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Design, Development and Assessment of a Multipurpose Robotic Assistant in the Field of Cognitive Therapy

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ABSTRACT

Advances in robotics have contributed to the support of different treatments for neurodevelopmental disorders (NDD) in children around the world. Several studies have developed and used robotic assistants to support these treatments, making robotic assistants a key tool for this purpose. Their results have been promising and have provided insight into what can be leveraged from them for future research. Therefore, this article presents a robotic assistant whose design and functionality can be adapted to support cognitive therapy processes. To test the adaptability of its design, an experiment is performed where some electronic elements are changed and it is verified that the design has changed automatically. A second experiment will test the feasibility of using the same robotic assistant in various types of cognitive therapies by modifying its functionality. The results show that the design of this robotic assistant can be adapted and it is also possible to determine if the new design violates any physical constraints. In addition, the results of the exercise performed previous to a cognitive therapy show positive results and this robotic assistant has been recommended by most therapists to be part of cognitive therapies.

Keywords: Cognitive therapy, Robotic assistants, Programmable design, iLogic.

INTRODUCTION

In recent years robotics has been a fundamental tool for the support of behavioral therapies in people with some kind of disability (Balasuriya et al., 2019). Countless robots have been designed to support cognitive therapies for children (Barcaro et al., 2018) resulting in robotic cognitive therapies that are characterized by applying scheduled goal-oriented sessions in a limited time. Here, robots guide children to meet these goals by providing them with precise instructions (Yuan et al., 2021). Among the most widely used robots, many papers show that Nao has been a robot in high demand for this type of therapy with children (Berrezueta-Guzman, Robles-Bykbaev, et al., 2021). Nao is a robot whose functionalities can be adapted to act as a companion in these therapeutic processes, and the results obtained have been significant in advancing this line of research over the years (Assad-Uz-Zaman et al., 2019; Robaczewski et al., 2021). However, some researchers have designed and developed robotic assistants to perform personalized cognitive therapies (Meghdari & Alemi, 2018; Tapus et al., 2009). It is evident that the development and use of robotic assistants are growing every year and so is the range of applications in the mental health care (Sun & Wang, 2021).

In this work, we have developed a multipurpose robotic assistant that not only allows us to adapt its functionalities, but also allows us to adapt its design based on the minimum hardware available. Here, we present how this ergonomic robotic assistant has a programmable design that automatically adapts its internal and external structure automatically. It is proposed two experiments to test this feature and also its feasibility for cognitive therapies with children.

RELATED WORK

Leaving aside the robotic assistants developed by brands such as Nao, we can find some models developed by researchers to carry out specific cognitive therapies for patients with Autism, Cerebral Palsy, Dementia, and Attention Deficit Hyperactivity Disorder (ADHD) (Berrezueta-Guzman, Robles-Bykbaev, et al., 2021; Cibrian et al., 2020; Cibrian et al., 2022). Each robotic assistant varies according to the type of therapy however, studies by (Rakhymbayeva et al., 2020; Tleubayev et al., 2019) show that the same robotic assistant can be used for both Autism and ADHD. It can also be verified in the study conducted by (Berrezueta-Guzman et al., 2020) that a robotic assistant designed to teach preschool children to avoid accidents at home or school can modify its design and functionality to elaborate behavioral therapies for children with ADHD, the results presented in (Berrezueta-Guzman, Pau, et al., 2021) were promising as in the first study. These investigations are the premises that a robot that has been designed for a specific therapy can adapt its functionalities and design to cover some other types of cognitive-behavioral therapies. However, reusing a robotic assistant could imply huge efforts for adapting its design and functionalities.

METHODOLOGY

The robotic assistant developed in this work has a design that has been automated by using programming rules. These rules use the dimensions of the hardware that composes the robotic assistant (see Figure 2) to adapt the dimensions of the internal and external structure of the robotic assistant. Parameters, configurations, interactions, assemblies, and constraints have been programmed so that each of them automatically adjusts to the new dimensions of the new electronic components of the robotic assistant. For this, we use Autodesk Inventor, which makes it possible to reuse the original design of the robotic assistant and adapt it automatically. Inventor uses iLogic technology, which standardizes and automates design processes by programming rules that are stored as objects directly in part and assembly documents (.ipt and .iam files). These rules determine and control the parameters and values of the design attributes, and by controlling these values you can define the behavior of the attributes, features, and components of a 3D model. It

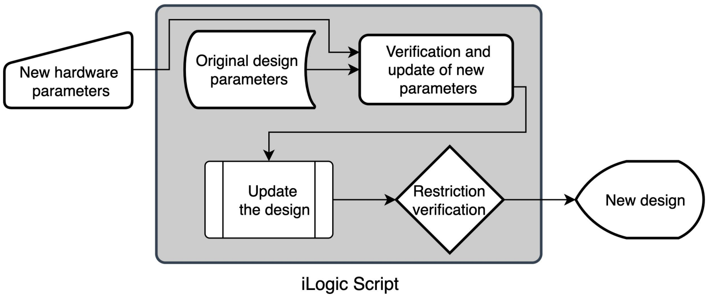

Figure 1: The processes inside the iLogic Script when some components are replaced.

