the motion of this system. The model consists in a kinematic chain containing several bodies connected through joints (Figure 1). The first body is the palm and links together the wrist and the proximal phalange of the finger, which is the second body of the system. The wrist allows the rotation of the hand with respect to the arm, meaning three degree of freedom (DoF). Metacarpophalangeal (MCP) joint allows two kinds of motions (two DoFs) to the proximal phalange of the finger:

- adduction/abduction (in the palm plane);
- flexion and extension (with respect to the palm).

The third body is the middle phalange and is linked to the proximal phalange through distal interphalangeal (DIP) joint. The last body of the studied system is the distal phalange, linked to the middle phalange through the proximal interphalangeal (PIP) joint. The last two joints have only one DoF each, so the whole system has seven DoFs.

Each joint is characterized by a specific geometry and by a minimum and maximum angle which constrain the motion of the system [2]. Another constraint is introduced by the naturalness of the hand motion [3]. 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 (the first one which moves is the proximal phalange, followed by the middle and then the distal phalanges [6]) until the object is fully controlled.

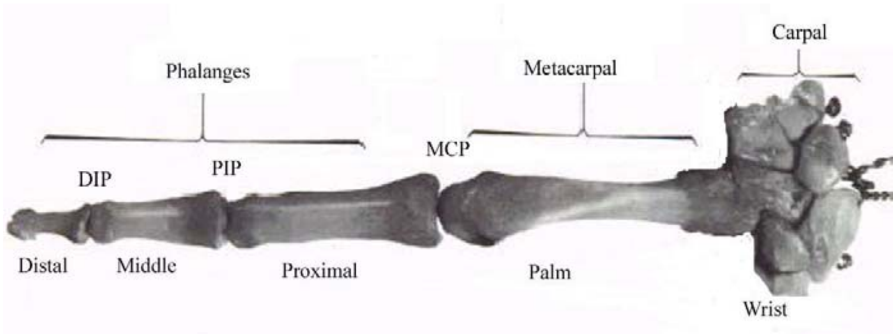


Figure 1
The anatomical palm-finger system

2 Modeling by Simulink

The model was created using the SimMechaniks Tools of Simulink (Figure 2), which assumes that all systems are made of bodies with different DoFs, specific positions, orientations and masses. This model can be used to simulate de flexion and extension motions of the middle finger, when the wrist motion and the adduction/abduction motion are irrelevant. This is the reason why 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), and the PIP and DIP joints are modeled using Revolute blocks, also. 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 the fingertip is captured using a Position Sensor block and plotted using a Scope block.

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.

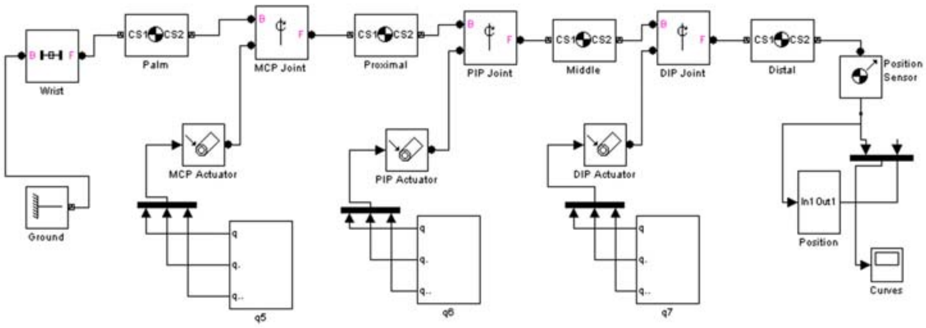
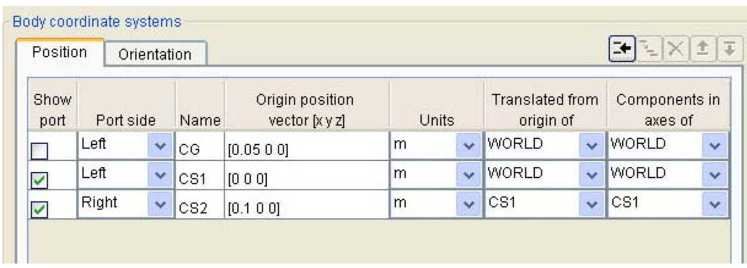


Figure 2
The Simulink model of the middle finger

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 two links: one with the wrist, and the other with the MCP joint. Each of this links has to have a CS (Figure 3). 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 has the origin translated with 0.1 m on *Ox* direction, meaning the palm's length.



