Ingeniería en Robótica y Telecomunicaciones

Departamento de computación, electrónica y mecatrónica.

Course Name:
Laboratorio de Robótica Aplicada P25-LRT4082-1

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## Introduction

In this project, we utilized the knowledge acquired in class to program predefined routines using RoboPlus Motion and RoboPlus Task to control the Bioloid GP robot. The primary objective was to execute a sequence of movements that allowed the robot to pick up an object from the ground, lift it, and transport it to a designated point behind it.

This report details the steps taken during the project, including the programming process, execution of movements, and the challenges encountered. The results demonstrate the effectiveness of predefined movements compared to customized ones, as well as the difficulties in combining motion sequences with manual control.

The Bioloid GP robot, equipped with Dynamixel actuators, provided a robust platform for testing and implementing complex motion sequences. By leveraging the RoboPlus software suite, we were able to create, modify, and execute motion routines with precision.

## Theoretical Framework

**The Bioloid GP Robot:**

The Bioloid GP is a humanoid robot designed for advanced robotics applications, particularly in education, research, and competitions. It is equipped with Dynamixel actuators, which provide high precision and a wide range of motion, making it suitable for complex tasks such as walking, object manipulation, and dynamic balancing (Robotis, n.d.). The robot's modular design allows for easy customization and expansion, enabling users to adapt it to various scenarios.

The Bioloid GP's ability to perform intricate movements is largely due to its inverse kinematics capabilities. Inverse kinematics is a mathematical approach used to calculate the joint angles required for the robot to achieve a specific position or posture. This is particularly important for humanoid robots, as it allows them to perform tasks such as reaching for objects or maintaining balance while walking (Craig, 2021).

**Motion Planning and Execution:**

Motion planning is a critical aspect of robotics that involves defining a sequence of actions to achieve a specific goal while considering constraints such as stability, speed, and precision. For humanoid robots like the Bioloid GP, motion planning often involves the use of trajectory generation algorithms to ensure smooth transitions between movements (Siciliano, 2010).

In the context of this project, motion planning was carried out using RoboPlus Motion, a graphical interface that allows users to create and modify motion sequences. Each motion sequence consists of a series of keyframes, where the position and speed of each servo are defined. By adjusting these parameters, we were able to create both predefined and custom motions tailored to the task of picking up and transporting an object.

**Automated and Manual Control:**

The integration of automated and manual control is a key feature of the RoboPlus software suite. RoboPlus Task enables users to program automated actions while also providing the flexibility of manual control through a virtual controller. This hybrid approach is particularly useful for tasks that require real-time decision-making, such as object manipulation (Robotis, n.d.).

In this project, we assigned specific motion sequences to buttons on the virtual controller, allowing us to manually trigger each movement during the execution phase. This approach provided greater control over the robot's actions, enabling us to make adjustments as needed during testing.

**RoboPlus Software Suite:**

The RoboPlus software suite is a powerful toolset for programming and controlling the Bioloid GP robot. It consists of two main components:

**RoboPlus Motion**: This graphical interface allows users to create and modify motion sequences by adjusting servo angles, speeds, and timing. It supports both predefined motions, which can be customized, and entirely new motions created from scratch.

**RoboPlus Task**: This block-based programming environment enables users to automate actions, assign motion sequences to controller buttons, and develop control logic. It is particularly useful for creating complex routines that combine multiple motions.

**Challenges in Humanoid Robotics:**

Humanoid robots like the Bioloid GP face several challenges, including maintaining balance during dynamic movements, achieving precise control over multiple degrees of freedom, and ensuring smooth transitions between motions. These challenges are often addressed through iterative testing and optimization of motion parameters.

In this project, we encountered challenges related to stability during turns and grip accuracy. These issues were resolved by reducing the speed of the hip servos and adjusting the arm servo angles, demonstrating the importance of motion optimization in robotics.

**Applications of Humanoid Robots**:

Humanoid robots have a wide range of applications, including:

Education: Teaching robotics concepts and programming.

Research: Developing and testing new algorithms for motion planning and control.

