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Research on upper limb biomechanical system

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ABSTRACT

Biomechanical systems for human upper limb have been studied and developed for more than 60 years, due to requirements of improving life quality for people who cannot partially, or totally, use their hand. This paper presents aspects related to preliminary research (kinematic model of thumb, 3D mechanic model, hard-software platform) of a bionic hand that will be done and is intended to be of high sensitivity, good accuracy, low weight, friendly user interface, with efficient command and control system.

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1. Introduction

Biomechanics is an interdisciplinary field that applies the principles of physics to biological systems to understand how organism move and interact with their surroundings [7]. This term, first used in 1899, comes from Ancient Greek βίος *bios* "life" and μηχανική, *mēchanikē* "mechanics" [8],

There are similar definitions of this term, out of which some are mentioned next;

- study of the mechanics of living body, especially of the forces exerted by muscles and gravity on the s keletal structure [9];
- development of prostheses [9];
- mechanics of biological and especially muscular activity (as in locomotion or exercise)[10];
- science of movement of a living body, including how muscles, bones, tendons, and ligaments work together to produce movement [11].

Modern biomechanics has countless advantages over the pioneering period. Nowadays technology can provide insights and measurements that science has never been able to achieve before. For example, a better understanding of nerve impulses came after the invention of EEG (a test in which a computer monitors electrical signals passing between cells). Further advances in microbiology and chemistry have highlighted the internal microscopic structure of the muscles. This enables having a complete and clear picture of the body and how it works.

Most of it, currently, organs can be produced by 3D printing techniques, so that biomechanics applications and benefits expand quickly. Special software systems for biomechanics are used so that design, 3D modeling, simulation and experimentation of biomechanical systems can be efficiently achieved, under the conditions of customized prototyping / manufacturing.

The biomechanical / bionic hand is aimed at improving life quality of persons who, from various reasons, do not (any longer) have this limb. There are over 60 years of studies on the topic, resulting in improvements of functionality, maneuverability and reliability of upper limb prosthesis. From another point of view, biomechanical hand can be used for maneuverability in dangerous environmental or, places difficult to reach, case when command and control are done by real human hand and computer.

This paper presents aspects on preliminary research and design of an upper limb biomechanical system, more specifically, prosthesis for people who do not (any longer) have upper limb. It would be light weight, provide accurate motions, ensure life comfort for person having it and, not least, affordable from the point of view of costs and expenses.

2. Basis on Kinematic Analysis of Biomechanical System for Hand Finger

The anatomy of upper limb is evidenced in Fig. 1 [1], where one can notice the three major parts that are: upper-arm, forearm and hand. Basic kinematic schemes of finger clamping system are presented in Fig. 2 [4] and are considered useful as basis of this research.

