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Simplifying user interaction solutions for the FUM Bionic Hand-I

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***Abstract*— The advancement of technology has enabled new functions and possibilities for prosthetic devices. This advancement has introduced additional complexities for the user of the prosthetic devices. The added complexities can actually force the user to use simpler passive prosthesis rather than more complex and more flexible ones. This paper discussed the various aspects of the FUM Bionic Hand-I, designed and built at the Ferdowsi University of Mashhad. It also discusses the various efforts placed to simplify the usage of this prosthesis by its user. The FUM Bionic Hand-I has 5 degrees of freedom and consists of several sub systems such as pattern learning glove, wireless EMG Signal transmitter, RFID system for identify objects and a rich graphical user interface (GUI). These features works simultaneously in order to minimize the users' efforts on control a prosthetics hand and makes the hand intelligent enough to cooperate with user. Finally, the paper discusses the force control capability of the hand in order to allow object grasping.**

Keywords*— FUM Bionic Hand-I; Prosthesis hand; teaching glove; GUI; EMG Signal Transmitter.

I. INTRODUCTION

Disable people expect their artificial limb to have high functionality as if it is a real part of their own bodies. To achieve this, researcher have presented many control systems for prosthetic hands. However, the prosthesis' dexterity is still far away from the actual human hands. The design and control of these prostheses are strictly limited due to technology [1]. In the course of evolution of artificial limb, the micro DC motors has replaced the mechanical cable.

The early hand prosthesis devices initially had one degree of freedom. However, with the development of science, several degrees of freedoms, DoF, were added with EMG signals to move the desired fingers [2]. Newly, prosthetic hands with the ability to move each finger independently are now commercially available. The first supplier of modern prosthetic hands was Touch Bionics whose I-Limb product offers a hand with fingers being capable of independent movement [3]. The RSL Steeper Company presented the Bebionic hand. This hand is similar to the I-Limb in aspect of design, but its cost is less than that of I-Limb [4]. These two companies also launched several software that helps the user to interact with their hands and allows customizations [3] [4]. Aside from the commercial world, there exists many research studies on the prosthetic hands. As good example of such investment in research on prosthetics hands belongs to the DARPA organization. In the past few years, this organization has invested hugely on the research of artificial limb to help and helped a vast number of soldiers having lost their hands on the battlefield. As a result of DARPA's investments two artificial upper limbs named DEKA and APL were developed [5]. These two hands are capable of closely match simply human hand motions. They also include a GUI software to help the user customize the prosthetic behavior. These prostheses are the most advanced of its kind. In the recent advancement of DARPA research, they have embedded RFID capsules in the remaining muscles of the amputee soldiers. This

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invasive technology allows them to detect patterns of muscle movement in order to move the corresponding fingers [5] [6]. The advancing in mechanical and electronic devices, enables the more complex prosthetics. Therefore, advanced and friendlier GUIs are needed to enable the user to control their own prosthetic hands. For example, the “my I-limb”™ android and iOS mobile application allow the users to quickly access features on the I-limb prosthetics. For example, the user can monitor the received EMG signals to calibrate his own muscles and choose his desired gesture among pre-defined gestures see Fig.1 and Fig.2 [7]. The successful and commercial BeBionic prosthetic hand, lack the smartphone GUI application. However, it has a PC based GUI to monitor EMG signal and setup custom gestures similar to the I-limb smartphone application [3] [8].

Yu Su te. Al, presented a 3D motion system and a Data-Glove with the goal of simplifying the usage of prosthetics hands. This allows them to estimate movements of the real fingers by recording a sequence of forearm EMG signals and transmitting them to a PC via PC sound card. The “Data-Glove” consist of 11 tiny electromagnetic sensors to capture corresponding human hand postures in real-time. The collected data are used to shape a 3D model in a PC. See Fig.3. Utilizing the collected information, the user can control every fingers of their prosthetics hand [9] [10] [11]. Several different researches and applications exists on interfacing MATLAB based GUI’s with prosthetics hands [12] [13]. In [14], the researchers presented a skeleton arm and graphically moved it in the VRML and MATLAB software [15]. Using this technique, certain motions are supported like arm flexion/extension, arm adduction/abduction and forearm flexion/extension. The GUI has been developed where a set of forces applied by the muscles are parameterized and the upper limb motion animation, in live time, is achieved through Biomechanics equations see Fig.4. A number of other investigators directed their efforts to extract patterns of EEG signals from the brain [16].In the present paper, the FUM Bionic Hand-I is used. It covers the various components of this hand allowing a simple and adaptive user interactive system resulting in a low-cost bionic hand for daily usage.

