A Low Cost Standalone Open-Source Robotic Platform for Performing Feedback based Liquid Handling Experiments

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We introduce a standalone robotic platform, an advancement over our original robot called EvoBot, for feedback-based liquid handling experiments, which is affordable owing to open-source hardware and software. EvoBot consists of three layers, moving head on top provides different functionalities through various modules, e.g. single or multi-channel syringes, pH sensor, or Petri dish gripper. The middle layer is a glass surface on which reaction vessels are placed. The bottom layer holds a camera recording raw image data of ongoing experiments, which is analyzed and used to provide feedback to the robot. EvoBot takes advantage of a Raspberry Pi 3, in lieu of external computer used in the previous version. The Raspberry Pi controls the robot, processes data obtained from sensing modules to detect changes in experiment parameters, e.g. through liquids color change, and interact with experiment, e.g. by injecting chemicals at specified locations.

Motivations for developing a standalone robotic platform include affordability for small labs and ease of software package management. Raspberry Pi 3 costs $35, owing to mass production price reduction. Furthermore, EvoBot's application programming interface (API) uses numerous software packages, like OpenCV and PyQt. Installing these libraries and managing their dependencies on an external computer proved to be time consuming and difficult for non-expert users. With the standalone platform we provide an image of the operating system with all required packages that can be easily mounted on Raspberry Pi's microSD card.

Evaluation of the standalone EvoBot demonstrates it is possible to perform routine liquid handling experiments and it has sufficient computational power to perform feedback based experiments, owing to tight integration of hardware and software. We use Pi Foundation's native camera module v2. On software side, we boost performance by building our image processing API on top of optimized PiCamera library and GPU accelerated OpenCV. For common image processing tasks, mean and standard deviation of frame processing rate per second is m=18.6, s=0.9 for 2,5GHz Core-i7 MacBookPro, and m=17.8, s=1.1 for Raspberry Pi. For experiments with extreme processing requirements, we overclock the Raspberry Pi by increasing GPU, and CPU frequencies when CPU utilization exceeds a certain threshold (75%). The above-mentioned computer processes frames at m=11.3, s=0.8, and Pi at m=10.3, s=0.9 (91% performance).

The standalone platform improves usability by providing a multi-platform interface for executing experiment code. Therefore users can execute experiment code on a web interface on any device, e.g. Mac, PC, mobile phone or tablet, without installing any libraries, as Raspberry Pi manages packages, and executes code. The web interface was developed taking advantage of modern web socket technologies, and using "Cron", a Unix utility to automate managing specific tasks.

In conclusion, we introduce a standalone open-source robotic platform to perform feedback based liquid handling experiments, which is affordable and eases software management. Using the native Raspberry Pi camera, developing image processing API for Raspberry Pi, and overclocking the Raspberry Pi adaptively, we gained satisfactory performance. Finally, the standalone platform is usable from network connected platforms without installing extra software.