An Open-Source, Low-Cost Robot for Performing Reactive Liquid Handling Experiments

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We have developed a low-cost, open source robot to automate reactive liquid handling tasks. Specifically, the robot, called EvoBot, targets reactive manipulation of motile droplets, a task prevalent in artificial chemical life research. We address hardware design and software implementation of our robot and demonstrate EvoBot's reactive capability, extensibility, and ability to perform experiments in interaction with the user.

EvoBot has a three layer design, 1) a moving head with plug'n'play modules such as syringes on top, 2) a transparent experimental layer, accommodating different chemical vessels in the middle, and 3) a camera as the sensing system at the bottom, providing a view of the experiment. From the raw camera image experiment specific data such as droplet size, position, speed, number, color, and shape are calculated. The computer vision system has an accuracy of 4% for droplet area calculation, and EvoBot an accuracy of 0.1 millimeters in positioning droplets on the experimental layer. EvoBot is able to detect a relevant change of behavior, and accordingly interact with the experiment, e.g. remove a specific droplet by absorbing it. Therefore EvoBot is capable of fully automating experiments, e.g. tracking a moving droplet and injecting a chemical at droplet center when the speed goes below a threshold. Eliminating the need for the presence of a human to perform the interaction is crucial as artificial chemical life experiments are commonly long lasting.

EvoBot's application domain is extendable owing to a modular design of hardware, and open source software. Evobot's modular design enables support for different modules, e.g. syringe modules for liquid handling, grippers to reposition reaction vessels or dispose of them, sensor modules including temperature, pH, etc, as well as other potential modules based on experiment needs. EvoBot's application programming interface (API), a programming interface allowing researchers to build on top of the functionality of the robot, along with the computer vision API allow modification of experiments with a limited programming effort. This is significant as in the case of artificial chemical life experiments often findings from experiments inspire experimenters to modify the design of forthcoming experiments.

In addition to fully automated experiments, there are experiments that require human robot cooperation. EvoBot supports an interactive mode, where the creativity of a human for novel experiments is coupled with the power of real time accurate computer processed data and precise liquid handling. For instance, EvoBot displays the distance from a clicked point to the center of a droplet on the experiment video, and can inject precisely at the desired point.

In summary, due to its precision, EvoBot improves the quality of experimental laboratory data, and empowers chemists to push boundaries of artificial life research by performing formerly infeasible experiments because of their interactive and long lasting nature. Finally, as EvoBot is based on open-source hardware, the cheap price of the robot makes it affordable even for personal labs.