Poppy: Open Source 3D Printed Robot for Experiments in Developmental Robotics.

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I. Introduction

Since the introduction of numerical computers in the robotic field, research on artificial intelligence has been more and more detached from the actual robot body. Eventually, researchers no longer saw the physical incarnation as an essential component of their research leading to algorithms mainly based on symbolic manipulation. In the end of 80's, a novel thought emerged thanks to researchers such as Rodney Brooks [1], Luc Steels [2] or Rolf Pfeifer [3]. In particular, the embodied artificial intelligence rejects the symbolic approach and postulates that it is not possible to have intelligence without the body and the environment [3].

Thus an interesting evolution of the last decades is the demonstration of the importance of the morphology for sensorimotor control, cognition and development. A great example is the Tad McGeer's passive walker. Thanks to the understanding of the intrinsic dynamics of its structure, Tad McGeer has managed to create a 2D biped robot capable of producing several steps without any controller or motor showing that such a complex task can be indeed achieved only with adapted morphology[4].

The role of the morphology appears as a fascinating open field. Exploring the interaction between body properties and cognition could lead to both a better understanding of animals behaviour (human being in particular) and to build robot more adapted and robust to an open environment with unpredictable interaction. In particular we can highlight the acquisition of sensorimotor task and the exploration of adapted bodies for natural physical and social interaction with humans.

In this context, we should not only take care of the robot body design but both introduce the morphology as an experimental variable and conduct experiments in the real world, indeed *the best model of the world is the world itself* - Rodney Brooks [1].

However such experiments raised two major issues researchers tried to avoid for years by using simulation. First, having a robot moving in the real world leads to problems linked to the platform robustness against mistake. An efficient experimental platform should not break itself while acting in the real world and at least, it should be easy to repair it in case of problem. Second, considering morphology as an experimental variable raised a major epistemological problem. How can we easily change it on a real robotic platform?

Along our work on building cognitive and developmental learning algorithms [5], [6], we had faced these issues and unfortunately no existing platform was available yet. Following the work we made with Acroban [7], we designed a whole new platform called Poppy, which aims to tackle these issues. As theses issues are encountered not only in our lab but also in the robotic community, we decided right from the beginning to make the platform easily accessible to anyone. For this purpose, we designed the robot to be easy to use and to reproduce but also we distribute it freely under open source licenses (both for hardware and software).

The challenges raised by the development of such platform and its diffusion in the research community take part of the Poppy project which aims to offer an highly-hackable robotic platform.

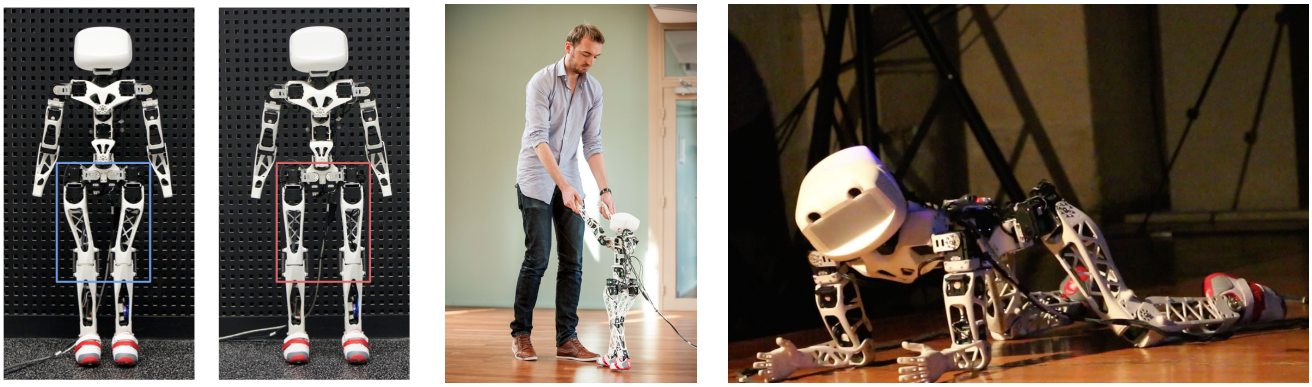
In this paper we ...

II. The Poppy project

The Poppy project aims at building an open-source humanoid platform based on robust, flexible, easy-to-use and reproduce hardware and software. Two key points are describing the project.

First, due to the need of exploring morphology alternatives, the use of 3D printing and rapid prototyping techniques are a central aspect of the project. They allow really considering the morphology as an experimental variable. Indeed, thanks to the democratization of such technologies, exploring morphological variants is now both cheap and fast. Associated with a modular structure and the use of off-the-shell components, we can reconfigure the robot in minutes.

Second, the project promotes open science and is driven by the wish to share not only scientific paper description but also actual experimental setup to easily reproduce experiments in any laboratories. A central goal is to provide a versatile robotic base that can be easily customized to conduct specific experiment. Thus everything developed for the project is released under open source licenses and we take care that the chosen solutions are reproducible.



(a) Exploring the role of morphology (b) Exploring social guidance (c) Autonomous sensorimotor exploration

Fig. 1: The Poppy platform in different experimental situations.

Poppy (see Fig 1a) is the first complete 3D printed open source and open hardware humanoid robot. Based on the use of common off-the-shell Robotis actuators and Arduino boards, Poppy presents an original mechanical structure which permits to obtain one of the lightest robot with 3.5kg for 84cm height. Its current morphology takes insight from the human functional morphology: large number of articulation (25 motors), the limbs respect human proportions, it has five articulation in the trunk and its thigh is bended by a $6\,\mathrm{deg}$ angle similar to the human which showed improvement on the biped stability [8].

Poppy is designed to conduct robotic experiments and integrate several key abilities in an easy-to-use robotic platform.

- **Easy To Duplicate:** The overall time to assemble all mechanic components of Poppy takes about 2 days. Adding extra sensors is simplified by the use of Arduino components.
- **Robustness & Lifelong Learning:** Poppy is designed to be robust to falls and to allow long experimentations (e.g. several hours). Also, its conception prevents it from destructing itself if wrong moves occur.
- **Easy To Setup:** We try to keep Poppy as Plugn'Play as possible.
- **Affordable:** To make Poppy widely accessible, we keep the cost relatively low. You can afford all components for 7500-8000€.

On the software aspect, we developed the *pypot* library which permits to easily control any robot using Robotis actuators. This library has been entirely written in Python as it allows fast development, easy deployment on all operating systems and quick scripting by non-necessary expert developers. It also offers a large variety of scientific and machine learning libraries used in robotics. This language is rather slow compare to C or Java, yet as the serial communication is handled through the standard library we can still achieve rather high performance (sensorimotor loop at 50Hz). Like the Poppy platform, *pypot* is open source and freely available on our GitHub page under GPLv3 License and allows anyone to customize or extend it for their own use. Thus on top of this control library, more high-level features can be developed. For example, we also linked the explauto library, developed in our team to use and compare different implementations of active curiosity-driven sensorimotor learning algorithms [6], with *pypot*. Thus, we can easily design experiments such as learning the inverse model of Poppys arm by using motor and/or goal babbling (see https://github.com/flowersteam/explauto).

Complementary Information

More information on the project can be found on our website **www.poppy-project.org**, in particular the current development of the platform is daily discussed on our forum: **forum.poppy-project.org**. Also all sources (hardware & software) of the Poppy project are distributed under open-sources licenses on our GitHub page **www.github.com/poppy-project/**.

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