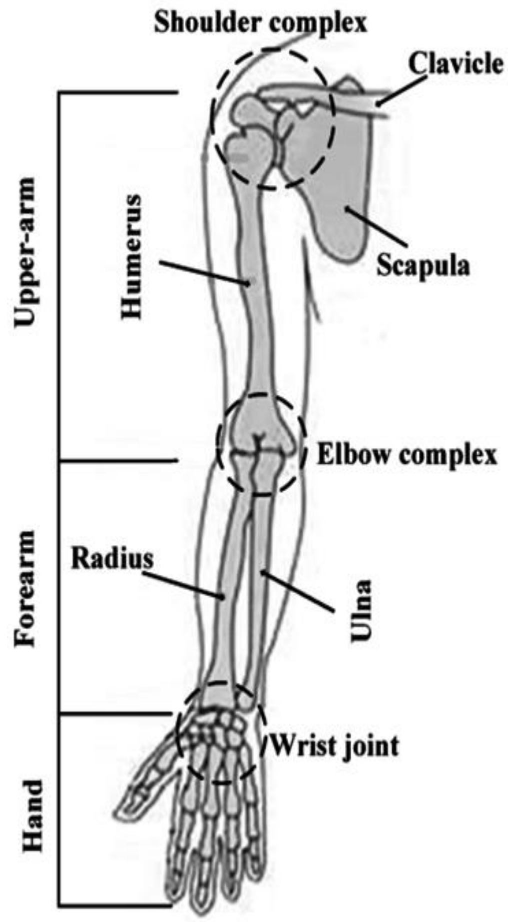
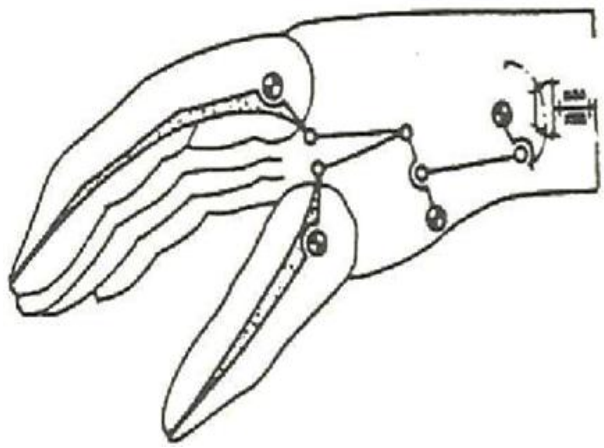
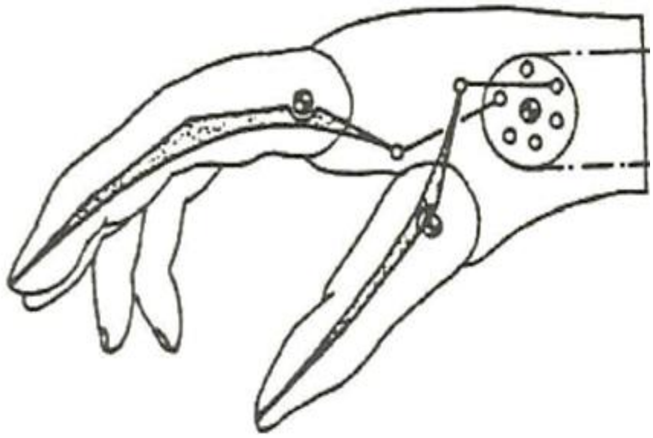


Figure 1. Human upper limb anatomy structure **[1]**

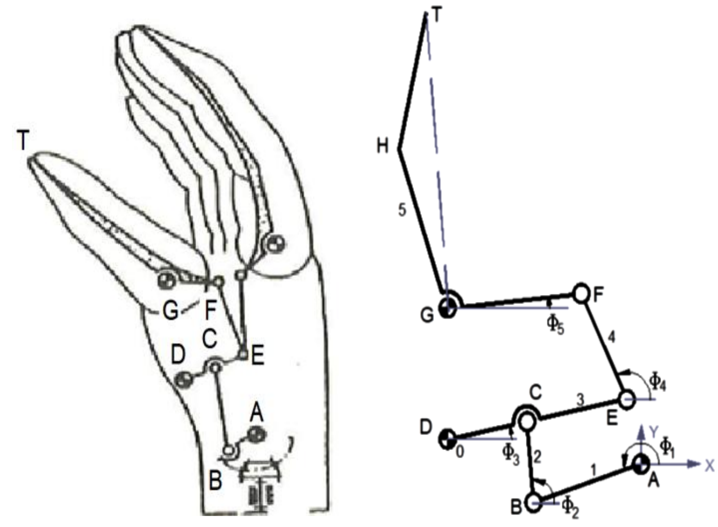


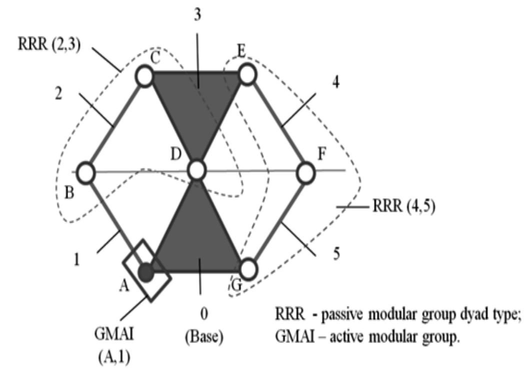
(Hufner, 1917)



