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Development of Soft Gripper Pneumatic Control System Based on Deep Reinforcement Learning

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Abstract

As interest in soft grippers soared, many studies have been performed to control the soft gripper. For the soft gripper control, a soft gripper model is required first. Usually, the soft gripper modeling has been done through finite element analysis, which takes lots of time and is effective only in limited situations. Therefore, research on deep learning-based modeling with a small amount of FEM results has been extensively conducted, and some satisfactory results have been reported. However, since the model is expressed in the form of a neural network, it is difficult to utilize general control methods, so research on optimal control or deep reinforcement learning is being attempted. In this study, we propose a pneumatic control system for the soft gripper control based on the DRL. To this end, the soft gripper and DRL-based controller are directly developed, and experiments are performed and the results are analyzed.

Introduction

As interest in a soft gripper has recently increased, many studies have been conducted to control the soft gripper[1]. The soft gripper model is required for soft gripper control. In general, soft gripper modeling is done through nonlinear finite element analysis. However, this takes a lot of time and is effective only in limited circumstances. Active research on deep learning-based soft gripper modeling using a small amount of nonlinear finite element analysis results has been conducted. However, the deep learning model is expressed in the form of a neural network, making it difficult to use general control methods[2]. Research on optimal control and control through deep reinforcement learning has been attempted. In this study, we propose a pneumatic control system for soft gripper control based on deep reinforcement learning.

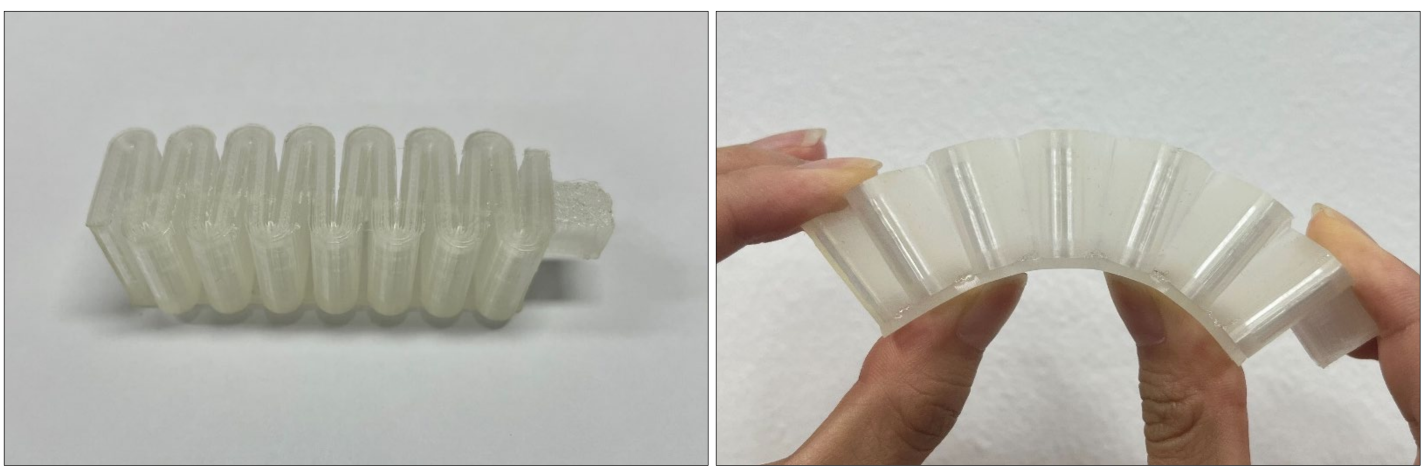

Fig 1. The soft gripper

The pneumatic control system

As shown in Fig 2, The proposed pneumatic control system consists of hardware and software. First of all, the hardware was equipped with the soft gripper so that it could be driven. The overall hardware configuration is shown in Fig 2, and it was possible to move the axis up and down, left and right to create various actuating and measurement environments. The pneumatic system for actuating the soft gripper was designed and manufactured. A small compressor was used as the pneumatic source, and the available maximum air pressure was 6 bar. A filter module was installed to remove moisture and foreign substances from the compressed air generated from the compressor.

