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2022 年度 永守財団 研究助成 研究報告書

所 属 機 関	早稲田大学 次世代ロボット研究機構
職位または役職	客員上級研究員
氏 名	Alexander Schmitz

1. 研究題目

NICEBOT―安全で人にやさしいロボットの開発

2. 研究目的

Nicebot is a robot arm equipped with special actuators: clutches are connected in series with the motors. The clutches act as adjustable torque limiters and make the robot arm extremely safe in case of impacts. The arm is also easy to move by hand, which can be used for direct teaching. Previous versions of the arm included passive gravity compensation mechanisms, which had benefits such as lower torque requirements for the actuators. However, the passive gravity compensation necessitates gaps in the cover of the robot. The next version of the robot will have no passive gravity compensation mechanism, while maintaining the benefits of the current design.

3. 研究内容及び成果

A. Hardware Development

We developed a new version of the robot, without passive gravity compensation, see Fig. 1. As the whole weight of the robot is supported by the motors, the clutches in series with the motors would need to be stronger. We used dual reduction gears for joint 2 (J2): a large reduction ratio between the motor and the clutch, and low reduction ratio after the clutch. We name this as a quasi-direct series clutch actuator, see Fig. 2. As the clutches are not directly connected to the output anymore, they can be smaller dimensioned. Furthermore, the clutches maintain a certain torque limit even without power.

B. Software Development

B-1. Safety: With passive gravity compensation, the clutches can completely decouple in case of impact. Without passive gravity compensation, they need to stay coupled to an extent so that the arm does not fall down due to gravity. We started to implement a new safety algorithm that takes these and under effects in consideration.

B-2. Direct teaching: The clutches need to provide the torque to lift up the robot arm (instead of the passive gravity compensation), so that the robot arm is easy to move during direct teaching. We started to implement the control algorithm to correctly set the clutches at each time step.

Fig. 1: New Nicebot

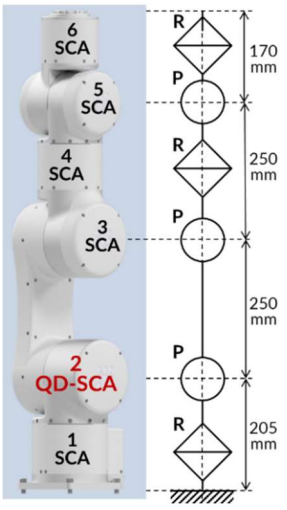

Fig. 2: J2 with QD-SCA

4．今後の研究の見通し

① **Research Plan:** We are investigating advanced control methods to achieve improved direct teaching, safety and force control.

② **Research Contents:** Implement advanced control methods, for example for teleoperation, surgical applications and human-robot collaboration

③ **Research Methods:** To demonstrate the advanced features of Nicebot, we will use Nicebot for applications such as teleoperation, surgical applications and human-robot collaboration. For example, for teleoperation and surgical applications, we will use two Nicebots: one on the operator side will provide force feedback to the operator; the teleoperated Nicebot will use its torque-limiting function to guarantee safety.

5．助成研究による主な発表論文，著書名

Muhammad Arifin, Yuta Kage, Yuchen Yang, Alexander Schmitz, Shigeki Sugano (submitted) *A Combination of a Controllable Clutch and an Oscillating Slider Crank Mechanism for Ease of Direct-Teaching with Various Payloads*. 2024 IEEE International Conference on Robotics and Automation (ICRA)