Integración de un torso, base móvil y una cabeza, para un robot humanoide

Torso, mobile platform and head integration for a humanoid robot

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Resumen: En el ARCOS-Lab, se tiene como proyecto principal, la construcción de un robot humanoide de cuerpo completo, capaz de realizar tareas de manipulación de objetos a un nivel elevado de precisión y complejidad. Para ello, el robot cuenta con una base móvil omnidireccional para desplazarse con facilidad, con un torso móvil que soporta dos brazos robóticos KUKA LWR 4+, de 7 grados de libertad, y una mano robótica con 5 dedos; tanto los brazos como la mano, poseen un control suave, llamado control por impedancia, que facilita la interacción con fuerzas externas y por tanto, las tareas de manipulación. Además, para el tema de percepción, se tiene una cabeza con dos cámaras de alta resolución, un Kinect V2.0 y una cámara térmica; junto con una estructura de cejas, boca y orejas que junto con matrices de LED conforman la cara emocional del robot, permitiéndole generar mayor empatía con los humanos de su entorno, mostrando felicidad, tristeza, asombro, y otras emociones. Para nuestro robot humanoide se plantean distintos ambientes de trabajo, el primero es una cocina inteligente, de una casa; este escenario representa un reto importante ya que al cocinar, los humanos llevamos acabo tareas cotidianas ante nuestros ojos, pero complejas de desarrollar para un robot. El otro escenario propuesto es un ambiende de bodega de una fábrica donde el robot sirva como asistente ó bodeguero, facilitandole equipo o herramientas a un operario, ó inclusive, colaborando junto con una persona en una etapa de ensamble de producto. En este artículo se explicarán las diferentes partes que componen el robot humanoide así como un resumen del proceso de diseño y construcción y los retos encontrados durante la ejecución del proyecto.

Palabras clave: robótica, investigación aplicada, tecnología avanzada, diseño, cognición

Abstract: ARCOS-Lab is currently building a whole body humanoid robot, capable to manipulate objects skillfully, in a complex and uncontrolled environment. To achieve that, the robot has an omnidirectional mobile base, a mobile torso that supports two KUKA LWR 4+ robotic arms with 7 degrees of freedom, and a robotic hand with 5 fingers; the arms and the hand have a smooth control called impedance control, that will allow the robot to perceive external forces, giving the robot an advantage to manipulation tasks. Also, to perceive the objects in different ways, the robot has a head with two high resolution cameras, a Kinect V2.0 and a thermal camera; the head also has an emotional face structure based on eyebrows, ears, a mouth and two LED matrices to give the robot the capability to show emotions and better interact with the people. Our robot is pretending to work on different scenarios, one of them is a smart kitchen, which is an important challenge because the complexity needed to develop tasks like cooking. Other of the scenarios is a warehouse environment where the robot will be an assistant, giving equipment and tools to the operators, or even helping them to assembly some product, working on a collaborative way. In this paper we will explain the different parts that our robot is composed of. We will describe the design and construction process and also many of the challengues encounter during its development.

Keywords: robotics, applied research, advanced technology, design, cognition

1. INTRODUCTION

If a humanoid robot is going to work as an assistant for humans in every day tasks it is necessary for the robot to have a dexterous manipulation system, that allows it to interact safely with humans and other robots. There are many tasks that require objects manipulations, like opening a jar, or moving a big object (like a pot) from one place to another. Therefore, it is important for the robot to have a body that is able to execute manipulation tasks as best as possible.

Typically, the robotic systems are designed to work with very specific conditions in precontrolled scenarios. A requirement for a robot that will work on many uncontrolled and unpredictable scenarios, is to have a manipulator that can perceive the environment (in many ways such as visual or tactile).

In this paper we present the work that the ARCOS-Lab has been doing as part of building a whole body humanoid robot, that could accomplish complex and skillfull manipulation tasks. Our robot is based on a omnidirectional mobile platform, a mobile torso in a linear system, two robotic arms, two hands and one perception head with an emotional face. We pretend that this robot will work on 3 different scenarios (Figure 1), a kitchen, a shared workspace and an intelligent warehouse.

