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Modeling and simulation of robotic hand pressure sensor in Simscape

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Abstract

The main advantage of humanoid robots over other devices is that they are more flexible and can be used for many purposes. In this project, a human-like robotic hand is designed and used for a task commonly performed by humans, namely grasping an object. During this study, the main focus will be the use of pressure sensors and the interaction between them to create an approach as close to reality as possible. For the various simulations and sensor testing, the Simscape and Solidworks applications were used, respectively, which enable the connection between the sensor and mechanical part of the robotic hand. An Arduino was used to build the algorithms, implement these instructions and control the sensors.

Introduction

Modern robotics is a widely studied field that has been around for many decades. Robots have been used in many fields and for many different applications, such as autonomous vehicles in the automobile industry, in the medical field in robot-assisted surgery, and in the industrial robot manufacturing industry. The list of robot applications comes and grows over time. One segment studied within this emerging community is humanoid robotics. The objective of humanoid robotics is to develop human-like machines that help and protect humans [1-3]. Different research groups, with different approaches, have been engaged in humanoid mechanics and control systems. In this study, the focus will be on the sensor approach to humanoid robotics, namely pressure sensors.

Material and Methods

The development in the field of electronics has reached a high level of integration, increasing the computational capabilities in ordinary objects. The possibilities of inclusion, offered by electronics, are many; digital circuits, actuators and embedded sensors. Industry and science are pushing the devices that are called "wearables".

"Wearable" devices are mainly used to collect information about the user and data related mainly to any physical activity or physiological parameters. Wearability is one of the important points in their design while the focus remains on the reliability of the measurement without hindering the user. Accuracy and reliability play an important role especially in health and sports applications. Force sensors are sensitive to deformations in all directions and are therefore used in conjunction with an electrical circuit, the Wheatstone bridge, which helps amplify a small change in resistance. The most used pressure sensors are FSR (force sensing resistor) often named as piezoelectric sensors or force sensors. They are resistive sensors that rely on different working principles. Force sensors rely on changes in the physical dimensions of the conductor such as; length and width, while resistive force sensors rely on changing the conductivity of the sensor itself. The resistive force sensor changes its resistance in relation to the change in its shape, traction or compression, as a result of the force applied to it. Equations for strain measurement in these types of sensors. $R = \rho \frac{L}{A}$ R (resistance), L (conductor length), A (conductor cross-sectional area)

$FS = \frac{\Delta R / R}{\Delta L / L}$, where FS (mechanical stress factor), ΔL/L = ε

Matlab is a programming and numerical computing platform used by a large number of engineers and scientists for data analysis, development and creation of models. Simscape allows you to create models of physical systems within the Simulink development environment. The models that are created rely on physical connections and can be combined to build schematics. The analysis is done by means of Simscape which defines and solves the system of equations that make up the constructed scheme. Arduino is a low-cost programmable platform, with which you can build "ready" circuits of all kinds for many applications, above all in the field of robotics and automation. It is based on the ATMEL microcontroller, ATMega168/328 [4-7].

Results and Discussions

Robotics enjoys a special interest and a growing demand in many directions; both for humans but also in the automation of industry. Tools like Matlab and Arduino development boards speed up and reduce the cost of building systems by leveraging the capabilities of computing machines. Matlab Simscape is a tool that can be used to solve a variety of problems while Arduino significantly reduces the costs of prototyping systems. The use of Simscape also reduced the calculation time during intermediate tests and since it is built taking into account the physical changes of the connected elements, it brings the simulation part closer to the real world [8-9].

Now we will illustrate the steps of the simulation through figures step by step:

1-The model of a permanent magnet dc electric motor is built by connecting different functional blocks of Simulink. (Figure 1) Demonstrates how signals (information) are converted into physical quantity value changes in Simscape and vice versa. Simscape and Simulink can be used in the realization of schemes, for this Simulink uses conversion blocks to migrate to Simscape.

