GloveBot: Design and Building of a Socioenactive Artifact

Marleny Luque Carbajal *M. Cecília C. Baranauskas*

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INSTITUTO DE COMPUTAÇÃO

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Abstract

Drawing on the enactivist-based perspective to cognition, emerges the concept of socioenactive system that is constituted by coupling together three elements: social, physical and digital, which exert mutual influence between each other. This work is a technical report about the design and building process of *GloveBot*, a socioenactive artifact, which is part of the thematic project *"Sistemas Socioenativos: Investigando Novas Dimensões no Design da Interação mediada por tecnologias de informação e comunicação"* (FAPESP, #2015/16528-0). In this technical report, we present the *GloveBot* artifact and describe its interaction design, components and implementation. The proposal of this artifact is engaging users in creative activities through socioenactive interaction.

Keywords: socioenactive interaction, enaction, embodiment, creativity

1 Introduction

Enactive theorists, a new strand of cognitive science, understand that cognition emerge through a real-time and improvised interaction with the environment and other agents in that environment [7, 13, 14]. The development of new technologies that allow a more physical and immersive interaction modality brought the concept of *enactive system*. For Kaipainen *et al.* [9], enactive systems are computational systems made up of human and technological processes dynamically linked, constituting feedback cycles using sensors and data analysis, enabling a fluid interaction between the human and the computer. Extending the concept of enactive systems, socioenactive systems are complex, demanding a process of design that considers different stakeholders, user interactions, environments, and multimodal ways of enabling the human-technology coupling [3]. Socioenactive interaction is a new concept that brings social and cultural values to embodied interaction making them explicit both individually and collectively.

This research is being developed as part of the FAPESP thematic project *"Sistemas Socioenativos: Investigando Novas Dimensões no Design da Interação mediada por tecnologias de informação e comunicação"* [1] [3], approved by the Research Ethics Committee (CEP) with number 72413817.3.0000.5404. This project aims to build a conceptual framework based on experimentation with different scenarios, which will equip those involved with the design and development of social and active systems. The technological solutions produced are characterized by ubiquity and effectively take into account the cultural context of those who participate in it, including their differences, needs, preferences, abilities and values. The thematic project has three research scenarios: a school, a hospital and a museum, that represent complex and challenging research contexts

*Institute of Computing, UNICAMP, 13083-852 Campinas-SP, Brazil, marleny.carbajal@ic.unicamp.br

†Institute of Computing, UNICAMP, 13083-852 Campinas-SP, Brazil, mccb@unicamp.br

[1] https://bv.fapesp.br/pt/auxilios/96114/sistemas-socio-enativos-investigando-novas-dimensoes-no-design-da-interacao-mediada-por-tecnologias-/ (access in March 2023)

that require a socio-technical understanding that must consider different perspectives and issues, ranging from the way people live and interact in their environments, to normative issues and well-established social/cultural protocols, and the existing/to-be-designed technical solutions for these environments with their respective possibilities and technological challenges. The present work is situated in the school setting.

In this work, our objective is designing a technological artifact following the main aspects of the socioenactive interaction [4]. That is, design based on the coupling of its three elements: social, physical and digital. Therefore, in this technical report, we present the design and building of *GloveBot*, a socioenactive artifact developed to promote creativity in children's actions. We provide technical details of the implementation of its components and the main aspects of its socioenactive interaction design. The document is organized as follows: in Section 2 we present the theoretical background about enactive cognition, enactive systems and socioenactive systems; in Section 3 we present key requirements for the interaction design of our socioenactive artifact; in Section 4 we present the technical specification of the developed artifact, with emphasis on the technologies used; in Section 5 we present the artifact functionalities and how the interaction occurs; and, finally, in Section 6 we present a conclusion with considerations about the process and the system, and directions for future work.

