FORCE CONTROLLED GRASPING IN A TWO FINGER ROBOTIC HAND

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Abstract. One of the most important human senses is the tactile sense – the force or pressure sensing in our hands. Many researches and applications deal with the development of force control in robotics in order to improve the intelligence of robot systems using additional sensing abilities. Within the framework of this development a two finger symmetric robotic hand has been developed. The experimental device is driven by a single DC motor. Both fingers are equipped with strain gauges based force sensors. The controlling hardware has been constructed and manufactured by ourselves that allows easy testing of the different solutions and further development. The control algorithm was programmed in LabVIEW environment. The general goal of this research is the improvement of upper limb prostheses. Force-feedback is necessary, because multi-loop control with visual feedback towards the user and position control with inner feedback loop are not sufficient for the implementation of precise motion. The topic of providing a kind of force feedback available directly for the user is a field in which extremely useful results can be achieved, promising extraordinary change in the usability of prosthetic arms.

Introduction

In this paper, an experimental two-finger gripper mechanism will be described, which is intended to improve the usability of robotic hands in the field of medical applications. The objective of a complex project is the development of a five-finger robotic hand with the most comprehensive control system that is possible to implement. To achieve this goal, the components of the control system have to be analyzed. The components of the control system of a medical purpose robotic hand are shown on Fig 1.

The main parts are as follows:

- Visual feedback to user for position control (commonly used)
- Inner position feedback (commonly used)
- Inner force feedback (less common)
- Force feedback to user (very rare/research phase)

The position feedback is always primary compared to the others; however the information obtained by the haptic sense might have the same importance as the position feedback. In many of the cases, force feedback is not available because of its complementary role and the difficulties of implementation. Typically, special control strategies of the position loop are attempted to substitute the force feedback loop [1,2].

In this study, the potential of the inner force feedback will be inspected. At the Budapest University of Technology and Economics, a force feedback robotic gripper has been developed for the experiments [3]. Using the gripper mechanism equipped with strain gauges, the gripping force can be measured. The acquired data is processed by software, programmed in LabVIEW. Not only the control algorithm that can be implemented, but the mathematical model of the entire gripper mechanism, in order to verify the different control strategies before applying them on the apparatus itself.

First, we verify the proper operation of the gripper mechanism by using a conventional force control with a proportional integrating controller. After that, new control strategies can be developed for additional features. By applying fuzzy control, unexpected situations can be handled in case of extremely fragile or soft materials – or, in possession of the mechanical characteristics of different types of objects – the material, of the handled object can be estimated, just as the proper strategy of grasping; taking advantage of the possibilities of pattern recognition [4] is gaining ground - a step towards cognitive systems.

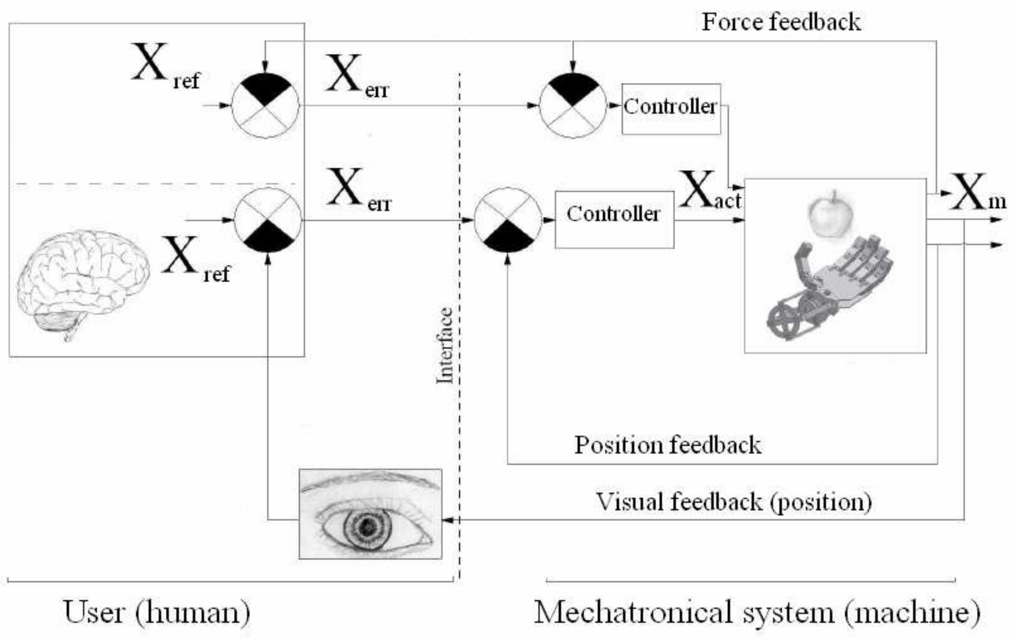

Fig. 1. The control system of an artificial hand

The experimental setup

The main unit of the experimental device is the two-finger gripper mechanism itself (shown on Fig 2). The gripper is driven by a single DC motor; the state variables that can be measured are the gripping force by two strain gauges and the motor rotational speed by a Hall-sensor. An additional unit for the measurement of the position is under development.

Currently, the gripper is able to perform the tasks of the inner force feedback control loop shown on the upper right corner of Figure 1; completed with the measurement of rotational speed and position can expand the possibilities of feasible functions of the experimental device.

