A Low-Cost Open-Source Cloud-based Liquid Handling Robotic Platform for Performing Remote Real-Time Collaborate Experiments

We have developed a robotic system capable of performing routine liquid handling experiments, as well as artificial chemical life experiments. Our platform consists of an actuation layer on top, an experimental layer in the middle, and a sensing layer at the bottom. The actuation layer comprises the robot head and modules mounted on it. The modules are designed to perform an action on the experiments, e.g. syringe modules, OCT scanner, extruder module, PH probe. The head holds the modules and moves in the horizontal plane. The experimental layer holds the reaction vessels. The sensing layer consists of a camera below the experimental layer to monitor the experiment. The sensing layer collects data from the experiment, and provides feedback for the robot to interact with the experiment.

In order to develop an open source multi-platform user interface for remote real-time control of our robotic system, we decouple user software for programing experiments and the robot control software. Therefore, we use an integrated controller hardware, namely a Raspberry Pi 3 single board computer, instead of a dedicated computer. The resulting platform eases software management as installing, and managing software libraries required for feedback based experiments on different hardware, and operating systems was difficult. Furthermore, it is affordable owing to the low cost of the Raspberry Pi. This approach enables us to implement a cloud based software architecture for our platform.

The cloud-based software architecture for our robotic system provides resource sharing and reusability of experiment protocols, the ability to work on the robotic system collaboratively, and parallelizing experiments on different robotic systems. Sharing resources allows users to benefit from experiment protocol templates provided for common experiments, as well as taking advantage of protocol examples developed by other users. Users can also develop their own sample protocols, and share it with their teammates or the rest of the community. This is specifically helpful as our liquid handling robot can be used for numerous applications by different users, therefore taking advantage of sample experiment protocols can save a lot of time for the user community. Collaboration on robotic platforms provides novel opportunities for researchers. Providing the users with the capability of working on experiments collaboratively means multiple users can work on the same experiment

simultaneously. On the user interface, they would see the changes other users are making to the experiment protocol real time. They can modify the same experiment as a team, or receive notifications regarding experiment progress. Moreover, users can continue to work on the same experiment on another machine. On the other hand, parallelizing experiments improves efficiency, specifically for artificial chemical life experiments, as several long-lasting experiments are performed on multiple platforms.

A cloud based implementation of the user interface of our robotic platform is a paradigm shift from single user single platform concept to single user multi-platform, multi user single platform, and multi user multi-platform approaches. A single user multi-platform paradigm, i.e. a user being able to control several robotic systems at the same time, and run the same code on multiple robots, allows for a high degree of parallelism. A multi user single platform, i.e. several users can work on the same robot simultaneously, provides a great potential for collaboration on the robotic platform. A multi user multi-platform approach, i.e. several users, e.g. a team, being able to work on multiple robots, enhances resource sharing, and reusability of experiment protocols.