2 Background

The principal idea of enaction is that a cognitive science system develops its own understanding of the world around it through its interactions with the environment. Enactive cognitive science has been originally formulated by Francisco Varela, Eva Thompson, and Eleanor Rosch in their book *"The Embodied Mind"* [14]. The term enaction highlight that the sensorial and motor processes, perception and action are fundamentally inseparable in lived cognition. It must be emphasized that they are not associated with individuals by simple contingency: they evolved together [14]. Thus, it can be stated that in this context, cognition is fundamentally a characteristic of living organisms in an adaptative and dynamics with the its environment. In the enactive approach, cognition is no longer understood as a formal computation of symbols, or is considered as an appropriate solution to a given task, but the action of the subject is thought of as member of a complex network formed at multiple levels of interconnected sub-networks that overcomes the dichotomy between individual/internal versus environment/external: the cognitive system of the subject will be part of a durable yet changeable existing world, in which individual and environment are instances that co-imply each other. According to Hutchins [8], enaction is the idea to complement that our experience of the world is created in our organism, modeled by our actions. It is possible to identify five linked ideas that make the notion of enaction, that are autonomy, sense-making, emergence, embodiment and experience [5, 12, 14].

i. *Autonomy*: the cognitive system is entirely self-governing and self-regulating: it is not controlled by any outside agency, and this allows it to stand apart from the rest of the environment and operate independently of it. The system is influenced by the world around it, through interactions that do not threaten its autonomous functioning;

ii. *Sense-making*: relationship between the knowledge encapsulated by a cognitive system and the interactions which gave rise to it. It refers to the idea that this emergent knowledge is generated by the system itself and that it captures some regularity or lawfulness in the interactions of the system, i.e., its experience. By understanding its experience, the system is building a model that has some predictive value. This self-generated model of experience allows the system a greater repertoire of possible actions that allow for richer interactions, increased perceptual capacity and the possibility of building even better models that encapsulate knowledge with even greater predictive power;

iii. *Emergence*: refers to the way in which cognition arises in the system. Specifically, the laws and mechanisms that govern the behavior of the component parts of the system;

iv. *Embodiment*: means that the system must exist in the world as a physical entity which can interact directly with the environment. This means the system can act on things in the world around it and they, in turn, can act on the system;

v. *Experience*: the cognitive system's history of interaction with the world around it, the actions that the system performs in the environment and the actions that arise in the environment and affect the system. These interactions trigger changes in the state of the system.

In the domain of HCI, the enactive approach to cognitive science provides a suitable framework to address how technological interfaces can mediate the human relationship with the world such that they can enhance the human perceptual interaction. An enactive approach considers the sensory input and motor output as two facets of the same process of generating meaning, i.e., of sense-making. Sense-making is the activity by which an autonomous and adaptive agent maintains a meaningful relationship with its environment. It is emergent from the ways in which an agent's movements are not just random physical events, but are goal-directed actions. Using the enactive framework for thinking about perception, action, and the design of interface technology, Froese *et al.* [6] define an enactive interface as a technological interface that is designed for the purpose of augmented sense-making. On the other hand, the proposal of Kaipainen *et al.* [9] challenges the very concept of interface, suggesting a more dynamics-oriented perspective on humans and machines. The core concept, an enactive system, is constituted by dynamically coupled human and technological processes, that is, a dynamic mind-technology embodiment. An enactive system does not assume a standard interface with goal-targeted conscious interaction; rather the function of interfacing is driven by bodily involvement and spacial presence of the human agent without the assumption of conscious control of system. Kaipainen *et al.* [9] propose the human agent to be regarded as a participant in a process rather than as a user of tools.

Extending the concept of enactive systems, socioenactive systems are complex, demanding a process of design that considers different stakeholders, user interactions, environments, and multimodal ways of enabling the human-technology coupling. Socioenactive interaction is a new concept that brings social and cultural values to embodied interaction making them explicit [3] both individually and collectively. The socioenactive system encompasses two main aspects: those of enactive systems, and the socio-cultural aspects surrounding the phenomena of the enactive experience with the technological system. Enactive systems are information systems that present a strong and dynamic body-technology coupling. In this type of system, the user is a participant that is accompanied by the system, the latter being an intelligent and ubiquitous technology. The socioenactive approach considers the human as a participant of the enactive system, seen as a complex physic-social agent that shifts the world around him/her while exercising mutual incorporation with other participants as well [3]. The experiences that each person has, the intentions that they might bring, social interactions among peers, and the emotional state when using the system are a few examples of the socio-cultural considerations to carry to the design process.

