Cooperative bridge building by self-reconfigurable modular robots based on ants' stigmergic behaviour

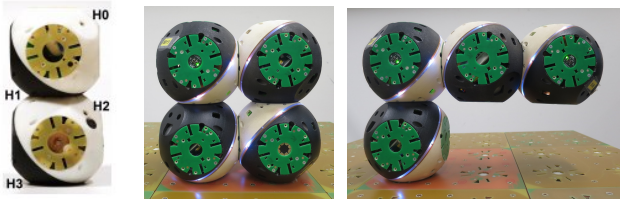
Jasmine Nguyen-Duc[a], Mehmet Mutlu[a,b], Simon Hauser[a], Alexandre Barnerdino[b], Auke Ijspeert[a]
[a]Biorobotics Laboratory, EPFL, Lausanne, Switzerland, *jasmine.nguyenduc@epfl.ch*
[b]Computer and Robot Vision Laboratory, IST, Lisbon, Portugal

1 INTRODUCTION

Insect societies have particular ways of self-organising. To improve their efficiency in task managing, ants are capable of forming a bridge-like self assemblage. "Army ant bridges are remarkably strong and adaptive; the insects begin to build them as soon as they sense a gap in their path and disassemble them once traffic has cleared" [1].

This research presents a method for robots to accomplish the construction of a bridge similarly to ants. For this, the concept of stigmergy must be studied. The use of stigmergy in the robotics field has lead to the creation of an artificial swarm intelligence. The particularity of stigmergy is mainly the use of indirect communication and the absence of a central leader. So the robots take initiatives without needing an external command or any direct communication with their "teammates". The decision making of each agent is based on a set of rules and on the time varying environment.

Roombots are self-reconfigurable modular robots (SRMRs) designed in Biorobotics Laboratory of EPFL. Each module has two adjacent cube-like shapes and has three rotary degrees of freedom (DOF) as seen in Fig. 1a. Roombots are capable of self reconfiguration and locomotion by gripping onto specific surfaces. Active Connection Mechanism (ACM) and proximity sensors are positioned at the extremities of each module.



(a) (b) (c)

Figure 1: (a) Single RB module [2] and (b) an agent composed of two modules in standing position and (c) during a step forward.

The most common way of controlling SRMRs is centralized where all SRMRs are connected to a central computation unit, which decides how each module should behave. However, there exists distributed control ways too [3], [4]. Centralized methods usually suffer from high dimentionality of SRMRs and distributed methods may fail to find a solution for a desired task. Creating an algorithm inspired by a biological method used by ants would enable Roombots to achieve a certain primitive task, namely, crossing a wide gap that requires collaboration of multiple modules.

2 METHODOLOGY

2.1 An algorithm from ants

In previous studies, ants have been noticed to follow a set of simple rules while forming bridges: (1) if a gap is ahead, stop moving or slow down; (2) if an ant is immobile in front, climb on top of it and continue walking; (3) as long as an ant is on top of another, freeze. These are morphology-free commands that can be converted to an algorithm.

In our Roombots adaptation, each agent randomly explores the environment. The exploration is modelled as: ant continues walking in the same direction with 80% chance, changes direction with 15% chance and stops (without detecting gap) with 5% chance. The formation of a bridge can take a very long time since the agents just walk around randomly in the environment. However, agents can be attracted towards a gap, for example, driven by smell or light. We considered that there exists a slight attractor towards the gap. Thus, ants are more likely to walk towards the gap and start forming bridges during the exploration.

When a gap is detected while exploring, an agent leans forward and freezes for a fixed amount of time. If no other robot climbs over it in during the frozen period, the leaning robot stands up again and resumes exploration. If on the contrary, another robot does climb onto it, it stays frozen independent of time. Thus, the foraging robot has enough time to walk across the leaning robot's body. Once the other side of the gap is reached by a climbing robot, the bridge is formed and allows others to forage across it. As long as there are foraging agents on top of the "bridge-builders", they cannot stand up. Once there are no more foraging ants on the bridge, the first agent that formed the bridge stands up first and crosses the bridge while disassembling it.

2.2 Roombot's mechanics

Each Roombots module has only 3 DOF that is quite low compared to capabilities of a real ant. In order to have more capable robotic units, metamodules of two modules