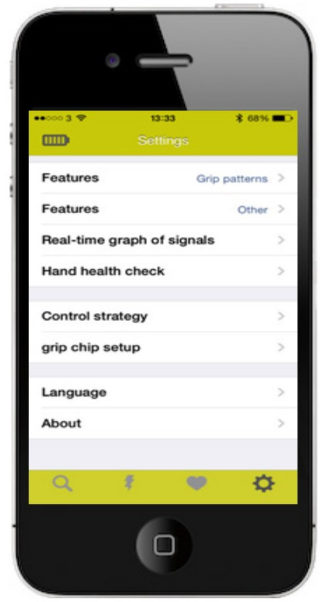

Fig.1.An example of I-limb ios mobile GUI

Fig.2.An example of I-limb Win PC GUI

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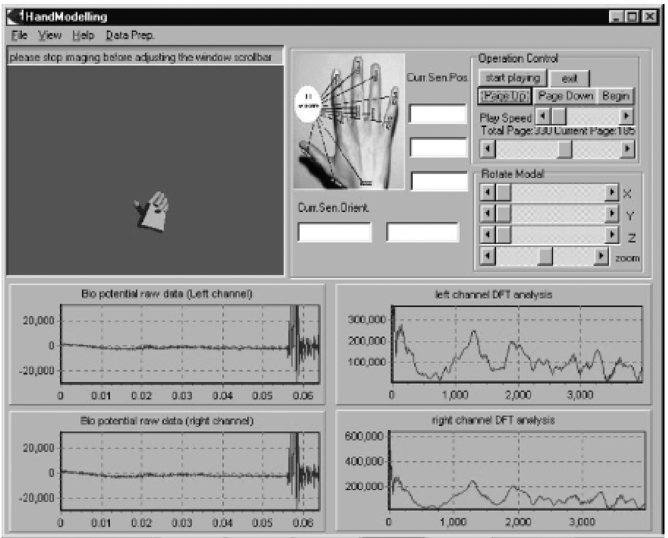

Fig.3. GUI of the simultaneous data recording

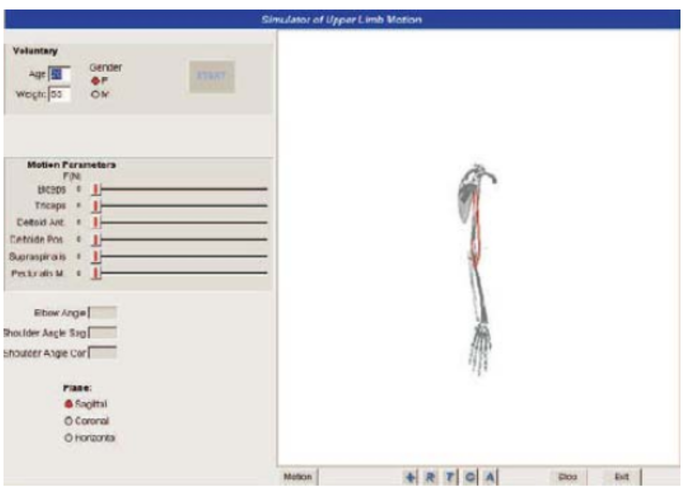

Fig.4. Human Upper limb in a System GUI

II. The FUM Bionic Hand-I

The FUM Bionic Hand-I is the first version of prosthesis hand designed and built in the Advanced Robotics Lab. of the Ferdowsi University of Mashhad. It has five degrees of freedom and weighs about 700grams. All the electronics and mechanical parts except the batteries are placed in palm of the hand in order to minimize the overall used space. The all-inclusive electronics and hand mechanics in the hand itself, offers adequate space for the batteries. This allows a rather larger battery size which in turn results in longer battery life for the hand See Fig. 5. As shown in Fig. 6, fingers are designed as a three-knuckle mechanism. Nylon monofilament wires are used as tendons to couple the three knuckles of each finger. The thumb finger is placed on the palm of the prosthesis and has only one DoF. In order to design a prosthetic hand for the local population of Iran, a small available data set was used. The mean and standard deviation of the data set for both male and female population.

