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Evaluation of an IEEE 11073 SDC Connection of two KUKA Robots towards the Application of Focused Ultrasound in Radiation Therapy

Abstract: The integration of surgical robotics into the operating room requires reliable and flexible communication with other medical devices. The IEEE 11073 SDC standard can provide the necessary requirements to deploy robotics for the application of focused ultrasound in radiation therapy. The aim of this work was to implement and evaluate an SDC compliant connection between two collaborative robots. For this purpose, the KUKA LBR iiwa 7 R800 was adapted and the connectivity modelled and then tested successfully with 42 transmittable properties. Latency measurements were conducted to evaluate the network stability, resulting in a median round trip time of 10.13 ms.

Keywords: IEEE 11073 SDC, Collaborative Robotics, KUKA, Focused Ultrasound, Radiation Therapy

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1 Introduction

Human-robot collaborative systems allow for flexible and swift operation in complex workspaces and can, therefore, provide great benefit in clinical applications. Deployment designs and safety measures to overcome known technical drawbacks during human interaction have already been introduced [1]. However, to integrate surgical robotic systems into the operating room (OR) a fast and reliable communication between all present devices has to be assured as well. The IEEE 11073 SDC (Service-oriented Device Connectivity) standard that was developed in the OR.NET project allows for a dynamic and vendor independent medical device-interconnection [2]. We have shown concepts and evaluations towards a combined focused ultrasound and

radiation therapy (FUS-RT) to position interventional devices with two collaborative KUKA arms [3, 4]. Utilizing two robots thereby allows for the flexible steering of a therapeutic FUS transducer and an ultrasound imaging probe for intraoperative target control respectively. Ensuring the robots safe behaviour in collaborative situations with physicians and multiple other devices in radiation therapy, e.g. radiation units (LINAC) or computed tomography (CT), a highly sophisticated information exchange is implied. The aim of this work is to implement a reliable and safe SDC compliant communication for collaborative robots (KUKA LBR iiwa as an example) and to evaluate the correct functionality and signal transmission speed.

2 Material and Methods

The properties of the KUKA LBR iiwa 7 R800 robot series (KUKA AG, Germany) were modeled and implemented inside the SDC conform medical device description. To share all necessary information via network the position, torque, stiffness, damping, velocity and functional state for each of the 7 robot joints were represented resulting in a total of 42 parameters. The evaluation of two connected KUKA robots was performed with the setup shown in *Fig 1*.

Figure 1: The evaluation setup of two KUKA LBR iiwa 7 R800 robots with their respective work station PCs connected via Ethernet.

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Both robots were controlled by a work station accessing the KUKA controller cabinet with ROS (Robot Operating System) via the *iiwa_stack* application provided by Hennersperger et al. [5]. The accessibility of information between the devices is provided within the SDC provider-consumer pattern, which was implemented in C++ utilizing the *SDCLib/C* solution [6]. Both systems were connected with a NETGEAR 8 Port 10/100 Mbps Fast Ethernet Switch.

Firstly, the correct provider functionality was tested by accessing and changing the states for each robot parameter remotely via network with a simple SDC consumer application. Secondly, a transmission speed evaluation was conducted by implementing a consumer-robot (CR) subscribing to the states of a provider-robot (PR) to mirror the joint positions between both devices. Given this setup, network round trip times (RTT) of 20 movement commands for each of the 7 joints and the respective state change messages were measured, resulting in 140 acquisitions.

Each movement command for the PR was triggered by an activation message of the CR. The PR reacted accordingly and sent a state change message back to the CR after triggering the movement. On receiving the response message the CR adjusted its own position. The RTT in this setup is defined as the difference between two timestamps t_0 and t_1 , with t_0 being the time point directly before sending a movement command to the PR and t_1 the time point directly before the mirroring command at the CR. The measured time, therefore, represents the duration it takes for the CR to react to a movement of the PR. To avoid time synchronization issues, all time points were recorded on the consumer work station. Fig. 2 provides a simplified overview of the systems communication flow.

Figure 3: Overview of the communication flow of the evaluation setup consisting of two robots (provider and consumer) and their respective work station PCs. The recording points of t_0 and t_1 are presented in brackets.

3 Results

All appliances (SDC standard compatible) in the robots network can react to state changes and send movement and planning commands to the robot via activations. After initial testing, all of the 42 defined parameters are accessible and changeable. The RTT measurements are provided in milliseconds in Fig. 3 as a percentile representation.

Figure 2: Percentile representation (1 to 100%) of the measured round trip times in the evaluation setup.

The measured latencies varied between a minimum of 8.54 ms and maximum of 15.01 ms. The median RTT was measured as 10.13 ms and the standard deviation over all measured durations as 1.56 ms.

4 Discussion and Conclusion

The robots functionality was successfully implemented inside the SDC standard, allowing for dynamic changes of its position, torque, stiffness, damping, velocity and functional states during interventions. This enables the robot to be integrated into any networked OR that supports the SDC standard. After testing the communication, all necessary information can be safely accessed. To be able to react swiftly in critical situations in the OR, fast transmission of changes in the robots state is mandatory. The measurements of the RTT for movements and resulting changes provide promising results. Transmission times of 15.01 ms and below assure a real-time-controllability of the KUKA robot systems in collaborative environments and a standard deviation of 1.56 ms shows sufficient network stability for the setup of

two robots. This is also represented visually in the percentile graph, showing no abrupt changes in transmission speed. By implementing the information exchange with the SDC standard, a highly flexible and reliable OR setup is, therefore, possible. However, since the measurements were only conducted for the network transitions, further investigations have to be performed. In future studies, the collaborative interaction for the specific clinical use case of a combined radiation and focused ultrasound therapy will be evaluated. In this scenario, not only information transfer but also robotic movement as a reaction to safety-critical situations has to be considered.

Author Statement

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