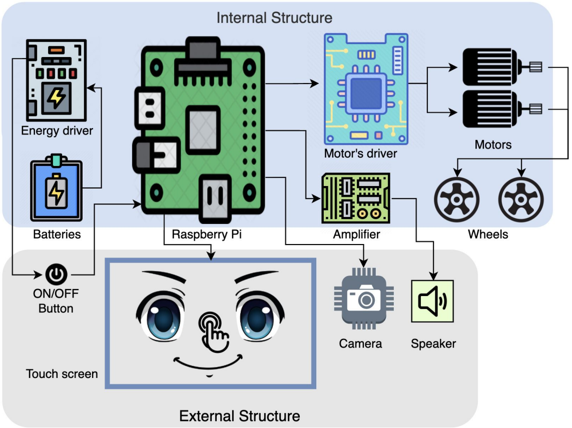

Figure 2: Components of the robotic assistant and the structures that hold them.

is possible to use these types of parameters to write rules containing input values other than numeric values, such as Boolean statements.

As shown in Figure 1, the parameters of the new hardware components are entered into our design, here the script compares these parameters with those of the original design to determine in which structure the change will be made. These parameters are updated and the design is automatically updated applying all the design rules. As an additional process, the program checks if both, the new center of gravity and the new balance point are ideal to keep the robot standing.

The robotic assistant design consists of an internal structure (part 1) capable of housing the Raspberry Pi, power controller, batteries, motor controller, motors, wheels, and amplifier. The external structure (part 2 and part 3) is capable of housing the touch screen, camera, power button, and speaker (see Figure 3). These devices can be replaced; however, the design cannot automatically accommodate additional components or removed some of the ones established in the original design. All redesigns will maintain the same number of components (an important rule).

The components of this robotic assistant and its design allow (1) its displacement on flat surfaces thanks to the motors and wheels on the lower part, (2) audiovisual projection through animations and sound on its screen located

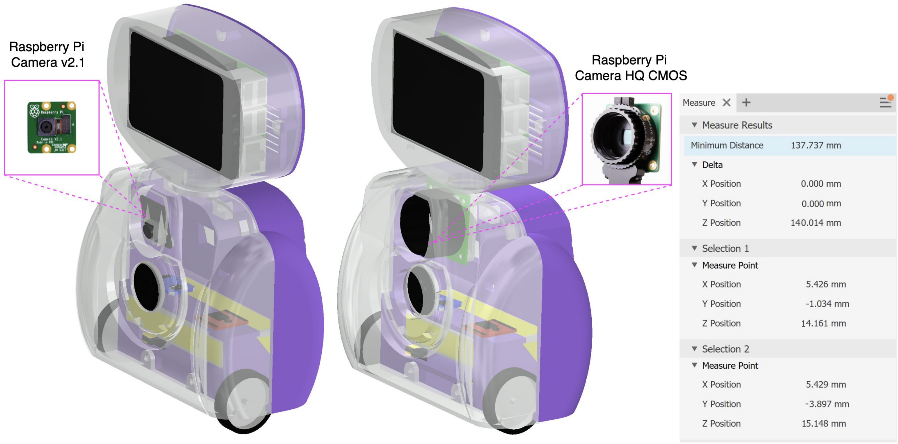

Figure 3: The design's adaptability and the balance point's calculation offset when the camera component has been replaced for another version.

on the head and its speaker on the chest, respectively, (3) computer vision, through its camera, and (4) interaction with the touch screen on the head.

The design process of this robotic assistant takes as a reference the electronic components and based on their dimensions, the original internal and external structure that will contain them is designed. The design of the robotic assistant and the distribution of the elements inside it, make the center of mass and the equilibrium point coincide on the Z-axis [x = 0, y = 0]. As there are only two wheels, the robot becomes a Segway-like (unstable) system, but the axis of these wheels and their motors coincide with the X-axis [y = 0], so the motor controller adjusts the displacement more significantly along the Y-axis and a third spherical wheel is adapted at the back to avoid an imbalance along this axis. The design of the robotic assistant and the distribution of the elements inside it, make the center of mass and the equilibrium point coincide on the Z-axis [x = 0, y = 0]. As there are only two wheels, the robot becomes a Segway-like (unstable) system, but the axis of these wheels and their motors coincide with the X-axis [y = 0], so the motor controller adjusts the displacement more significantly along the Y-axis and a third spherical wheel is adapted at the back to avoid an imbalance along this axis. Another constraint is the weight distribution of the robotic assistant when its components are replaced. In this case, it is determined that the displacement of the center of mass does not present a significant difference in the X and Y axes concerning the original design, from this value depends that the robotic assistant maintains its balance as well.