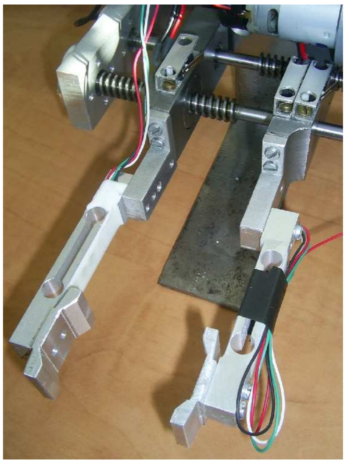

Fig. 2. The construction of the gripper mechanism

The further units shown on Figure 3. are needed to control the gripper. First, a precision instrumental amplifier circuit, and a bidirectional motor controller circuit are necessary in order to create the conditions for measurement and actuation. Since the strain gauges have differential outputs and the voltage range is between ±10mV, the instrumental amplifier has to be precise and must be equipped with proper noise filtering (in addition, digital filtering shall be applied after sampling). We use a three-operational-amplifier circuit for the measurement, as it has high reliability yet easy to manufacture.

The inputs for sampling and outputs for actuation are made available by a National Instruments USB-6008 data acquisition I/O unit. With this equipment, the analogue-digital and the digital/analogue conversion and the connectivity with a personal computer are possible also. The software of the control algorithm is running on the PC, what can raise issues about the speed of the control system; since the speed of the I/O unit is 10 kSample/sec, the speed necessary for the software is easily accessible including all signal processing procedures needed.

The software has built-in controlling toolbox, however self-developed control algorithms can be implemented also. The connection with the data acquisition device is pre-constructed; the focus of development can be merely the elaboration of the control strategy for the grasping procedure.

Fig. 3. The experimental setup

Mathematical model and simulation environment

As it was mentioned earlier, the verification of different control strategies is an important phase of the research. The mathematical model can be described in two phases; first, a simple, linearized model has been created, then the non-linear components can be added to the numerical simulation.

From the structure graph, the differential equations of the system can be achieved; after adding the non-linear components, the mathematical model is ready for testing. With this method, a suitable model can be implemented; however the development of a state-space model is planned for more accurate results. The linear part of the mathematical model can be described by the structure graph of each unit (Figure 4.):

- DC motor
- Gear with flexible shafts
- Thread spindle
- Flexible levers

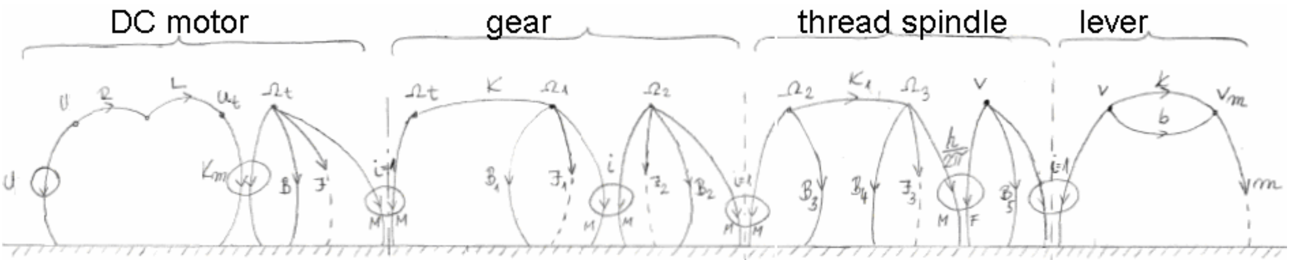

Fig 4. The linearized model

The most conspicuous non-linear behavior is the chuck of the gears. Because of this effect, constant gripping force can be measured however the levers are moving. In this case, the pertinence of the action is cannot be verified without additional information or special control strategy. By increasing the robustness of the control software, the undesired effect of non-linear parts can be avoided, and the system can handle unforeseen events or malfunctions.

One way of giving the software the desired robustness is the application of fuzzy control. Since the approprite action is influenced by many circumstances, the efficient way for the regulation is the application of numerous if – then type fuzzy rules. By applying the rules, the controller can determine the action suitable for the highest amount of rules. Fuzzy logic control is a well-developed field of science, but it provides infinite approaches in particular tasks just as robotic grippers [5].

The fuzzy control is helpful not only by the means of the feedbacks on the machine side; it can be applied developing a human-machine interface. The EMG signals controlling robotic hands used as prostheses are often processed by neuro-fuzzy algorithms, exactly for the facilitation of controlling by the means of pattern recognition [6].

The most effective tool for the implementation of the numerical simulation and the control algorithms is the National Instruments LabVIEW (Figure 5.); a considerable number of other studies also use it for modeling and simulation tasks regarding robotic grippers and force feedback [7,8]. Bulit-in control and simulation tools have been used to implement some features and data communication, but self-developed subroutines were necessary for special purposes, e.g. the non-linear behaviour of the gears. Based on the information provided by the simulations, the expected operation of the manufactured gripper mechanism can be estimated without endangering the device.

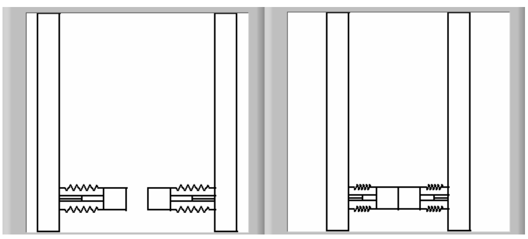

Fig 5. Detail of the software GUI

Conclusion

The paper presented an experiment designed to improve the abilities of gripper mechanisms, particularly in the field of medical applications. Different force-feedback control strategies can be implemented using the experimental setup – furthermore – the algorithms can be verified using the simulation environment implemented in LabVIEW.

The information obtained from the experiments will be utilized in future projects on the way towards the main goal – the development of a fully functional five-finger robotic hand.

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