The kitchen scenario presents many different objects, with different shapes, textures, kinematics, weights, and many other properties. A kitchen scenario is very challenging because there is a great amount of different possible tasks with a lot of different objects.

In another scenario, the robot will work in a collaborative way with a human, helping the person to assembly some product, making the process faster, and handling the risky and difficult tasks, ensuring the protection of human life during the work.

Another scenario is a more industrial one, a warehouse from a factory, where the robot will work as a technical assistant, managing object identification, location, position, the robot would have to handle tasks like carrying weight objects and using some tools on that object.

Figure 1: *ARCOS-Bot Scenarios: Kitchen, collaborative work and warehouse (left, center and right respectively)*

In this document, we present some related work, and similar robots in Section 2, then we will present our work in the robot developed at ARCOS-Lab, in Section 3. And in the Section 4, we discuss the next part of the building process and future improvements of our robot.

2. RELATED WORK

Many general purpose intelligent robots up to now. We will concentrate in this section to robots that are (at least partially) humanoid but with strong manipulation capabilities.

Beetz, M. et al. (2011) presents a setup with two humanoid robots that are able to make pancakes, a cooking task. One of the robots, the TUM-Rosie is a robot capable of advance manipulation capabilities. It has arms and hands with impedance control (soft interaction with the environment). . TUM-Rosie has two KUKA LWR4+ arms, two DLR-HIT II hands, anomnidirectional mobile base, a KINECT and thermal sensor in its head for perception and a pan-tilt unit for neck movement. TUM-Rosie has been very successful as shown in many different demonstrations (preparing breakfast, object pushing and many more).

Another work, is presented on Ott, Ch. et al. (2006), its called Justin, and it's the humanoid manipulator robot from the German Aerospace Center (DLR e.V.). They developed the LWR arms which then they sold to KUKAJustin has a more complex and advanced torso, with 3 degrees of freedom, that allow the robot to move like a human spine to take objects. Its mobile base is also omnidirectional and has active damping. It is a really ergonomic robot, and its focused on advanced manipulation tasks.

3. HARDWARE INFRASTRUCTURE

Our humanoid robot proposed design is shown in figure 2. The robot is composed of an omnidirectional mecanum-wheel mobile platform, a torso, two kuka LWR 4+ arms, two Wessling Robotics hands and a perceptive head. The head is in turn composed of a neck, a perceptive skull and an emotional face.