As stated in the literature the normal angular velocity of each joint for human hand is about 3 to 4 radians per second (roughly between 28.6 to 38.2 rotations per minute) and a torque of nearly 193 (mN.m) [17]. To reach these goals, ZGA12 micro motors, manufactured by Zheng was selected. The selected motors provide good torques and speeds along with small footprints suitable to fit in our prosthetic hand see Fig.5.

One of the main challenges in operationalizing the prosthetic hand was to design a customized and small electronic circuit with low power consumption and high noise immunity. Electronic system of this prosthetic hand can be categorized into 3 sub-systems, main processor, motion controller board and EMG signal processor and transmitter. In the main controller sub-system, a powerful microcontroller, STM32F407VGT6, is used which is capable of performing 210 million instructions per second. Thanks to its industrial and automotive grade, the microcontroller benefits from high noise immune [18]. In motion controller sub-system, six fully separated channels with maximum power of 24watt per channel are considered. All the components in circuit design were surface mounted devices to minimize the footprint space see Fig.7. In the EMG Signal processor sub-system, the EMG signals, provided by muscle neurons, are used to determine muscle activities so as to control the prosthetics hand movements. It is the first human to machine interface of FUM Bionic hand, through which user can interact directly with his prosthetic hand. FUM Bionic Hand-I uses only one channel of EMG signals to interact with user. However, it is clear that using one channel of EMG is not sufficient for controlling a complex prosthetics hand with 5 DoFs. On the other hand using more than one channel of EMG signals needs High efforts and focuses by the user and brings more complexity to the control. Therefore, this is not a user friendly choice. To overcome the complexity and bringing simplicity the following interactive system of Fig. 8 is suggested.

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A. PC and Smart phone GUI

Users need customizability and portability in their prosthetics hands. Considering a PC based GUI is a good option for customization but clearly disabled people cannot have their PCs with them all the day. So having an alternative GUI on their smartphone was our choice. The smartphone application of FUM Bionic Hand-I, has some useful features for users like monitoring and re-calibration of EMG signals, gesture learning and customization program and the battery level indicator. Having these interesting features makes the FUM Bionic Hand-I hand reliable enough for daily usages (see Fig.9 and Fig.10).

B. RFID technology to detect objects

RFID tags are known for their unique serial numbers and their contactless reading assets. This feature of the RFID tags is used to determine the type of the object, being approached. The prosthetic hand can then make the corresponding gesture according to the previously learned data. Whenever user wants to add a new object type to the system, he/she can place the tag on desired object and teach system about that tag. Afterwards whenever prosthetics hand approaches that specific tag, it takes related gesture according to previously learned data.

C. Gesture customization and learning system

FUM Bionic Hand-I is capable of detecting objects and making corresponding gestures. It can learn about different gestures by its pattern learning glove and user can customize the gestures or categorize them for future usage in GUI.

D. Force control

In prosthetic hands in order to grab and hold objects, estimation of the force is required. A control system has been implemented to control the output force of motor using applied current to each motor. In order to measure the current of DC motors, current shunt resistors have been placed in current flow. The total resistance of those shunt resistors was about 1 ohm which makes about 250mv voltage drop across them. As shown in Fig.11, a current shunt amplifier, MAX9918, has been used to amplify the voltage.

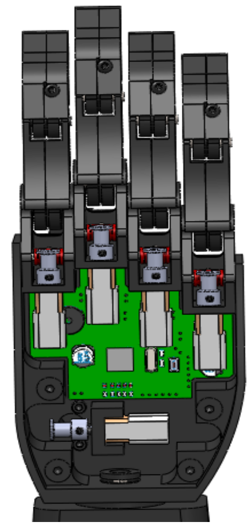

Fig.5. All DC Micro motors and electronic boards have been placed in the palm

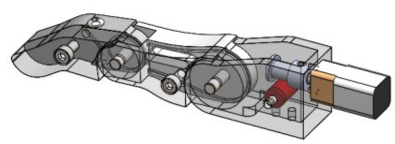

Fig.6. fingers are designed as three-knuckle

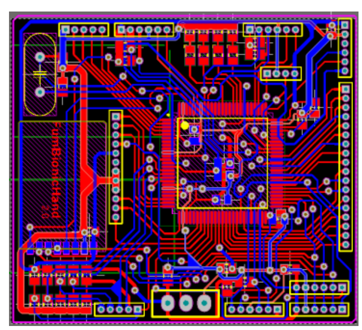

Fig.7. PCB board of main processor

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Fig.8. Connections of hand prosthesis