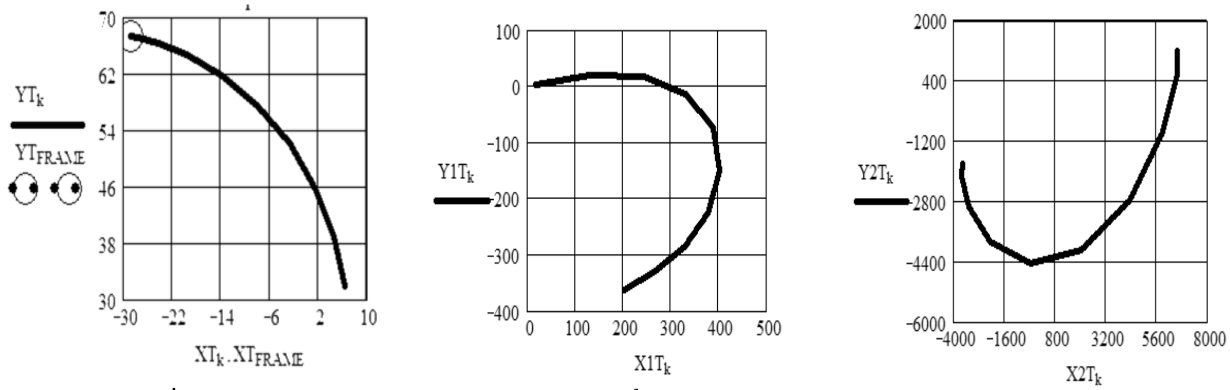
(M.M., 1925)

Figure 2. Kinematic schemes of finger clamping system [4]





a. Kinematic scheme for one phalanx thumb b. Structural model – WATT kinematic chain



trajectory speed acceleration

c. Kinematic analysis plot results, for thumb point, T – trajectory, speed and acceleration

Figure 3. Basic kinematic analysis for thumb with one phalanx – based on Hufner kinematic scheme

Based on the above kinematic scheme (Hufner, 1917), a brief and basic kinematic study on thumb (with one phalanx) has been done. The arch shape trajectory of its upper point (T), as well as its associated speed and acceleration were plotted (with Mathcad software– free version) – see Fig. 3.

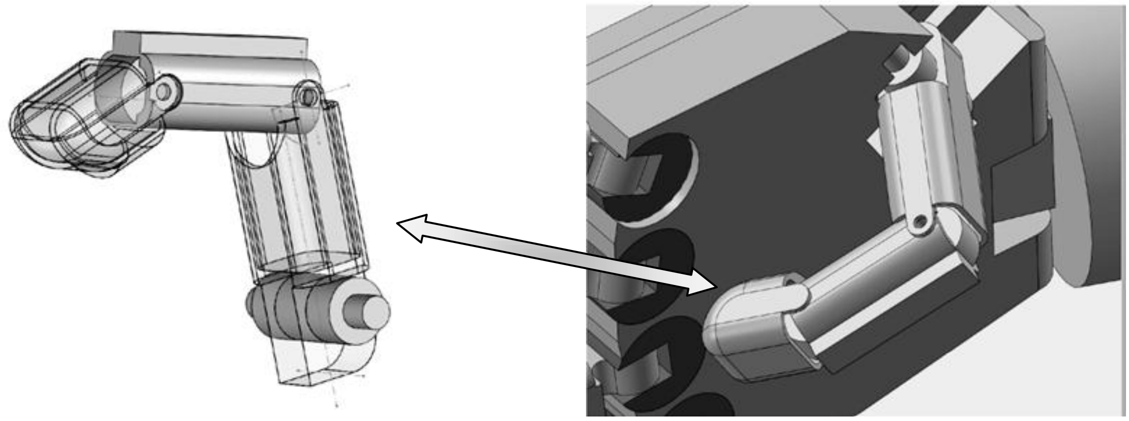
3. Preliminary 3D Model of Upper Limb Biomechanical System

Preliminary design of upper limb biomechanical system has been done. This refers to a prosthesis for the upper-arm (below shoulder), forearm and hand. It is mentioned that this proposed model is not yet completely defined. Thus, kinematic analysis of its components (finger, hand, forearm) would further be done, once all component elements, as well as their geometric dimensions will be set.
Final validation of the upper limb biomechanical system will de done after 3D printing of mechanical components, sensors mounting and setup of correlated command and control system.