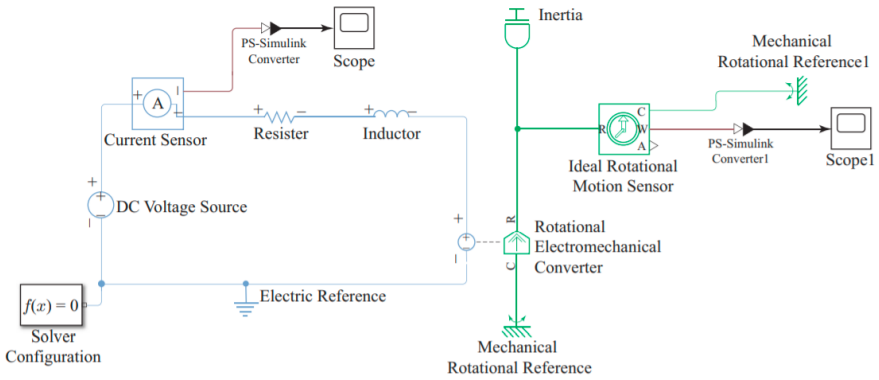

Figure 1. Modeling dc motor in Simscape

2-In Figure 2 (second image) Coupling circuits for the force sensor. Voltage divider circuit using Simscape and Simulink.

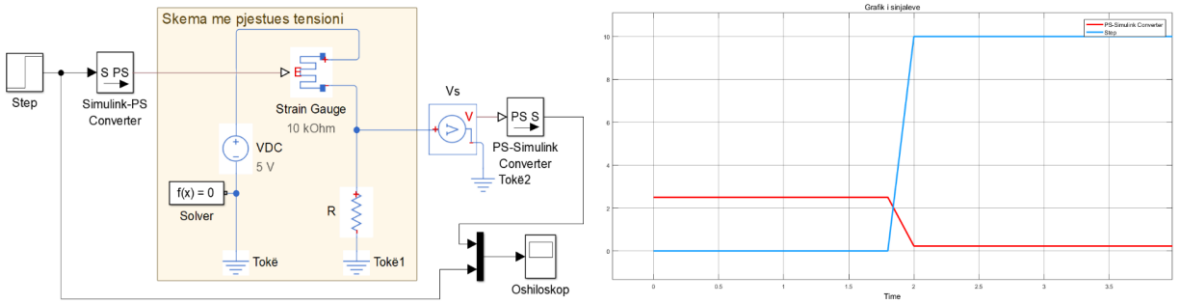

Figure 2. Modeling the force sensor circuit with voltage divider in Simscape.

3- This model shows how to model a pressure sensor together with the measurement made by the amplifier. (Figure 3) The sensor is located in one leg of the Wheatstone bridge, which is connected to a differential amplifier.

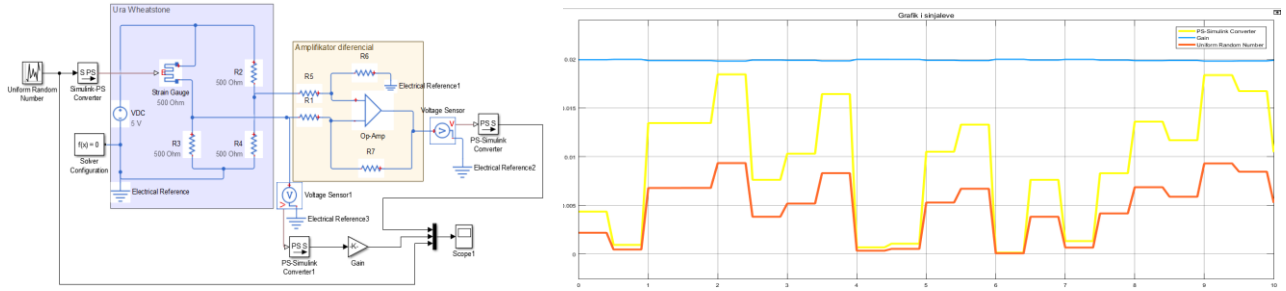

Figure 3. Graphs of simulated signals in Simscape of voltage divider with force sensor and Op. Amp

Results

The table shows (Table 1) the calculated values for the resistive values of the sensor and the resistance of the voltage divider, the voltage value at the output of the divider for the force range exerted on the pressure sensor in the range 0 N – 53.94 N. This force range belongs to the weight range 0 g – 5500g, the requirements are up to 5 kg weight per sensor. The calculations above are needed for circuit design as well as for comparison with real values [10-12].