The socioenactive system is constituted by the coupling of social, physical and digital elements [4] and the relations between these three elements (see Figure 1). Each element has the ability to affect itself and each other. The social element refers to the joint interaction of people with each other and with the physical elements of the environment. The physical element, which mediates the social-digital relation, refers to tangible artifacts and other elements of an environment that can affect and support the user's interaction, for example a sound speaker, a robot, even other people. The digital element refers the software control of the environment and its communication process.

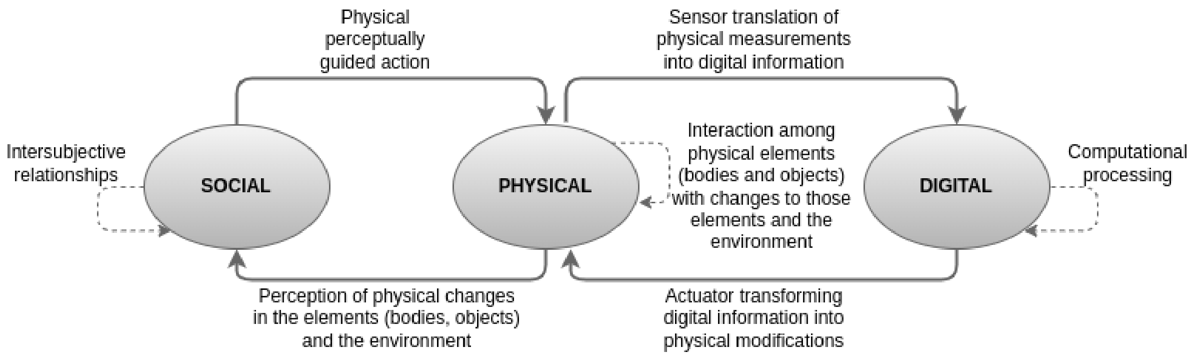


Figure 1: Relation between Social, Physical and Digital elements in a socioenactive system [4]

3 Design of the Socioenactive Interaction

Based on the works presented in the Section 2 [5, 12, 14] and mainly on the Baranauskas *et al.*'s work [4], we defined the following key requirements for our socioenactive artifact:

A. *Embodiment*: The artifact should allow interaction through body actions.

B. *Joint Exploration*: The artifact should allow joint action (involving coordination and joint attention).

C. *Social-Physical-Digital Coupling*: The artifact should allow to acknowledge the role of peer's actions.

D. *Joint Coordination of Actions*: The artifact should allow collaborative interaction, i.e., dynamic relationship among the joint attention, joint action and social coordination.

E. *Participatory Sense-making*: The artifact should allow a shared control among the children acting together.

Besides that, as the artifact is to be used by children, the artifact should be safe and work reliably. From these requirements, we created the *GloveBot* artifact (see Figure 2), with the vision to become an artifact that promotes the creativity in children through socioenactive interaction. Table 1 shows the requirements met by the artifact.

The *GloveBot* artifact will afford both the involvement of each child (attention, body and action) as well as her/his identification with other people's action. Besides that, our artifact affords observing the actions of others, acting together with others in a coordinated way and reflecting on what the actions bring forth. Figure 3 illustrates how the coupling of the three socioenactive elements takes shapes in the *GloveBot* artifact.

4 Building a Socioenactive Artifact

In this section, we present the chosen technology and the construction of *GloveBot*'s components.

Table 1: Socioenactive design requirements met by the *GloveBot* artifact

Requeriments	*GloveBot*
A. Embodiment	It utilizes hand gestures for interaction.
B. Joint Exploration	It requires the participation of at least 4 people together.
C. Social-Physical-Digital Coupling	Each *Controller Glove* has a specific movement, then each person participating in the action has a specific role.
D. Joint Coordination of Actions	The *Robot Car* moves by the coordinated combination of hand gestures transmitted by *Controller Gloves*.
E. Participatory Sense-making	The control commands are distributed in the 4 gloves.