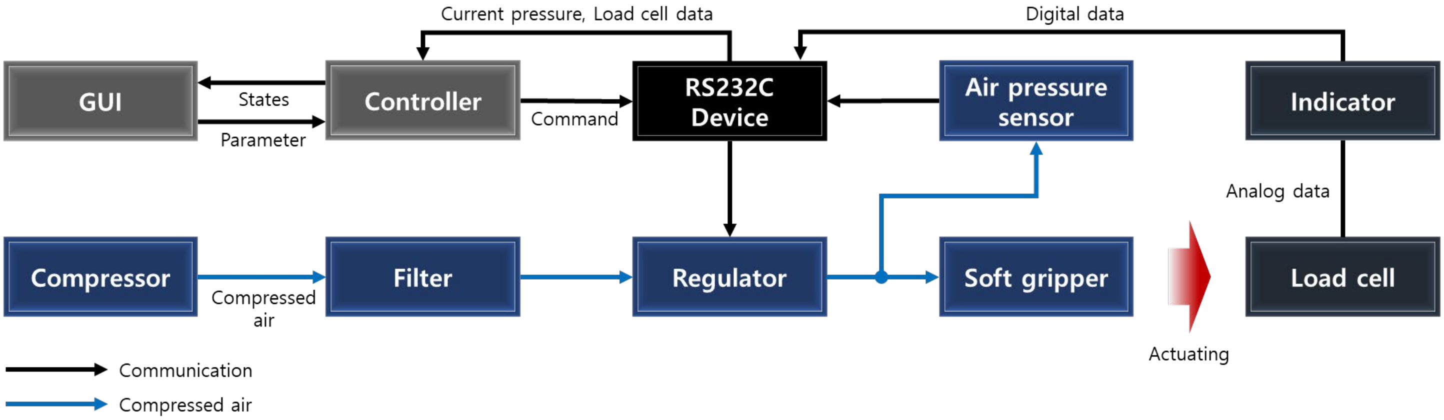

Fig 2 Conceptual diagram of the soft gripper pneumatic control system

The motorized regulator used in this study is a ITV-1090 model of SMC, and was controlled by a PC. This system generates operation commands through software composed of GUI and controller, and the entire communication is composed of RS232C. In addition, the load applied to the load cell can be monitored in real time through the operation of the soft gripper. since the interface is already configured, soft gripper control is sufficiently possible simply by changing the controller part to a DRL-based controller.

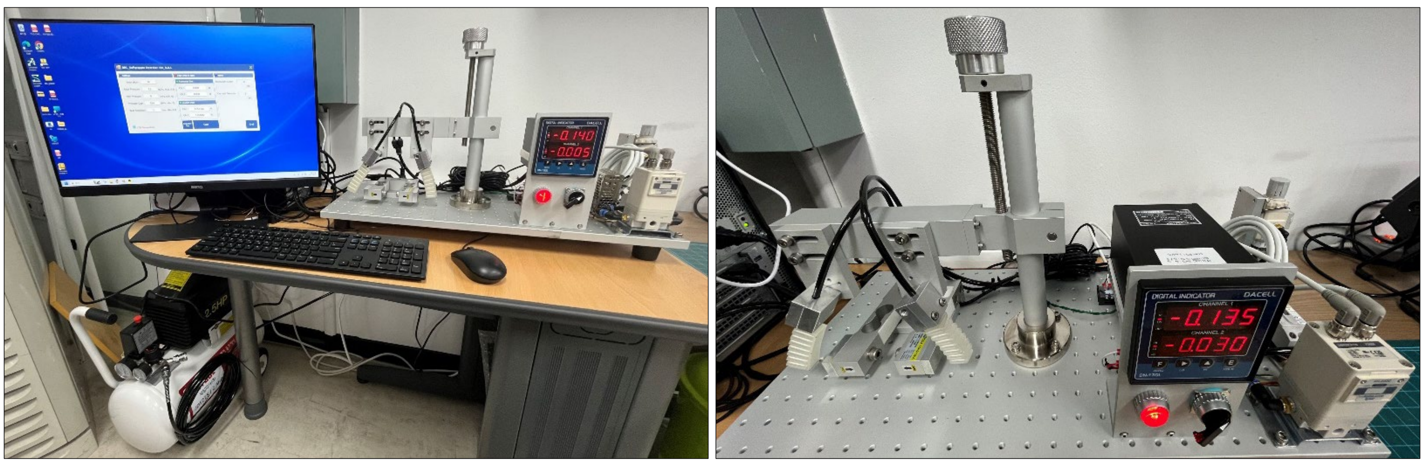
Fig 3. The soft gripper pneumatic control system