Competitions: Participating in robotics challenges that test the robot's capabilities in tasks such as object manipulation and navigation.

The Bioloid GP's versatility and programmability make it an ideal platform for exploring these applications, as demonstrated in this project.

## Methodology

The project was divided into several key phases to ensure a systematic approach to programming and testing the Bioloid GP robot.

1. Understanding the Robot and Software:

   We began by familiarizing ourselves with the Bioloid GP robot's capabilities, including its range of motion and the functionality of its Dynamixel actuators.

   We explored the RoboPlus Motion and RoboPlus Task software to understand how to create and modify motion sequences.

2. Motion Design:

   Predefined Motions: We used existing motions such as "Walk Forward" and "Turn" from the RoboPlus Motion library. These motions were modified to suit our specific needs, such as adjusting the speed and angle of the servos.

   Custom Motions: For tasks like picking up the object, we created custom motions in RoboPlus Motion. This involved programming the robot to bend its waist, extend its arms, and grip the object.

3. Button Mapping in RoboPlus Task:

   In RoboPlus Task, we assigned each motion sequence to specific buttons on the virtual controller. For example:

   Button 1: Walk Forward

   Button 2: Bend & Grab

   Button 3: Turn 180°

   This allowed us to manually trigger each motion during the execution phase.

4. Testing and Optimization:

We conducted multiple test runs to evaluate the robot's performance. Initial tests revealed issues with stability during turns and grip accuracy.

To address these issues, we reduced the speed of the hip servos from 300 RPM to 240 RPM, which improved stability. Additionally, we adjusted the arm servo angles by 15° to enhance grip accuracy.

5. Final Execution:

   After optimizing the motion sequences, we executed the complete routine, which involved:

   Approaching the object.

   Gripping and lifting the object.

   Turning 180° and transporting the object to the designated point.

   Releasing the object.

## Results

1. Robot starts in a neutral standing position. Servos calibrated; robot ready to receive commands.

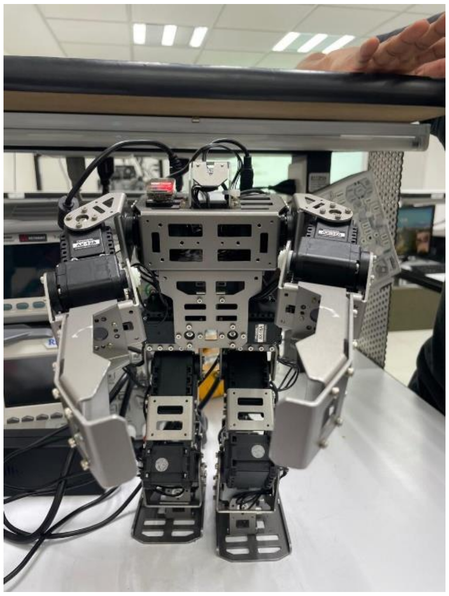

Figure 1. Initialization.

2. Custom motion to lower the torso (waist servos at 45°). Reduced waist servo speed to 50% for stability.

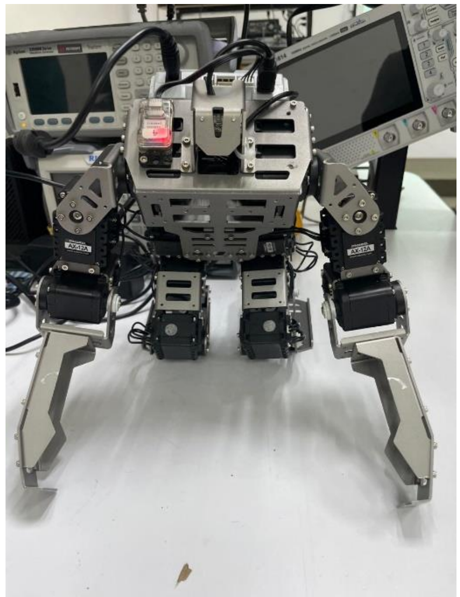

Figure 2. Bend Waist.

3. Arm servos programmed to reach the object (arm angle: 30°). Initial grip failed; adjusted arm angle to 35° for better reach.