Figure 2: *GloveBot* artifact

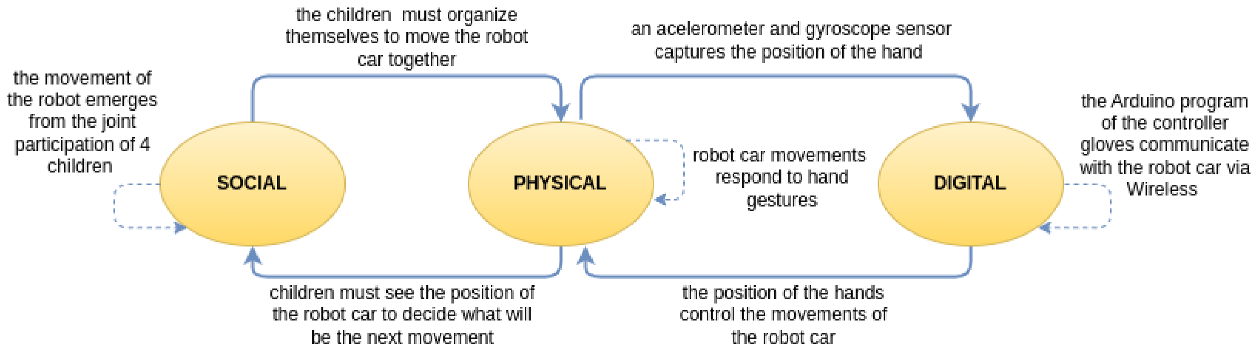


Figure 3: The coupling of the three socioenactive elements instantiated in *GloveBot* artifact

4.1 Technical Specification

We chose as main hardware an *Arduino Nano* (see Table 2). Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. It is possible to send a set of instructions to the microcontroller on the board using the Arduino programming language (based on *Wiring*[2]), and the Arduino Software (IDE), based on *Processing*[3]. The Nano Family is a set of boards with a tiny footprint, packed with features. It ranges from the inexpensive, basic Nano Every, to the more feature-packed Nano 33 BLE Sense / Nano RP2040 Connect that has Bluetooth® / Wi-Fi radio modules. These boards also have a set of embedded sensors, such as temperature/humidity, pressure, gesture, microphone and more[4].

We chose Arduino technology due its software to be easy-to-use and flexible. Arduino also simplifies the process of working with microcontrollers and it offers some advantage over other systems:

- inexpensive, compared to other microcontroller platforms;
- cross-platform, the Arduino Software (IDE) runs on Linux, Macintosh OSX, Windows operating systems;
- simple, clear programming environment;
- open source and extensible software and hardware

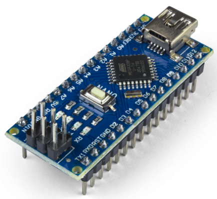
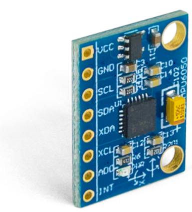
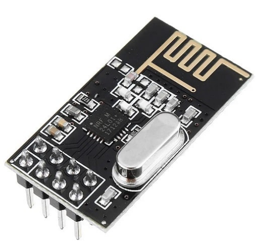
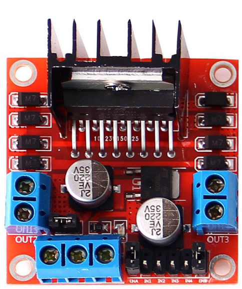
In the following subsections we present the components of the *GloveBot* artifact (see Figure 2), which are based on Arduino technology.

4.2 *Controller Glove*

In order for the interface to be as natural as possible, we developed a glove-based controller. We designed the *Controller Glove* embedded with Arduino board and sensors (see Figure 4) to enable the user to control the *Robot Car* using hand gestures. Inside the *Controller Glove* there are: an *Arduino Nano* board; an accelerometer & gyroscope sensor MPU6050; and a Wireless module

[2]http://wiring.org.co/
[3]https://processing.org/
[4]https://www.arduino.cc/en/hardware