Show port	Port side	Name	Origin position vector [x y z]	Units	Translated from origin of	Components in axes of
☐	Left	CG	[0.05 0 0]	m	WORLD	WORLD
☑	Left	CS1	[0 0 0]	m	WORLD	WORLD
☑	Right	CS2	[0.1 0 0]	m	CS1	CS1

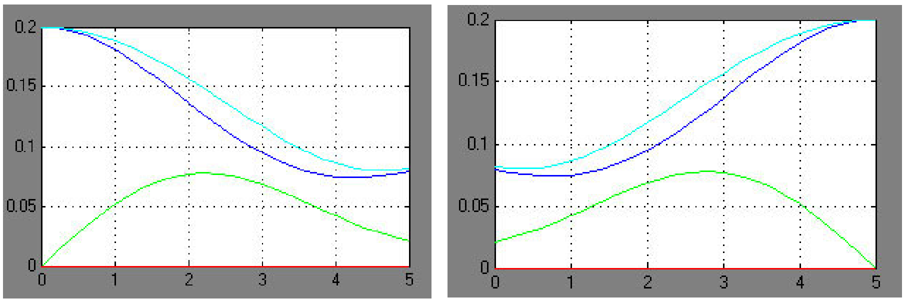
Figure 3
The CSs specification of the Palm body links

The motion of the system goes around *Oz*, in *xOy* plan. The anatomical constraints of the natural system motion where fulfilled:

- the movable joints are actuated using the correct angular value, generated by the blocks named q_5, q_6 and q_7;
- the actuation is made simultaneously for all movable joints for a natural motion.

3 Motion Study

The curves for flexion and extension motions obtained using the model form Figure 2 are depicted in Figure 4. It can be seen that the motion is planar (*xOy* plan), like the natural one.



a) b)

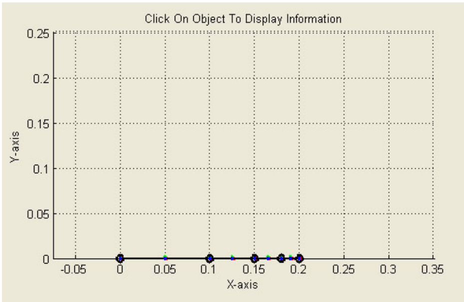
Figure 4
Motions of the middle finger: a) flexion, b) extension

One of the greatest facilities of Simulink is that it can provide graphical visualization of a model. So, Figure 5 plots six phases from the flexion motion of the finger, depicted from the *xOy* plan point of view:

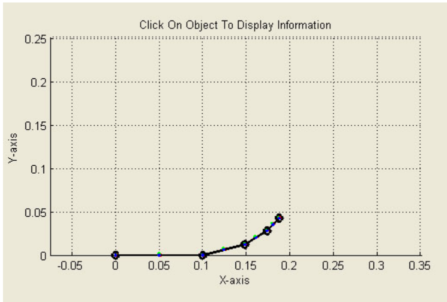
- full extension a);
- intermediate positions b) – f);
- full flexion f).

In the same way, also from the *xOy* plan point of view, Figure 6 plots, six phases, from the extension motion of the finger, between full flexion a) and full extension f).

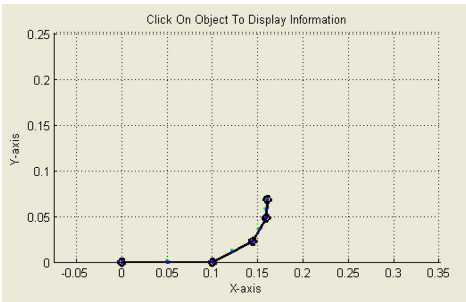
From both figures (Figure 5 and Figure 6) it can be seen that the motion of the system is natural like. To flex the finger starting from the full extension (when on *Ox* it can be seen the length of the system) every movable joint is actuated with a corresponding value and every phalanges is moving accordingly until the full flexion. The trajectory of the fingertip is the one depicted in Figure 4a).