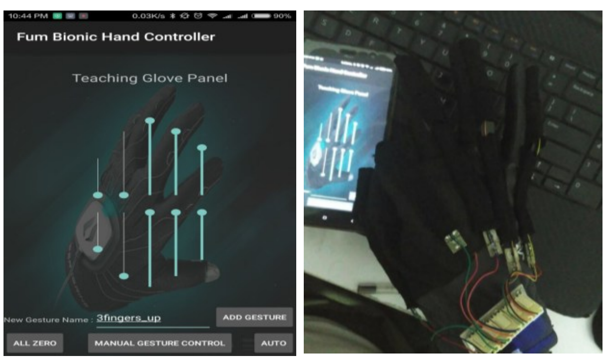

Fig.9.Glove glow pattern and its relationship with the mobile GUI

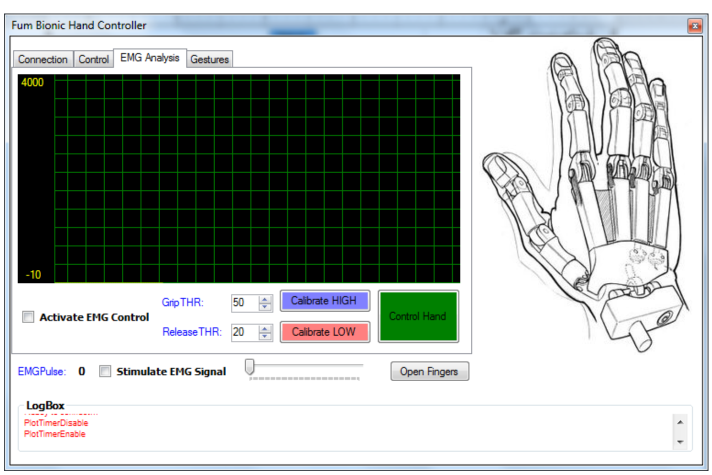

Fig.10. The GUI PC

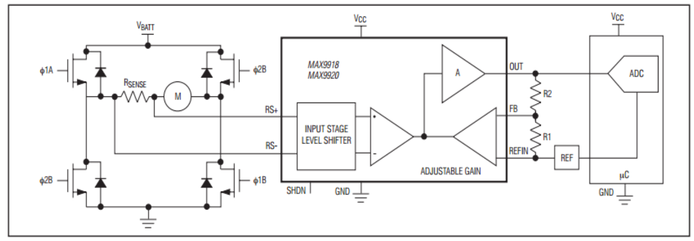

Fig.11. Schematic of current control circuit

IV. CONCLUSION

The team of Bionic Hand at the Ferdowsi University of Mashhad spend over 22 months to do intelligence design and bring ease of use to the FUM Bionic Hand-I. This hand has five independent fingers and has a relatively low weight see Fig. 12, and Table 1. It offers a simple force control and has additional elements of RFID, Pattern Learning Glove, GUI on both Android and PC and EMG. The combination of all these feature bring added functionality to the hand along with simplicity in use see Fig.13.

The efforts of synchronizing the EMG signal with the motor speed and torque was a good achievement allowing natural functioning of the hand. Despite the common belief of challenges with EMG signal processing, the team was rather successful in recording, filtering and monitoring the EMG signals used in operating the hand. The team discovered that the cable mechanism to drive the motors is not reliable. Additionally, it was learned that current control in order to control the fingertip forces is not dependable. Currently, the team is working on the second version of the hand, the FUM Bionic Hand-II with high reliability and much more human like functionality.

TABLE I. Mechanical specification

Mechanical Specifications							
DOF	Actuation Method	Number of Actuators	Finger Coupling Method	Weight	Dimension (mm)		
					Height	Length	Width
5	DC gear motor	5	Tendon-MCP to PIP phalange	700g	40	206	86

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Fig.12. FUM Bionic Hand-I

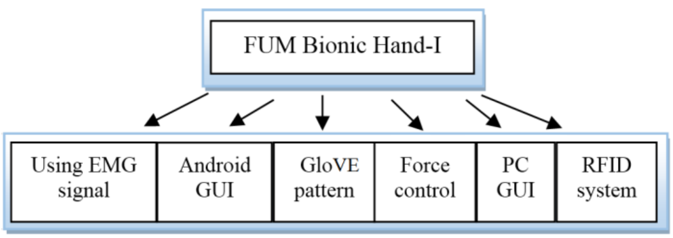

Fig.13.Peripheral equipment of FUM Bionic Hand

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