Table 2: Main devices of the *GloveBot* artifact

Devices	Technical Specification
Arduino Nano [2] 	It is a board based on the ATmega328 (Arduino Nano 3.x) microcontroller. It has 22 digital I/O Pins (6 of which are PWM) and 8 analog input pins. It works at 16 MHz, has 32 KB of flash memory of which 2KB used by bootloader, 2.5KB of SRAM and 1KB of EEPROM. It operates at 5V and can consume 19mA. It is programmed using the Arduino IDE.
Accelerometer-Gyroscope MPU6050 [1] 	It contains a gyroscope and an accelerometer on a single chip. It provides information about the acceleration of 3-axis and there are 3-axis for the gyroscope, with a total of 6 degrees of freedom (6DOF). The gyroscope measures rotational velocity or rate of change of the angular position over time, along the X, Y and Z axis. The accelerometer measures angle of tilt or inclination along the X, Y and Z axis. It accepts input voltages of 3.3V and 5V. It and consumes 4mA.
Wireless Module NRF24L01 [15] 	This module is designed to operate in the 2.4GHz worldwide ISM frequency band and uses GFSK modulation for data transmission. It transmits and receives data on a specific frequency know as a channel. This channel can have any frequency between 2.400 and 2.525 GHz. The NRF24L01 includes a feature known as Multiceiver (Multiple Transmitter Single Receiver). The module's operating voltage ranges from 1.9 to 3.9V and it consumes 26µA in standby mode and 900nA in power down mode.
Motor Driver Module L298N [11] 	It can control the speed and spinning direction of two DC motors (also called TT motors). This module has 11 pins: 3 power pins, 4 output pins, 2 direction control pins and 2 speed control pins. The L298D motor driver has a supply range of 5V to 35V and is capable of 2A continuous current per channel.

NRF24L01 (see Table 2). These components are coupled to read the analog values which are used to capture the hand pose of the user. An IO button is incorporated to allow the user to turn the *Controller Glove* on or off. Each *Controller Glove* is powered using a standard 9V battery. Figure 5 illustrates how the *Controller Glove* is wearable in hand. The pin diagram and connections are shown in the Figure 6.

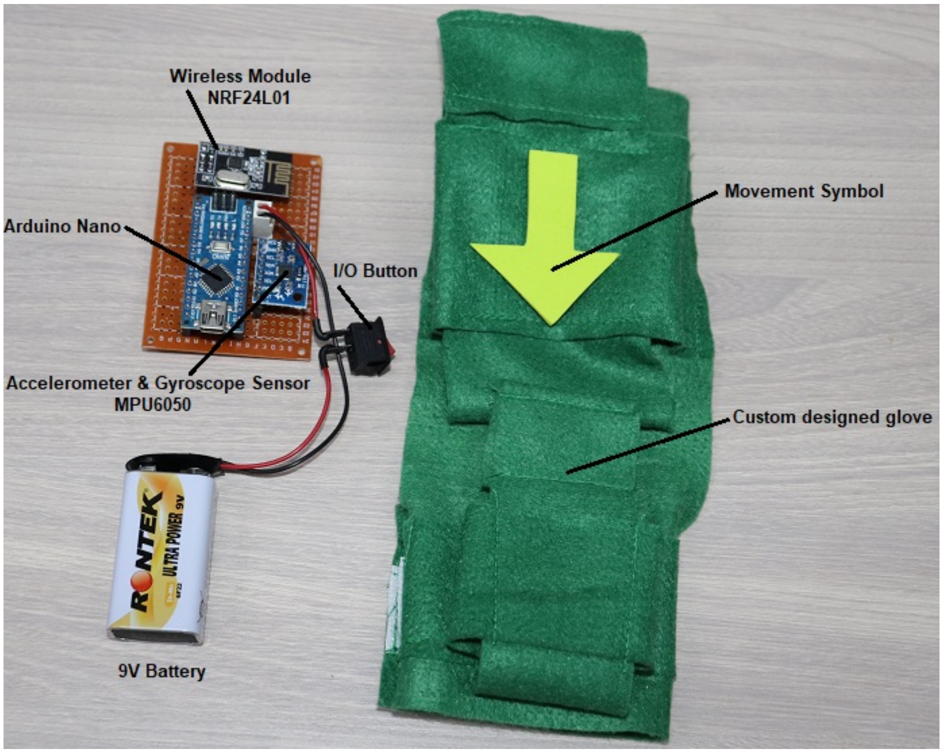


Figure 4: Electronics embedded in the *Controller Glove* (left) and custom designed glove (right)

