Towards EvoBot: A liquid-handling robot able to automatize and optimize experiments based on real-time feedback

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Extended Abstract

The EVOBLISS project combines scientific approaches from robotics, artificial intelligence, chemistry, and microbiology and aims to capitalize on the state of the art in these disparate disciplines and combine them together into a coherent project to produce i) a generally useful, expandable and customizable technical platform for the artificial evolution of new materials and applications based on a real-time feedback robotic workstation and ii) a specific improved technology, namely a microbial fuel cell, that incorporates natural as well as artificial macro-, micro-, and nanoscale elements for improved function. Scientifically, we will investigate the possibility of optimizing artificial chemical life, microbial ecosystems, and nanoparticles and their physiochemical, dynamic environments using robot facilitated, artificial evolution.

This paper deals with the first goal of the EVOBLISS project, to produce a useful, expandable and customizable technical platform for the artificial evolution of new materials and applications. Specifically, the objective of this paper is to define the capabilities of our liquid handling robot, called EvoBot. This robot will be a mature and robust version of the SplotBot robot which was used to show the feasibility of this approach [1]. This robot was able to perform proof of concept experiments, but was too fragile to conduct systematic scientific experiments in artificial chemical life. Furthermore, the EvoBot robot will increase the features of the SplotBot robot in order to make new types of experiments. Proceeding, the capabilities of the EvoBots are presented based on prerequisites for mature and robust functionality, and also features requested by partners.

General design

The EvoBot robot will be designed following a modular approach and it will be based on three layers:

1. Actuator layer: A head, carried by a XYZ table, will contain the basic actuators and sensors. In addition, it will contain standardized connectors to increase the capabilities of the robot. The vertical movement of the head will allow to work with different height objects (microbial fuel cells, Petri dishes, etc.) and to print parts using an extruder.
2. Experiment layer: It will consist of a flat and transparent surface where the experiments take place. It will support Petri dishes and microbial fuel cells.
3. Visual sensor layer: A head, carried by a XY table, will contain a camera to obtain the feedback and the same standardized connectors as in the actuator head.

The layers will be independent and we will be able to increase their functionality by adding new modules. So, we could have different layers specialized in one type of experiment. For example, the head of the robot in the actuator layer will carry the basic liquid handling tools (six syringes and a gripper) but an operator will be able to easily mount other modules. These modules will increase the functionality of the robot to perform specific measurements such as an OCT scan, an extruder for 3d printing or devices to measure the pH. Regarding the experiment layer, we will add a heated bed module for printing parts or some pumps for microbial fuel cells experiments. Furthermore, we will also add modules to this layer for dispensing or cleaning the Petri dishes or changing the pipette tips of the robot. Finally, the visual sensor layer will consist of a mobile head where we can plug visual sensor modules such as cameras, OCT scanners or hyperspectral sensors. Or we can add fixed cameras to perform several experiments in parallel. This modular solution allows us to configure the robot to perform different experiments using the same basic unit with specialized modules. A schematic diagram of this approach is shown in the Figure 1

Liquid handling

The EvoBot will have at least 6 syringes and each syringe will be controlled independently in two different ways: the vertical position of the needle and the volume to dispense. On one hand, the robot must control the volumes of liquid to dispense or absorb and its injection speed with accuracy. Also, each syringe “head” could be replaced with a direct injection flow pipe connected to a syringe pump or two syringe pumps for semi-continuous volume input. On the other hand, the robot has to control the height of each needle to place the tip of one needle where required.

In addition, the robot will have a microtitre plate of 96 wells to store different liquids and there will be a cleaning system to guarantee the repeatability of the experiments. The cleaning system can be based on disposable pipette tips or on a cleaning process for the pipette tips.