On the other hand, the software was configured using the VB.net language in Microsoft's Visual Studio environment. As shown in Fig 4, The graphical user interface (GUI) was created for user convenience. The user can set a target pressure, the time taken to reach the target pressure, and the number of repetitions of the experiment can be automated through these settings.

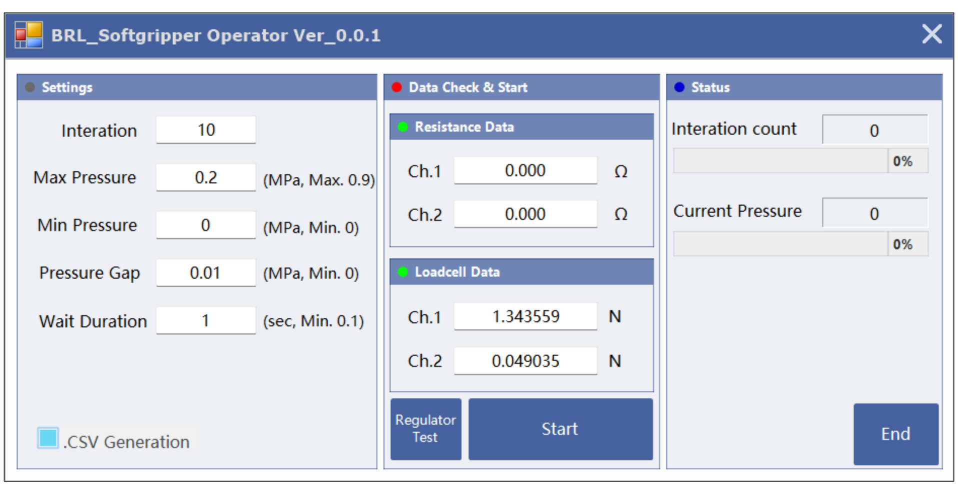

Fig 4. The GUI for soft gripper pneumatic control system

In addition, the air pressure currently supplied to the soft gripper and the pressure applied to the load cell by the gripper can be monitored in real time.