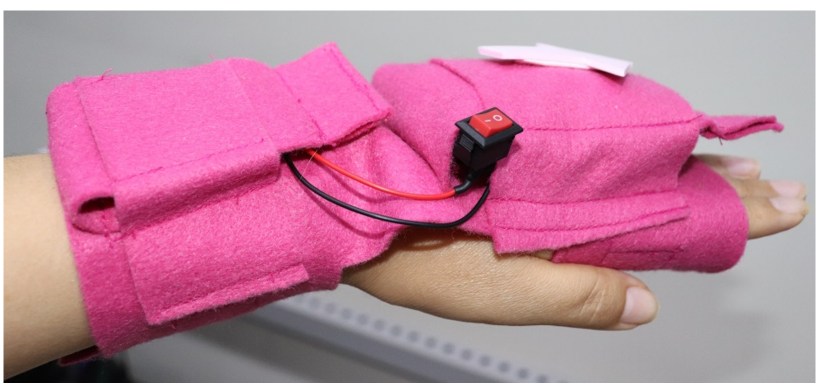


Figure 5: Pink *Controller Glove* (movement: FORWARD)

4.3 *Robot Car*

We built the *Robot Car* (see Figure 7) to respond to hand gestures transmitted through the *Controller Glove*. The robot has connected 2 DC motors (also called TT motors) on a transparent

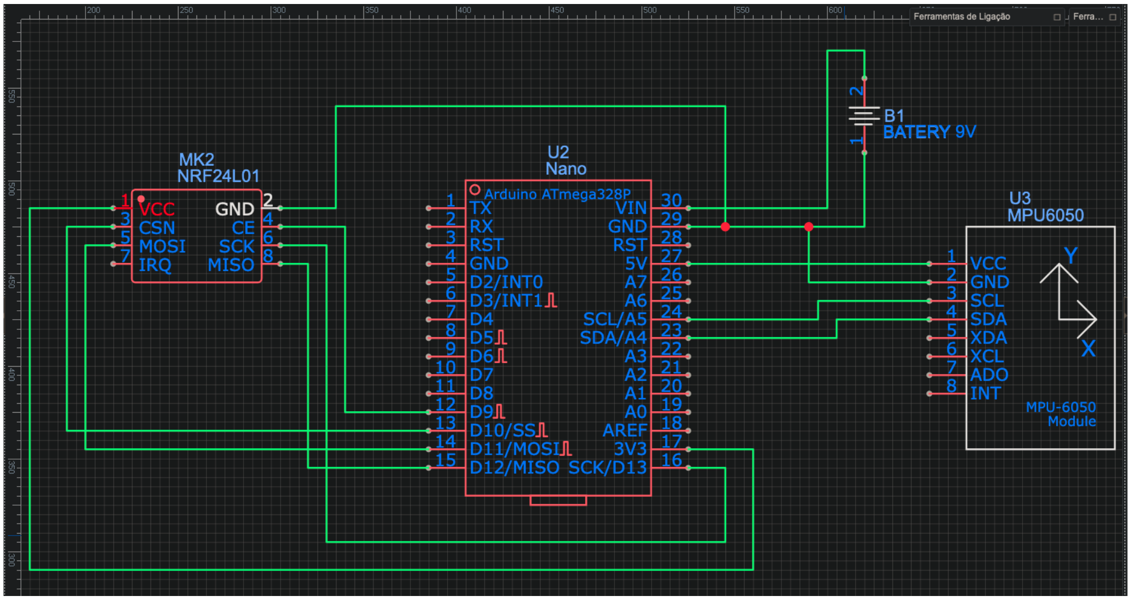


Figure 6: *Controller Glove*'s wiring diagram [source: author]

chassis, a motor driver module L298N, an *Arduino Nano* and a Wireless module NRF24L01 for communication (see Table 2). An I/O button is incorporated to allow the user to turn the *Robot Car* on or off. This robot is powered using 6 AA batteries. The pin diagram and connections are shown in the Figure 8.