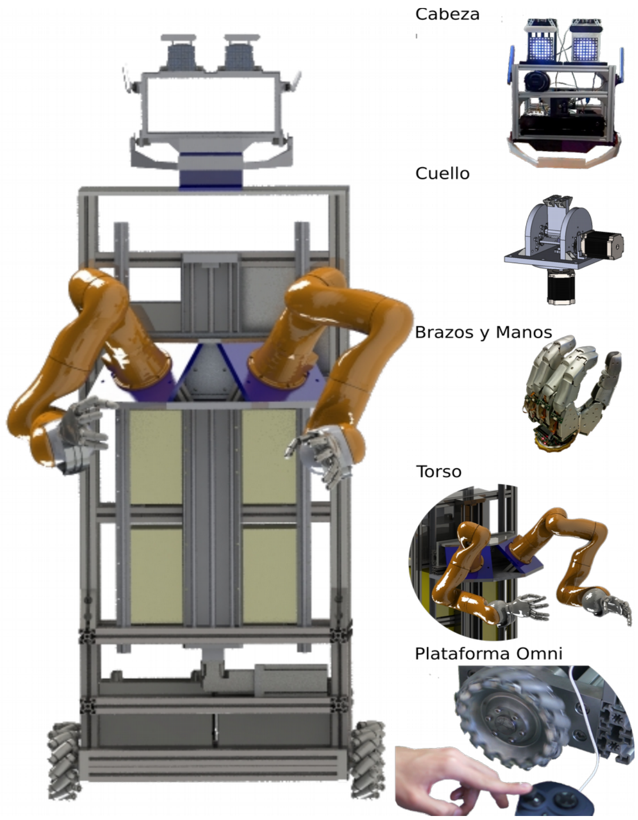

Figure 2: *ARCOS-Lab humanoid robot*

At the center axis of the robot body, there will be the arms and hands controllers, the batteries and the computers that will allow the robot to be controlled.

3.1 Omnidirectional mobile base

The humanoid robot has an omnidirectional mecanum-wheel mobile base (Figure 3), because the robot is planned to move on environments with a regular enough surface the robot doesn't need human-like legs. The mobile base developed on Gómez, F. (2015), contains four high capacity batteries to give certain autonomy to the omnidirectional platform, it also contains the power electronics circuits, and the four servo motors connected to the wheels.

The four mecanum-wheel have 60 degrees rolls along its circunference, that allows the robot to move on any direction depending of each wheel direction. (Figure 4). The mobile base and the basic robot structure is built with Bosch aluminum profiles, that will support the almost " 400 kg " robot weight.

The four actuators that move the platform, are controlled by two circuit boards developed in the laboratory, and a STM32F4 discovery microcontroller, to control the direction and speed of each wheel. A project called Open-CoRoCo (Open complaint robot controller) will allow the mobile platform not only to move but it will also give the mobile platform impedance control, making it safe with the environment.

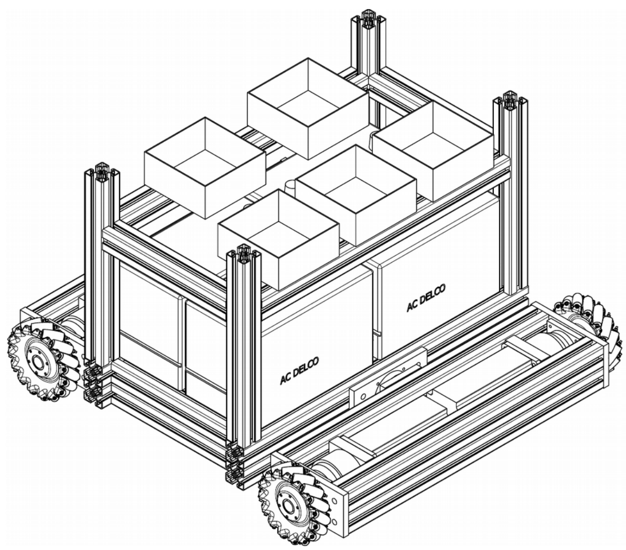

Figure 3: *Omnidirectional mobile base visualization*

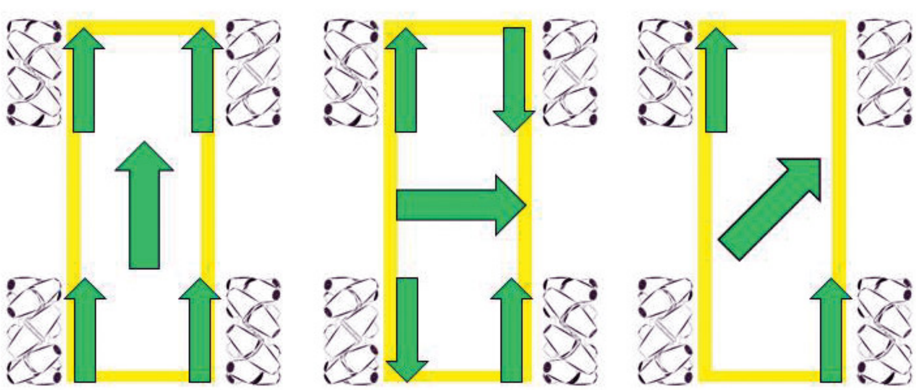

Figure 4: *Four mecanum-wheel base movement diagram*

3.2 Mobile torso

The torso is composed of a space for storing computers and controllers for the robot and also of a motorized lifting structure that allows the robot to move the arms up and down. On top of that structure the arms will be mounted in a particular configuration (Figure 5).