The experiment results

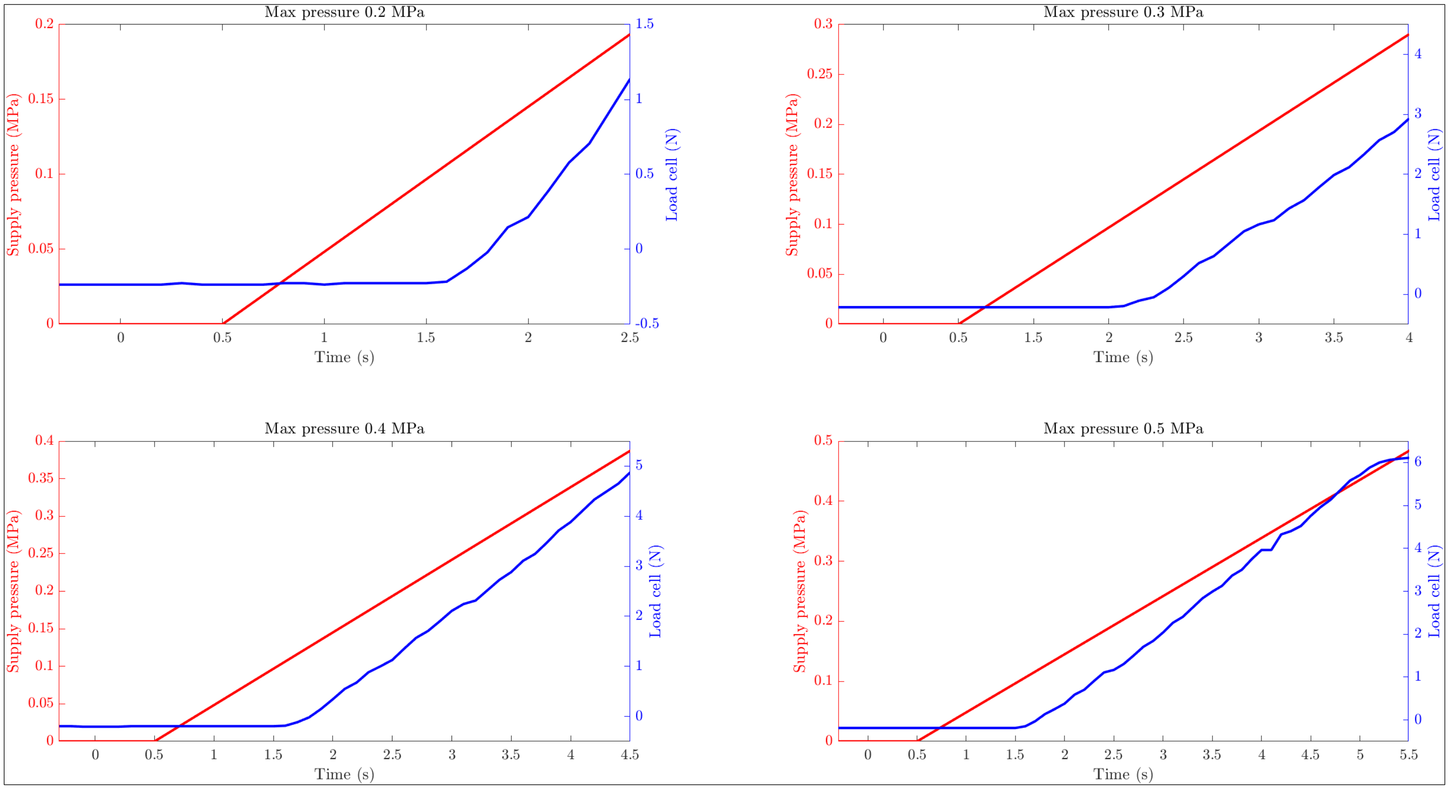

Fig 5. Correlation between a supply pressure and the load applied to the load cell

As shown in Fig. 5, the soft gripper actuating experiment was performed using the constructed system, and it was confirmed that this system operated normally. The proposed system is easy to access by controlling the entire system through GUI. Therefore, various functions of the soft gripper can be verified and tested smoothly. Furthermore, This system is evaluated to be effective in actuating and controlling various types of soft grippers as an integrated form of hardware and software.

Conclusion

The proposed system was built to utilize the DRL-based controller when controlling the soft gripper, and the possibility was confirmed through driving experiments. Therefore, it can be effectively used for actuating and controlling the soft gripper through the DRL-based controller in the future.

Acknowledgement

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References

[1] Kim, Daekyum, et al. "Review of machine learning methods in soft robotics." *Plos one* 16.2(2021): e0246102.

[2] Tawk, Charbel, Rahim Mutlu, and Gursel Alici. "A 3D printed modular soft gripper integrated with metamaterials for conformal grasping." *Frontiers in Robotics and AI* 8 (2022): 799230.