Table 1. Calculated force sensor values

Force	Mass	R_{FSR}	$R+R_{FSR}$	I_{FSR+R}	V_{out}	V_R
0 N	0 g	Infinit	Infinit	0 mA	5 V	0 V
2.45 N	250 g	100 kΩ	110 kΩ	0.13 mA	2.14 V	1.3 V
4.9 N	500 g	30 kΩ	40 kΩ	0.13 mA	2.14 V	1.3 V
12.75 N	1300 g	15 kΩ	25 kΩ	0.2 mA	1.87 V	2 V
26.48 N	2700 g	10 kΩ	20 kΩ	0.25 mA	1.66 V	2.5 V
49.03 N	5000 g	7 kΩ	17 kΩ	0.29 mA	1.46 V	2.9 V
53.94 N	5500 g	6 kΩ	16 kΩ	0.31 mA	1.36 V	3.1 V

Conclusion

This work attempts to facilitate the classical mathematical modeling of the physical system with the help of Simscape, a tool which uses a physical modeling approach for developing system models.

References

1. Haghshenas-Jaryani, M., Patterson, R. M., Bugnariu, N., & Wijesundara, M. B. (2020). A pilot study on the design and validation of a hybrid exoskeleton robotic device for hand rehabilitation. Journal of Hand Therapy, 33(2), 198-208.
2. Giovanelli, D., & Farella, E. (2016). Force sensing resistor and evaluation of technology for wearable body pressure sensing. Journal of Sensors, 2016, 9391850. https://doi.org/10.1155/2016/9391850
3. Sadun, A. S., Jalani, J., & Sukor, J. A. (2016, July). Force Sensing Resistor (FSR): a brief overview and the low-cost sensor for active compliance control. In First international workshop on pattern recognition (Vol. 10011, pp. 222-226). SPIE.
4. Pajaziti, A., Basholli, F., & Zhaveli, Y. (2023). Identification and classification of fruits through robotic system by using artificial intelligence. Engineering Applications, 2(2), 154-163.
5. Alnajjar, F., Umari, H., Ahmed, W. K., Gochoo, M., Vogan, A. A., Aljumaily, A., ... & Shimoda, S. (2021). CHAD: Compact Hand-Assistive Device for enhancement of function in hand impairments. Robotics and Autonomous Systems, 142, 103784.
6. Saleh, M. A., Soliman, M., Mousa, M. A., Elsamanty, M., & Radwan, A. G. (2020). Design and implementation of variable inclined air pillow soft pneumatic actuator suitable for bioimpedance applications. Sensors and Actuators A: Physical, 314, 112272.
7. Gerez, L., & Liarokapis, M. (2019, July). An underactuated, tendon-driven, wearable exo-glove with a four-output differential mechanism. In 2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) (pp. 6224-6228). IEEE.
8. Metalla, J. & Dume, G. (2012). Speed regulation in "DC motors" through LabVIEW 2012 software - Bachelor's Degree, Albanian University

9. Truby, R. L., Katzschmann, R. K., Lewis, J. A., & Rus, D. (2019, April). Soft robotic fingers with embedded ionogel sensors and discrete actuation modes for somatosensitive manipulation. In 2019 2nd IEEE international conference on soft robotics (RoboSoft) (pp. 322-329). IEEE.
10. Song, K., Kim, S. H., Jin, S., Kim, S., Lee, S., Kim, J. S., ... & Cha, Y. (2019). Pneumatic actuator and flexible piezoelectric sensor for soft virtual reality glove system. Scientific reports, 9(1), 8988.
11. Navarro, S. E., Nagels, S., Alagi, H., Faller, L. M., Goury, O., Morales-Bieze, T., ... & Duriez, C. (2020). A model-based sensor fusion approach for force and shape estimation in soft robotics. IEEE Robotics and Automation Letters, 5(4), 5621-5628.
12. Simscape - MATLAB & Simulink - MathWorks, https://www.mathworks.com/