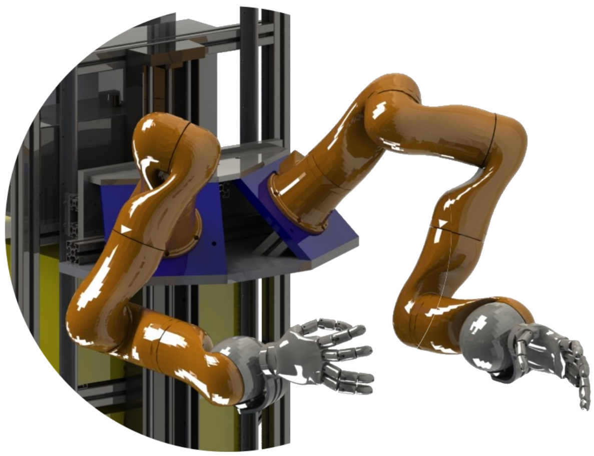

Figure 5: Torso structure

The torso structure supports two KUKA LWR4+ arms, and the DLR HIT II robotic right hand. With the 7 degrees of freedom arms and the human-like hand, the robot can basically manipulate objects with a similar movement capabilities of a human being. Also, both, arm and hand, have impedance control and torque sensors, which give them the possibility to measure and perceive external forces, allowing the robot to know: the weight of an object during manipulation tasks, to perceive a contact with a human or a bigger object; and most importantly, the robot will choose to act or not, and how to, based on those forces.

To determine the best setup for mounting the arms, in Chaves, I. et al. (2018) 20 000 000 different reaching task simulations, with both hands, for a spherical specific size object, using the humanoid robot simulator for the ARCOS-bot were executed. This paper developed a representation of robot manipulation capabilities for two arms that we called a dual capability map. With this map we were able to determine the best position for mounting both arms where they could reach and manipulate objects with more flexibility(Figure 6). As a result of that work, the shoulders and setup of the two arms got updated in Alvarado, A. (2019).

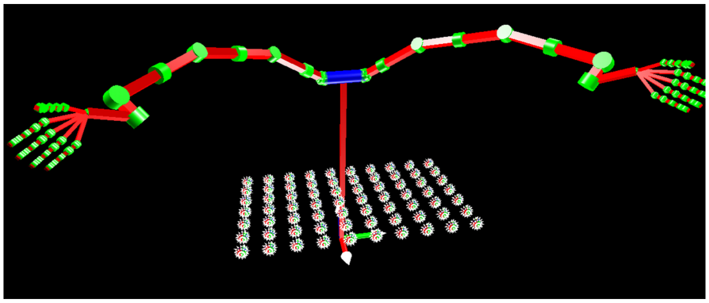

Figure 6: *Dual capability map simulation case with reaching goals*

3.3 Head and emotional face

At the upper part of the robot the head will be located. Three versions of this subsystem were developed. The latestby Hernández, P. (2018), contains two high resolution cameras, a thermal camera, and a KINECT V2.0. This allows the robot to perceives the 3D environment, the position, color, shape and temperature of the objects. With these sensors, the robot gets a large quantity of information that will help it to determine better how to locate objects and their properties.

Also, the head has an emotional face, created with two ears, two eyebrows, and a mouth, moved by servo motors, and two LED matrices that show human-like eyes interactions. All these actuators are controlled by a RaspberryPi system, to allow the robot to show different emotions to people. This design gives the robot the possibility to better interact with people. (Figure 7).