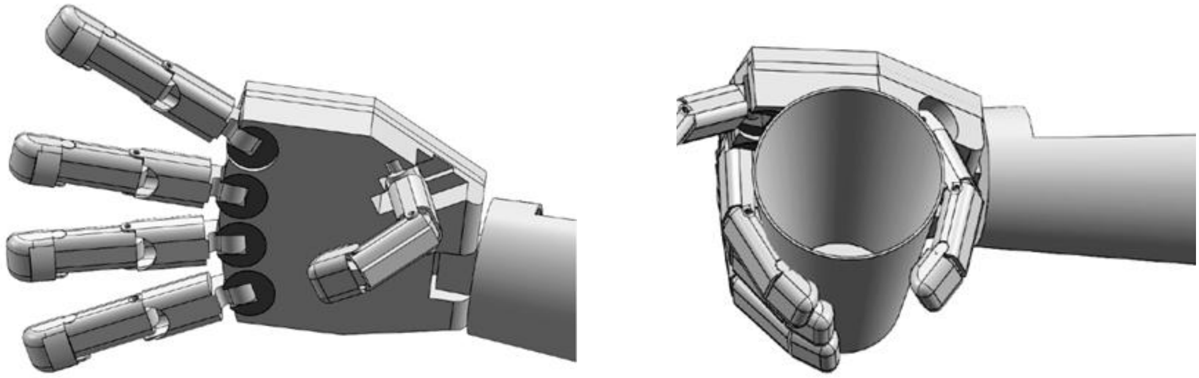
The preliminary 3D model was designed based on real person physical upper limb dimensions and aided by SolidWorks software (free-version). Some features of this proposed model are as follows:

- each finger (three phalanges) is supposed to have independent rotational motions, around each of the OX and, respectively, OZ axes.;
- the forearm and hand do also have independent motions, meaning rotations around OY and OZ axes.

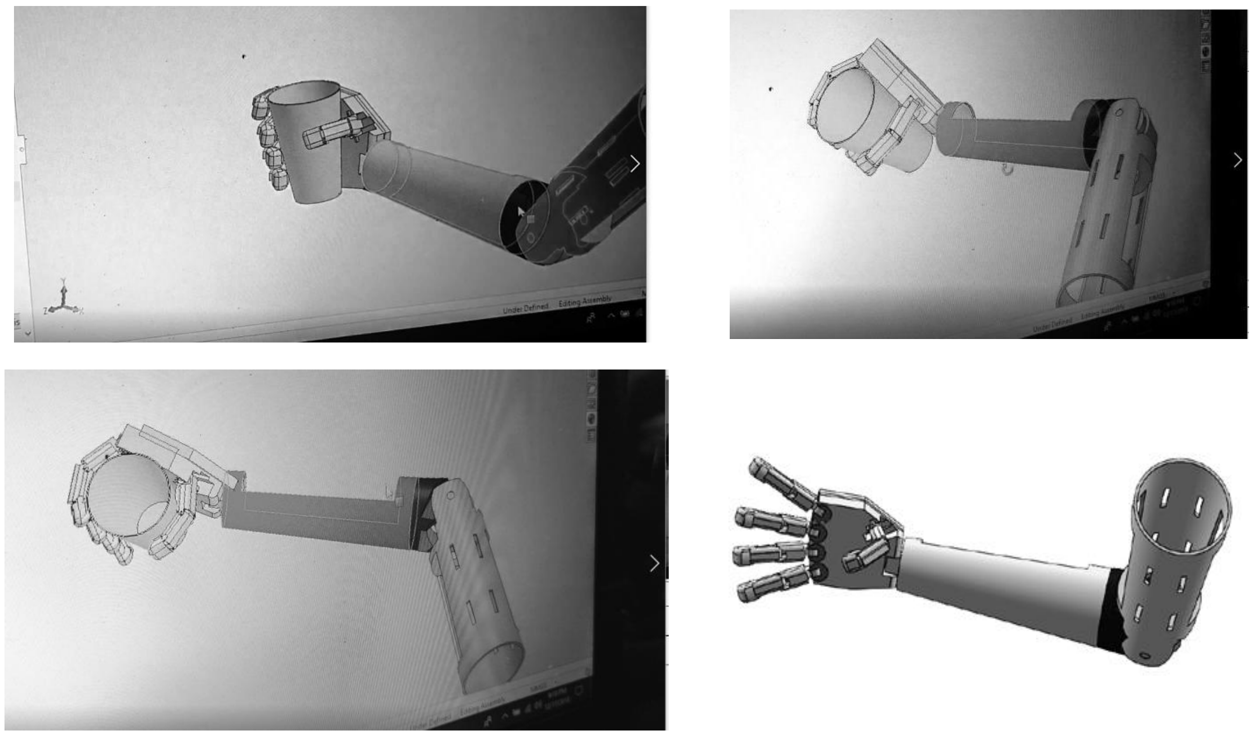
Images of the 3D model are presented in Fig. 4.



