Cellulan World: Interactive Platform To Learn Swarm Behaviours

Demonstration Track

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ABSTRACT

Swarming behaviours are ubiquitous in nature, and an important topic to teach and learn. In the learning sciences domain of complex systems understanding, studies have shown that novices tend to assume that centralized control and leadership should exist whenever they see complex patterns. In this paper, we present an educational framework consisting of a swarm of virtual and/or physical agents (robots) as a game-based learning environment to introduce the underlying rules of swarm behaviours.

KEYWORDS

Human Swarm Interaction; Complex Systems Understanding; Education

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1 INTRODUCTION

A swarm is the coherent behaviour that emerges from simple interaction rules between self-organized agents. Many examples of swarms can be found in biological systems from the microscopic (atoms and cells) to larger-scale aggregates of ants, bees and birds. Ubiquitous in nature, the swarming behaviour has inspired a wide range of research domains. Swarming behaviours are complex systems, and learning about such systems is challenging. Many studies investigate the difficulty that humans have in grasping complex systems, alongside common misconceptions about them [1, 3, 4]. Indeed, students often assume the system to be controlled *by lead* (i.e., by a leader orchestrating the others' actions) or *by seed* (i.e., by a pre-existing entity in the environment), rather than to result from decentralized interactions [5]. This inclination toward centralization is referred to as *Deterministic-Centralized (DC) Mindset* [5]. To address the above challenge of humans learning about complex systems, this project presents a novel approach for human learning with swarms (of virtual as well as physical agents), specifically envisioning the development of a swarm platform that is versatile for educational scenarios. This platform will introduce a play-based learning environment allowing learners to explore the connection between the micro-level behaviour of individual agents and the macro-level emergent patterns resulting from their interactions. In this paper, we first describe the design principles of the learning activity we developed to overcome the DC mindset and then the system we implemented for this purpose.

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2 LEARNING ACTIVITY

We design the learning activity as an educational game. The story line is introduced as follows:

> In the underground dungeons have recently emerged the species of Cellulans. They have to find a way to work together and address all their challenges.

The game is organized in levels, during each of which the learner is faced with a number of challenges which require them to implement a swarm behaviour. Examples of such behaviours are coverage, flocking and foraging. In each level, the player has a set of rules available to define the behaviour of the agents which we explain more in details in the next section. Examples are shown in Fig. 1 (left). After the main task, each level has a set of sub-levels, each with a few modifications w.r.t. the main task, designed to allow the trapping of the use of a centralized solution. The traps are built around the robustness of decentralized control when a dynamic change occurs and belong to either of the following 3 categories:

(1) Perspective change: global view vs local view; i.e, giving or limiting the access to the global environment.
(2) Environment change: a static vs a dynamic environment;
(3) Capabilities/Functionalities change: expanding or limiting the capabilities of an agent (e.g. field of view, communication range, etc) or even breaking it (complete failure).

Such a design stems from the theory of *conceptual change* in the learning sciences [2]. Conceptual change refers to the learning that occurs when the learners revise and restructure the concepts that build their knowledge, after "trapping" the misconceptions they had [2]. A typical example is the "wool adds warmth" misconception. A trap to address it is, for example, an experiment comparing the melting time of an ice cube covered with wool vs one not covered with anything: contrary to the misconception, the second ice cube will melt first. Faced with a contradiction, learners revise their