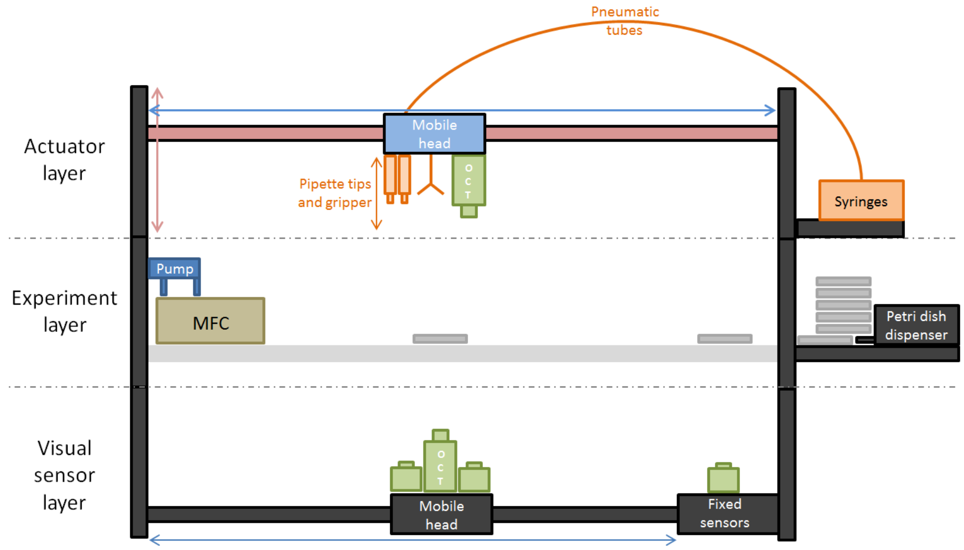

Figure 1. Schematic representation of the EvoBot robot.

The liquid experiments will be carried out in commercially available Petri dishes and the robot will be able to move them across its working surface. This will allow the robot to run multiples experiments. To work without any human intervention, the robot should have a Petri dish dispenser and a Petri dish stacker.

Vision feedback

The EvoBot will have cameras to record experiments and to provide feedback to the control system and to interact with the experiments. The cameras will be placed below the experiment and monitor the experiment from below. For this to be possible, the experimentation surface and petri dishes should be transparent. The robot will analyze the images from the camera in real time to extract relevant features from the experiments. Furthermore, we will employ a method to transform from the pixels of the camera to the coordinates in the reference system of the robot. This transformation matrix will be found as a result of a calibration process without any human intervention and it will allow to interact with the experiments.

Specialized visual sensors as OCT scanners or hyper-spectrometers can be placed in the visual sensor layer or can be carried by the head in the actuators layer if they need to focus the images.

Microbial fuel cell experiments

The EvoBot will have specific sensors to perform the MFC experiments. First, it has to measure the output current and voltage of the cells, but the robot will be able to measure other parameters such as the pH of the cells. Another requirement for some experiments is to maintain a constant flow in the MFC. Therefore, the robot can have some pumps in the experiment layer to maintain and regulate this flow.

User interface

The software of the robot will have a simple graphical user interface (GUI). This user interface will be intuitive and it will allow making experiments without previous knowledge of the robot. That is, setup order of adding chemicals, positions, timing, and simple conditions.

Finally, the standalone robot will have a serial connection to a computer to be able to control it using external commands. This option will allow users to control the experiments using a computer, which can manage computationally expensive calculations. Or we could control the experiments with high-level languages such as Labview or Matlab.

Optimization

The robot will also have embedded optimization functionality based on evolutionary algorithms or other techniques. This will be fully supported by the user-interface with a user-friendly mode for non-experts and an advanced mode where parameters ranges can be defined and the parameters of the optimization algorithm, including fitness function, can be set. Thus, it will be able to optimize over a wide spectrum of parameters e.g. physical shape of the reaction chambers, proportions and positions of injection of chemicals and microbes, etc. In addition, we can evolve systems where temporal or spatial aspects matter.

References

[1] Hanczyc, M. M., Parrilla, J. M., Nicholson, A, Yanev, K., and Stoy, K. (2014). Creating and maintaining chemical artificial life by robotic symbiosis. Submitted to *Artificial Life*.