a. Thumb



b. Hand



c. Hand, forearm and lower part of upper-arm

Figure 4. The 3D model of upper limb biomechanical system

4. Hardware Model

Relatively normal life for a person using upper limb prosthesis would be possible only if this biomechanical system makes possible motions similar to the ones of a normal upper limb. This involves special electronic, electromechanical and mechanical components like: sensors, actuators, servo-motors, controllers, gears, pulley, cables, special light-weight materials etc., used in many other applications [2], [3]. Starting from similar achievements [5], [6], there was developed the architecture of upper limb biomechanical system (ULBS) - see Fig. 5. There is to be mentioned that: input transducers perform sensory functions (simulating the function of sensory nerves), bringing information from the muscle to the brain; motion is done by micro-motors and actuators (simulating the motor nerves function), bringing information to muscles. All data are integrated into a hardware-software processing system.

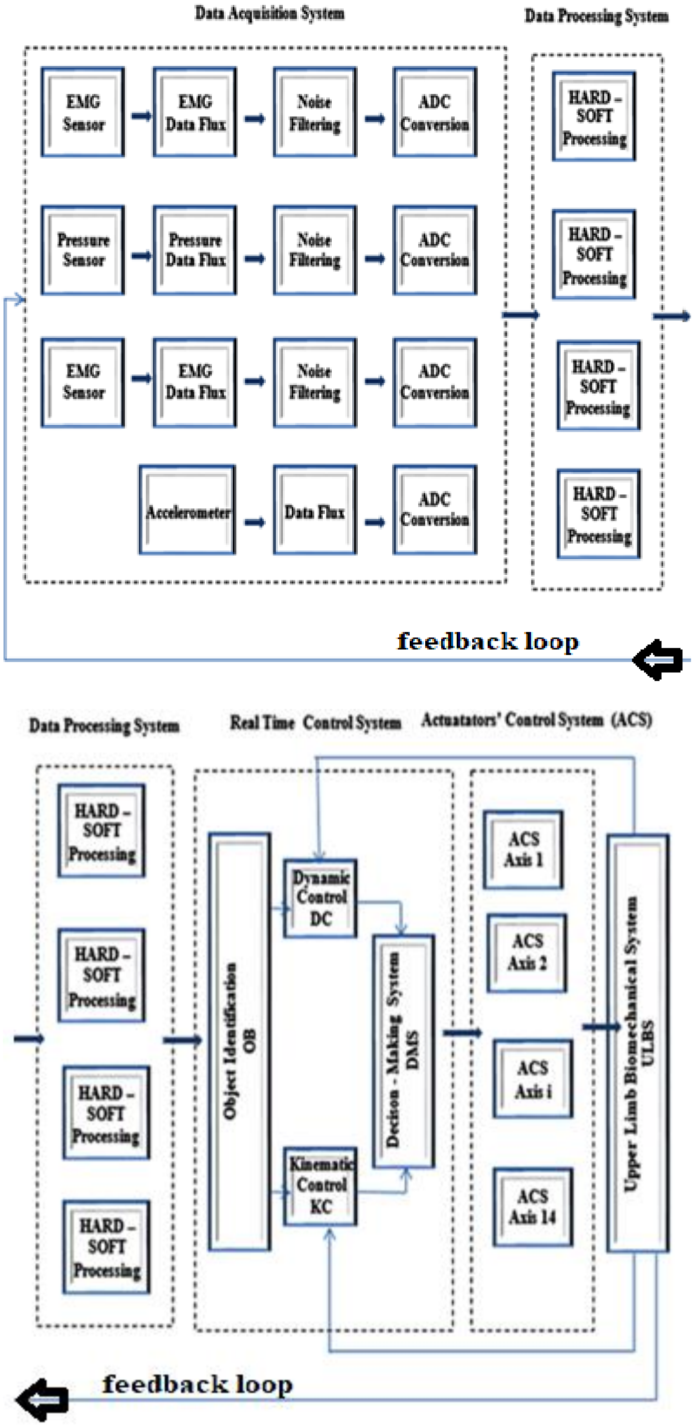


Figure 5. Architecture of the Upper Limb System

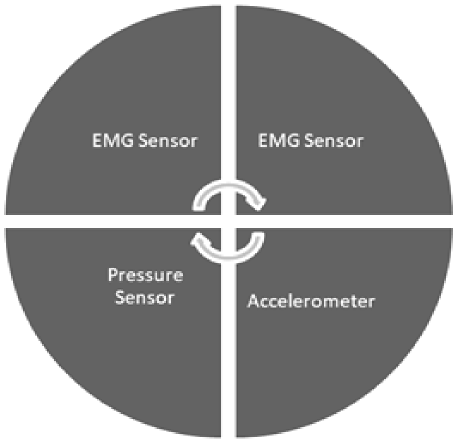


Figure 6. Block diagram of sensors' scanning

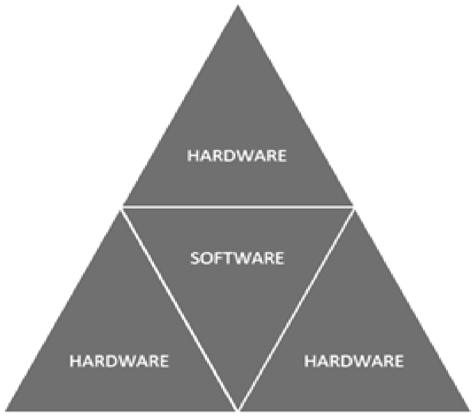


Figure 7. Hardware-software hierarchical scheme

There are to be involved many types of sensors, so that all required functions to be done, as follows.

- EMG sensors – for detection of electrical potential of muscles. The signal is taken by an electrode placed on skin, positioned perpendicularly on muscle path. This sensor type is used for coordinating motions of upper-arm and forearm.
- Pressure sensors – are potentiometric ones and mounted on / within phalanges of the fingers. In correlation to actuators and tensile cables they will do the gripping.
- Acceleration and gyration sensors - ensure motion and position hand, forearm and upper-arm.

These devices will be integrated within a hardware-software platform. All data flux, perceived and transmitted by sensors are processed (filtered, converted, hard-soft) so that, finally, reliable control of ULBS motions. Block diagram of the above mentioned sensor scanning is shown in Fig 6, while the hierarchical scheme is evidenced by Fig. 7.

5. Conclusion

Some aspects related to preliminary research on biomechanical system for upper limb (bionic hand) are presented. This system is intended to be of high sensitivity, with efficient command and control system, of good accuracy, as well as low weight, friendly user interface. Kinematic analysis for thumb with one phalanx has been considered worth presenting, as basis for research.

Further development of this work would involve rapid prototyping of mechanical components, sensors mounting, as well as actuators and servo-motors programming, finally tests and results validation.

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