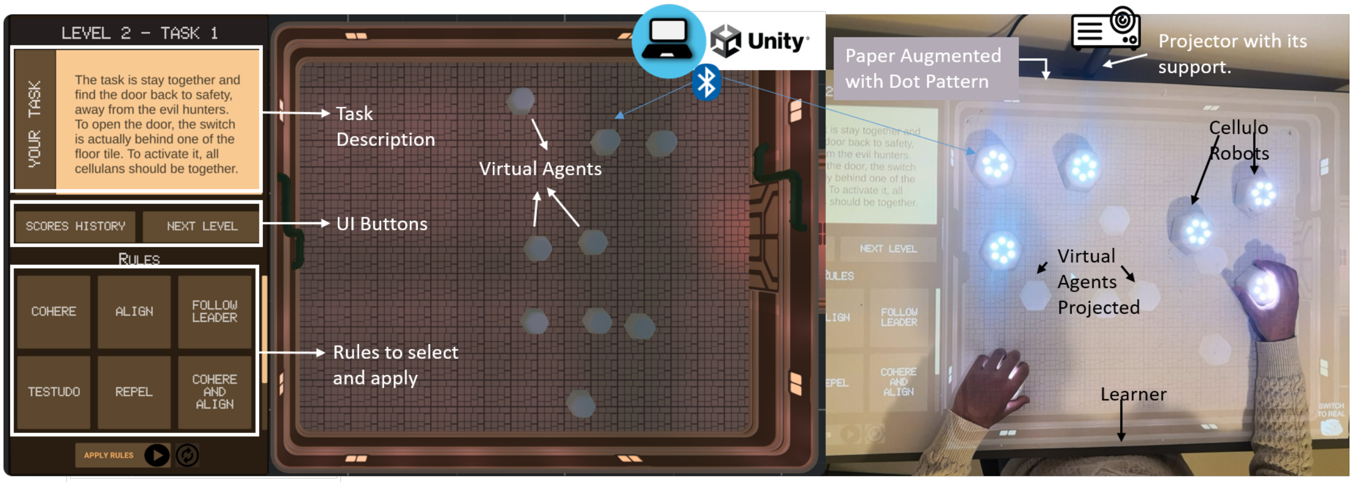

Figure 1: Overview of the system setup (left: virtual modality, right: the physical one.)

conceptions towards the normative one, and our game attempts to do the same through the sub-levels which highlight the limitations of the centralized mindset.

3 SYSTEM DESCRIPTION

We design a new framework to easily develop learning activities following the theories discussed previously, relying on the existing Cellulo platform developed within CHILI lab to support robot-enhanced learning [6]. Our system shown in Fig. 1 is composed of four main components: Agents, Environment, Learner(s) and Interactions. Furthermore, we seamlessly support two modalities of the activity, a virtual and a physical one.

1) Agents: Our agents are the *Cellulans* from our learning activity (ref. section 2). These can be either virtual agents on the screen, or physical agents embodied by the Cellulo robots, handheld haptic-enabled mobile robots capable of holonomic motion and absolute global localization. Each robot has a top equipped with touch sensors and LEDs which allow for simple visual and touch interaction. The robots can be moved by the user or move autonomously.

2) Environment: The environment is the space where the agents are placed and are interacting. In the virtual modality, it consists of a virtual "room" possibly including real-time changes and animations depending on the (sub-)level objectives. In the physical modality, this consists of printed sheets of paper "augmented" with a dot pattern. When placed on it, Cellulo robots can self-localize with sub-mm accuracy via an image sensor placed underneath the robot and facing downwards. The graphics on the paper can be designed according to the specification of the activity. While the environment in this case is thus, by default, static, we make it dynamic by projecting it from a small overhead projector.

3) Learner(s): The learner is the user interacting with the virtual/physical agents and the environment. Depending on the learning activity design, this can be single person, or multiple people.

4) Interactions: Our system enables a number of interactions, occurring at and between different components.

i) Agent-agent interactions: These interactions occur at the "micro" scale upon the encounter of two agents. We have implemented several agent-agent interaction rules, including centralized rules such as *follow a leader*, and decentralized ones such as *separation* (avoid collisions with nearby agents) or *cohesion* (attempt to stay close to neighbours).

ii) Agent-Environment interactions: These interactions occur when the action of an agent is directed towards the environment. In this case too we have implemented centralized rules such as following predefined "spots" or "targets", as well as decentralized ones such as leaving marks/pheromones trails.

iii) Learner-Agent interactions: In the virtual modality, these interactions are mediated by mouse or keyboard interactions for moving the agents. In the physical version, the interactions are tangible, i.e, learner(s) move the robots by their hands (thus applying forces to the robots) and feel haptic feedback (thus feeling forces applied by the robots).

iv) Learner-Environment interactions: These interactions are mostly the user interaction with the application itself such as UI buttons and rules-related buttons (Fig. 1 - left).

All these interactions are made possible through a cross-platform Unity application which runs the logic of the activity (either on a desktop computer or a consumer-grade tablet). In the physical version (Fig. 1 - right), this application in addition coordinates the movements of the robots through a star network composed of point-to-point Bluetooth SPP links. Each robot connects wirelessly to the central controller, reports to it all events (e.g pose changed) and receives from it commands (e.g. reference velocity to track).

4 CONCLUSION

This paper presents the design and implementation of a novel learning framework integrating virtual and physical agents to help users understand swarm behaviours. A demo video showing the different components of the system and the activity can be found here. Future work targets conducting experiments to validate the effectiveness of our system and learning activity design.

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