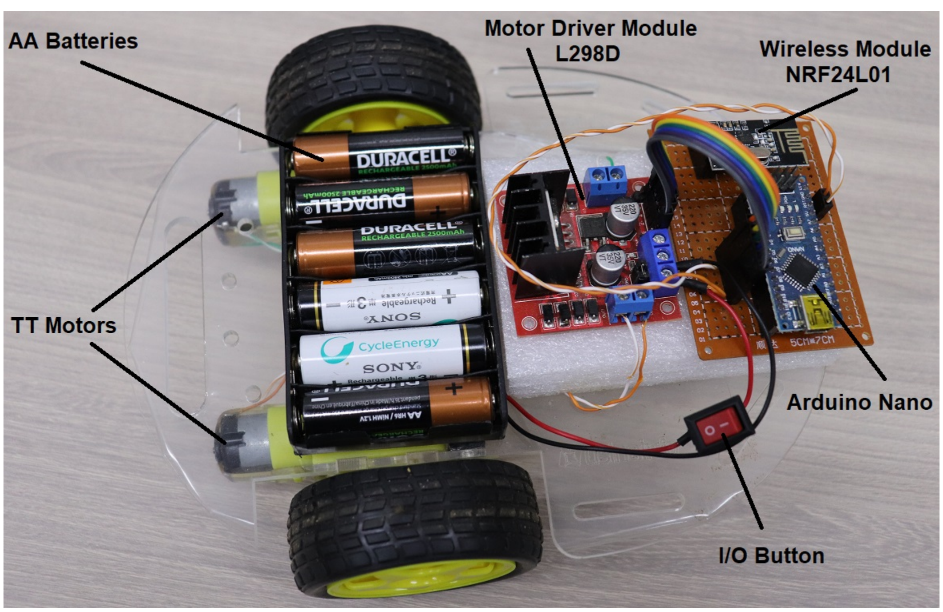


Figure 7: *Robot Car*

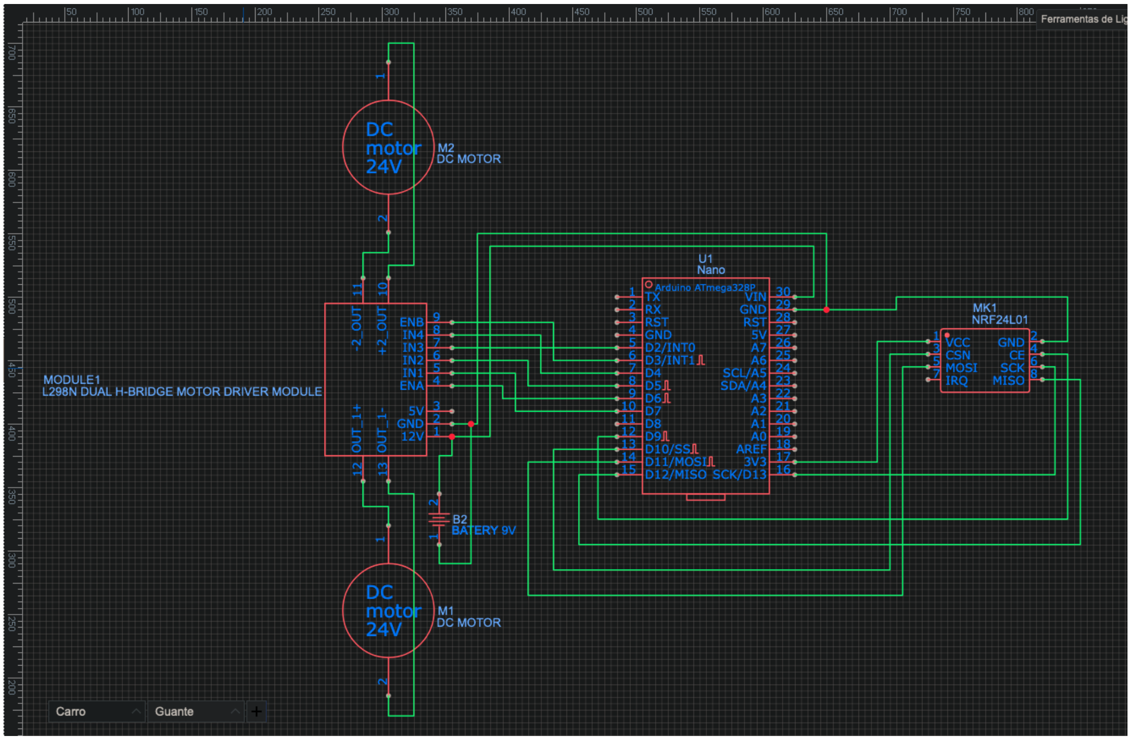


Figure 8: *Robot Car*'s wiring diagram [source: author]