Figure 3 shows how a component, specifically the camera, is replaced by a different version: from Raspberry Pi Camera V2.1 to Raspberry Pi Camera HQ CMOS). The dimensions of the new camera are 4 times larger than the previous version, and its weight is double according to the official documentation (Raspberry-Pi, 2022). However, the camera represents 4% of the total weight of the robotic assistant making the balance point move only 2.863 mm on the Y-axis and 0.003 mm on the X-axis (this displacement is insignificant because the camera is symmetrical on that axis). This variation of the balance point does not represent an imbalance for the robotic assistant. Otherwise, we should get a warning message in the calculation.

EXPERIMENTS

To test the feasibility of the automatic design of the robotic assistant, it is proposed to replace three components of the original design: the camera, the motors, and, consequently, the wheels. These new components will cause the design of the internal and external structure to change. To do this, following the process in Figure 1, these new versions of components are digitized and their dimensions (3D) are introduced into the design of the robotic assistant assembly. It is verified that the structures have been redesigned in seconds. Also, to check that the program recognizes whether the new design may represent an imbalance in the robot structure, we replace the dimensions of the touch screen from 3.5 inches to 7 inches, and its weight (doubled). The result shows that the balance point leaves the robot structure on the Y-axis, as well as its center of mass. This represents that the robot has no balance and will fall as soon as we place it on a flat surface.

To test the feasibility of the robotic assistant as a support in a therapy process with children, an introduction to a cognitive therapy session consisting of a concentration and memorization game is performed. Here, a group of 10 children will try to remember pictures without labels, labels without pictures, and pictures with labels. This exercise is ideal to find out how the child can retain information in the short term. Normally, this exercise is done with sheets of paper, but with the robotic assistant, it was only necessary to program the game in Python. This means that the multimedia content (images and labels) allows several iterations without repeating the images, and the feedback the child receives from the robotic assistant motivates him to continue and improve with each iteration.

RESULTS

The first test demonstrates that automatic redesign brings significant advantages to researchers who want to take advantage of an already designed robot, but with other versions of the hardware. The result of the first experiment showed that the robotic assistant can be redesigned very quickly by replacing its components, for example, the new camera changed the external structure. And by changing the motors and wheels, the internal structure is automatically modified. These modifications did not alter the balance of the robotic assistant.

In a second test, the reconfiguration of the robot's functionalities for the cognitive therapy process is examined, demonstrating that the procedure for configuring a game is simple and can take advantage of unlimited resources (multimedia). All multimedia content can be imported into the robotic assistant and can be deployed according to the needs of the cognitive therapy. The game designed in Python provides greater freedom for the use of visual resources, as it leverages its touch screen as a way of interaction, replacing printed images. The children find this exercise more engaging using the robot, so 3 of the 4 therapists consider the robot ideal to support a cognitive therapy session. They also believe that they could obtain better results with the robotic assistant in such therapies as the child's attention is maintained over time.

CONCLUSION

This work shows a robotic assistant that allows adjusting its design according to the available hardware. Despite the restrictions that prevent adding new elements or removing existing ones, the presented methodology allows replicating this robot with substitute elements such as other versions of these components. However, this development can save the development team 90% of the time invested in the design of a robotic assistant, without taking into account the time to 3D print it. The experiment demonstrates that automation in design also makes it possible to determine whether an element does not meet the physical conditions of the robotic assistant, such as balancing it.

The exercise performed for cognitive therapy demonstrates that the robotic assistant allows to easily adapt its functionality. After this exercise, the robotic assistant was accepted by the children in the therapy session and was an element that made the therapy process innovative. The therapists have used its functionalities and in this first approach have proposed important improvements to the robotic assistant that the developers can quickly adapt thanks to its ergonomic features. Although it is a novel element, one therapist considered that the robotic assistant could be replaced by a tablet, however, the other three therapists stated that a tablet is a distracting element in a therapy session. To support the use of the robotic assistant instead of a tablet, the children were asked individually and 90% of them expressed that they would like the robot to be part of the therapy instead of a tablet because they like the way it looks and works.

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