Figure 3. Extend Arm.

4. Close gripper (servo torque: 80%). Torque increased to 85% to secure the object.

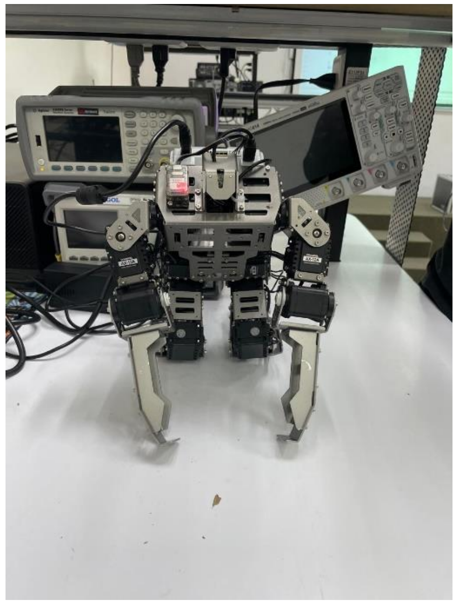

Figure 4. Grip Object.

5. Vertical lift using combined waist and arm motions. Added a 2-second pause mid-lift to prevent shaking.

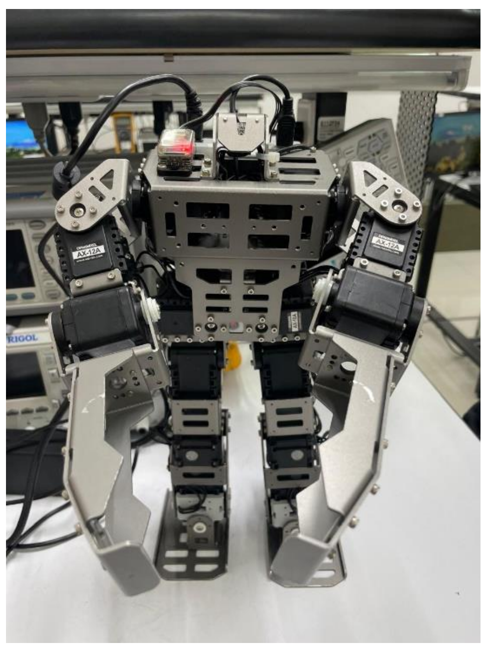

Figure 5. Lifting Phase.

In the previous figures we show the movements of the robot without the object. The object can be seen in the following figure.

Figure 6. Object.

During the execution of the programmed routines, we configured the robot's motion parameters to ensure precision in key tasks such as walking, turning, and releasing the object. However, we encountered a technical issue with several servomotors in the robot's right leg, which were not functioning correctly. This malfunction significantly impacted the robot's ability to perform certain movements, particularly during the turning phase.

The walking phase can be observed by going to the following link.

https://www.youtube.com/shorts/NlQvlPUCFGA

The object dropping phase can be observed by going to the following link.

https://www.youtube.com/shorts/q0L1HLXX910

## Conclusions

In this project, we successfully programmed and executed a sequence of movements for the Bioloid GP robot using RoboPlus Motion and RoboPlus Task. The robot was able to perform key tasks such as walking, picking up an object, turning, and releasing it at a designated point. However, we encountered a significant challenge related to the servomotors in the robot's right leg, which were not functioning correctly. This issue directly impacted the robot's ability to perform smooth and stable turning motions.

The integration of manual control via the virtual controller allowed us to make real-time adjustments during testing, demonstrating the flexibility of the RoboPlus software suite.

However, the limitations imposed by the malfunctioning servos also revealed the need for robust error-handling mechanisms in robotic systems, particularly in scenarios where hardware failures can disrupt planned movements.

Overall, this project provided valuable insights into the challenges of motion planning and execution in humanoid robotics. It emphasized the importance of iterative testing, parameter optimization, and hardware maintenance in achieving precise and reliable robot performance. Future work could explore more advanced techniques for fault detection and compensation, as well as the development of autonomous decision-making capabilities to handle unexpected hardware issues.

## References


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