5 *GloveBot* Operation

The *Robot Car* is controlled by hand gestures (see Figure 10) transmitted through *Controller Gloves* via Wireless communication (see Figure 9). We created four *Controller Gloves* with a specific color for the following movements: FORWARD, BACKWARD, TURN LEFT and TURN RIGHT. These colors are inspired by the author's work on tangible programming with preschool children [10]. In that work, the movements: FORWARD, BACKWARD, TURN LEFT and TURN RIGHT, are related to the colors: pink, green, white and black respectively, at the suggestion of the preschool teachers. In this way, each *Controller Glove* can only transmit a single movement and to carry out all movements, it requires the participation of four users.

6 Final Considerations and Future Works

In this technical report, we presented the *GloveBot*, a socioenactive artifact that enables the user to control a robot using hand gestures. Our artifact was designed based on the three elements (social, physical and digital) of the socioenactive systems, which argue that the social aspects of the experience should be made explicit in technology-based design, understanding that the experience within (smart) contemporary technology-based environments involves the social-physical-digital tripartite coupling. In this sense, the *GloveBot* artifact represents an important contribution to the *"Sistemas Socioenativos"* project, mainly in the school setting. We predict that our artifact provides open possibilities to creative learning as it allows for active involvement of children and practice to learn many necessary skills such as collaboration, perception and spatial understanding. Future works involve evaluation of the performance of our socioenactive artifact in terms of responsiveness and intuitiveness of gestural control. Besides that, investigating and understanding how *GloveBot* can

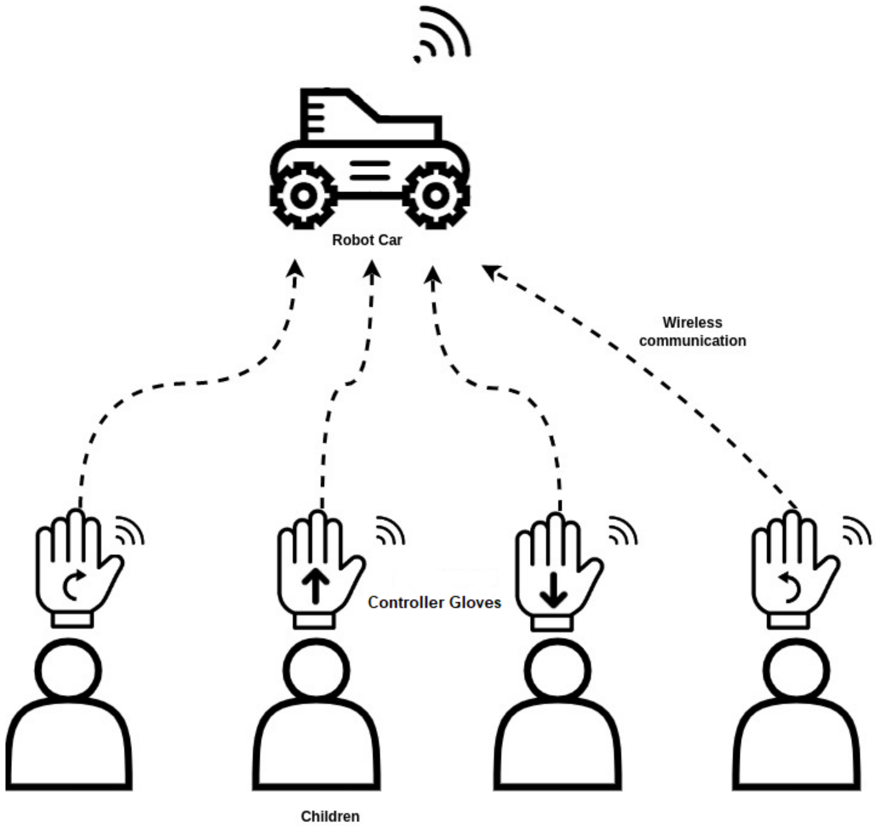


Figure 9: Socioenactive interaction scenario of *GloveBot* artifact

Figure 10: *Controller Glove*'s movements

facilitate creative learning in an educational setting.

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