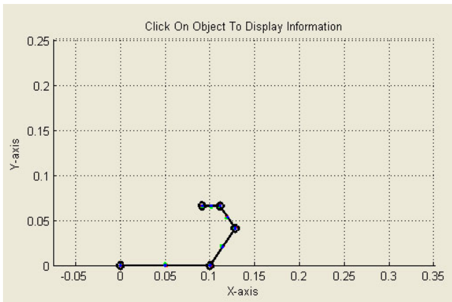
a)



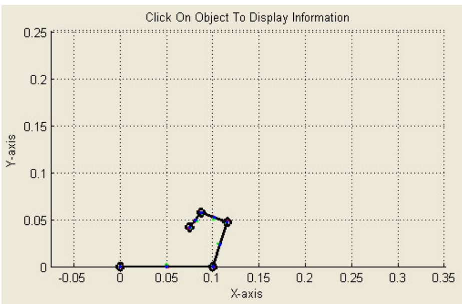
b)



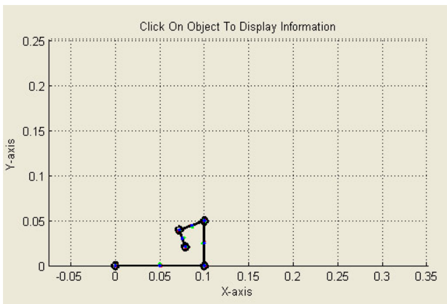
c)



d)



e)



f)

Figure 5
Middle finger flexion

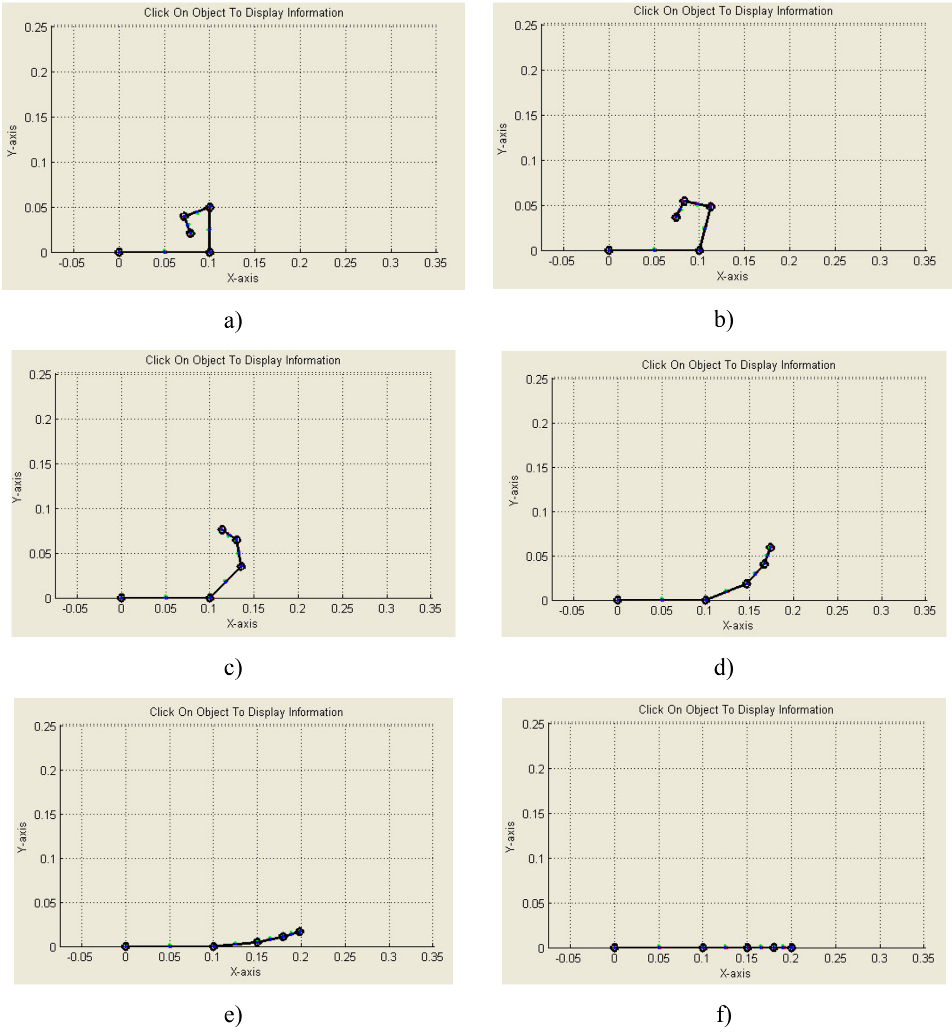


Figure 6
Middle finger extension

Conclusions

The study of the human hand can offer interesting solutions for the human hand prosthesis development or in fields like computer animation or gesture recognition. The model presented in this paper is an anatomical one, having the same elements and the same motions. It can be successfully used to develop a functional prototype capable to copy as much as possible the natural model. The developer will have to decide what components should be used in order to obtain a cost-efficient and useful prosthesis so the patients will be eager to wear it.

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