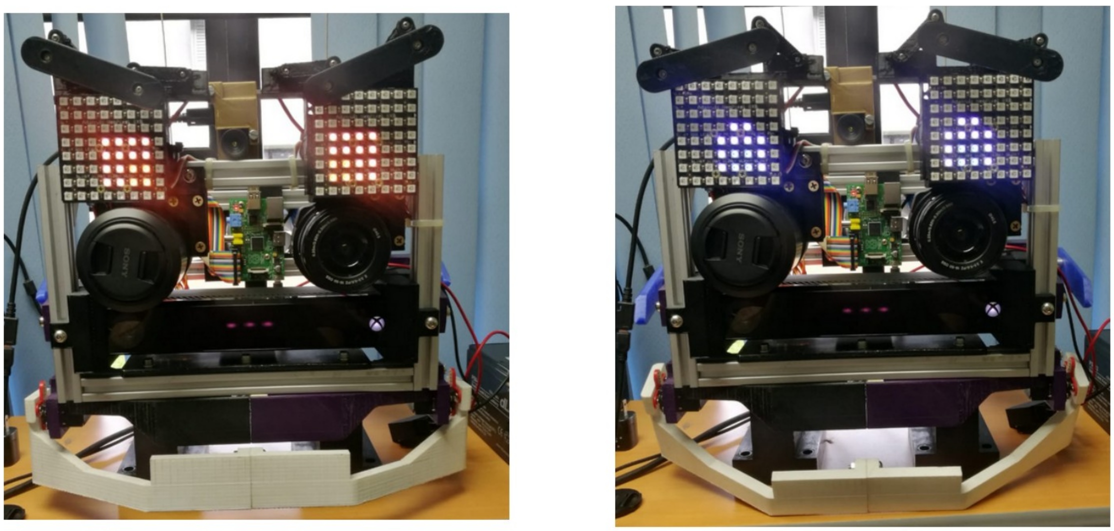

Figure 7: *Angry and sad (left and right respectively) emotions of the robot face*

In order to increase its perception capabilities the head of the robot must be able to move to look for objects in different directions. Therefore, it’s necessary to mount it on a pan-tilt unit (the “neck” of the robot).

4. DISCUSSION AND FUTURE WORK

Currently, the humanoid robot is on the last part of its building process, integrating all the principal parts, the omnidirectional base, the mobile torso with both arms and the right hand, the neck and the head. Also, it will include the computers and batteries to make the robot work.

In comparison, our robot have improvements of TUM-Rosie version, like for example, the motorized vertical movement for the torso, allowing the robot to take objects in a large range of different heights. Another distinction, is the emotional face and the improvements for the head, that take into consideration the interaction with people for a future robotic assistant.

The humanoid robot will allow us to make research on new and important challenges for robotics, related to object manipulation, human interaction, collaborative robotics, environment and objects perception, and many others topics.

Future improvements:

- Mounting the second hand, the left one to the correspondant arm to give the robot two symmetrical hands to manipulate with.
- Implementation of impedance control on the omnidirectional base, by using the circuits and hardware part developed on the ARCOS-Lab, in each of the four wheels, to ensure that the robot will work in a collaborative and secure way with people. That would give the robot the possibility to move smoothly on any direction and to stop if it “feels” a contact with an obstacle or a person.
- Create a skin, like an armor to the robot, to protect all the systems, specially the electronic circuits, and to give the robot more personality and aesthetics, that would help to create a better interaction with people.
- Implementation of impedance control on the torso, basically on the linear and vertical axis of the torso. This will allow the robot to move its shoulders in a smoothly way and react to unpredicted external forces like a contact with a human or some furniture structure.
- Mounting the robot head over the shoulders structure, directly on the torso, to make it easier for the robot to perceive objects. The head would move together with the arms bases.
- Develop and implement our own robotic manipulator arm with 7 degrees of freedom and impedance control.
- Mechanical improvement to the robotic hands to allow more mobility on the robotic thumb.

5. ACKNOWLEDGEMENTS

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