NannyBot for Robots Developing to Walk

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1. Introduction

1.1 Objective

All around the world, humanoid robots are being developed. The development of humanoids robots is natural and important, as they are made to do things instead of humans. Humanoids can be used to venture into dangerous places, or check if some place is safe for humans to traverse. An essential part of a humanoid robot is its walking system. A common way to teach robots to walk is through reinforcement learning. Using reinforcement learning, the robots try to walk, fail, and learn from their failures and try in different ways until they are able to walk at last. Naturally, this requires many trials and errors. The errors mean that robots will inevitably fall many times, and require to be stood back up, either by a person's help, or by a machine, or by its own strength. However, not all robots can stand by itself, and machines that help robots up must be pre-installed in the place, so could be restricted by the environment. The human help is the most reliable, but it is tedious, and could be dangerous if the robot learning to walk is of a human size.

Professor Kim Joohyung pitched the idea to build a robot that will do this job for the people. Our goal is to build a wheeled robot that can be controlled by a human, but do the heavy lifting for the human. The robot we intend to build is will be for small robots learning to walk, whose size is around 30cm*30cm*50cm, and maximum weight is 5kg. Our robot is meant to be a prototype, which, if it works well, Professor Kim will look into making ones for bigger robots.

1.2 Background

Throughout the world, many companies are developing humanoids and walking robots for various purposes. These companies include Google, UBTech, Boston Dynamics, and much more. These robots are not limited to small sizes, but include human sized robots as well, or even larger robots. For larger robots, falling is an even bigger problem, because the extra weight they have means that they will hit the ground harder when they fall. Naturally, the issue of robots falling has been studied thoroughly already. Many robots can detect themselves falling, and some can even react to prevent themselves from falling. Some places have machinery pre-installed to recover the robot after it falls. Some robots are built to reduce fall damage, and some robots can stand back up by itself to continue walking. However, not all robots have these features, and it's also possible people test the robot where robot fall prevention machineries are not pre-installed. Highly expensive robots could be damaged if a fall prevention system fails to work, and if the robot is large, people could get hurt while trying to get the robot back up. Our robot is meant to prevent the falling of the robot by having straps attached to our NannyBot, which will detect the robot falling, and pull the robot back up when it does fall. This NannyBot won't require pre-installing, and be able to function anywhere with the robot so long as it has power. It will be compatible with almost all walking robots of a certain size. made possible by using different harnesses for different shapes of robots.

1.3 Physical Design

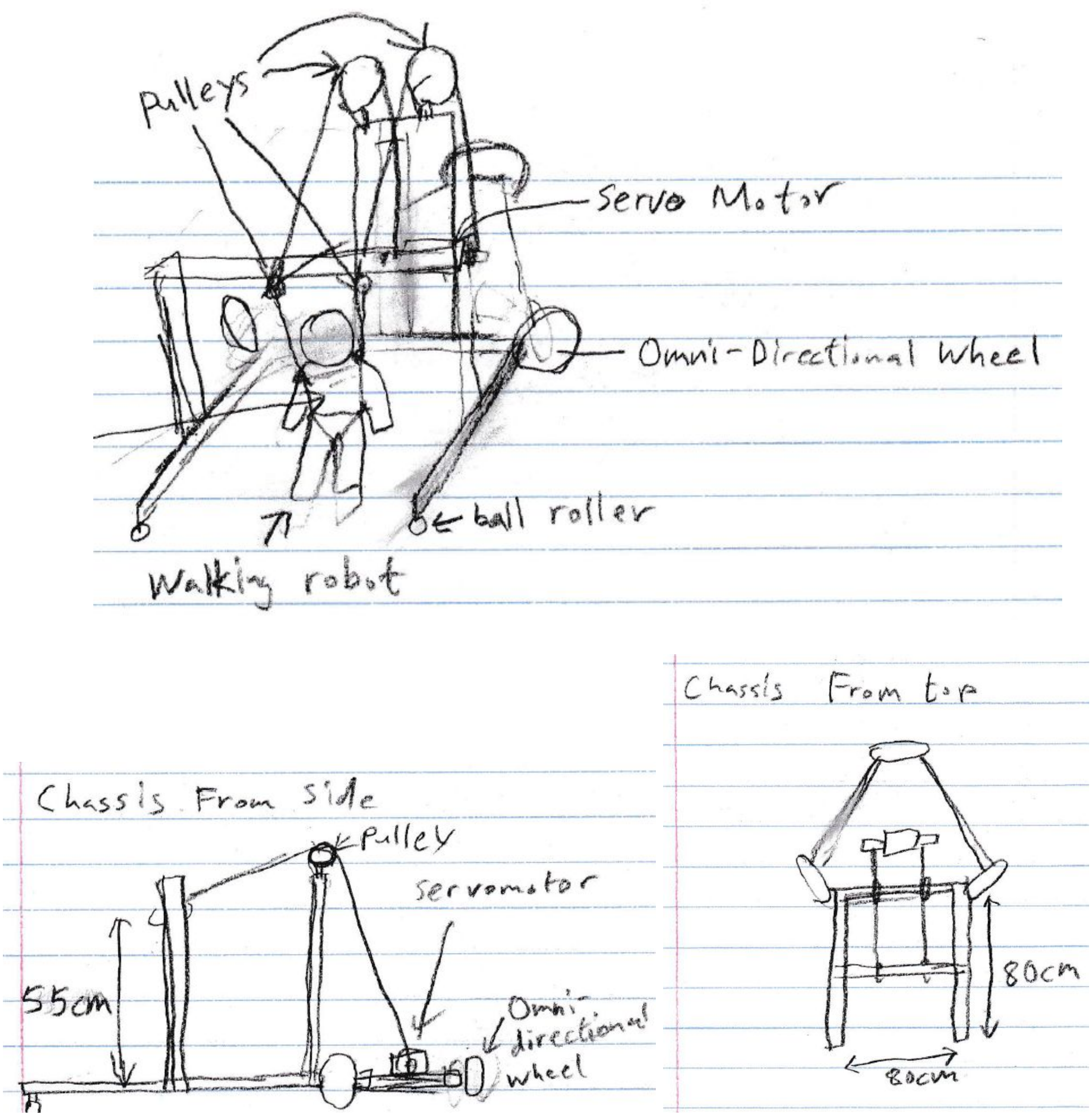

Figure 1

The figure 1 shows the physical design of the Nannybot from various viewpoints. The NannyBot is composed of a Chassis, a pickup system, and a pair of legs that stretch out to the sides of the walking robot. The legs help distribute weight when the walking robot is lifted, and also act as a place to put supports for the pulleys that pull the walking robot up. They are 80cm apart so that the walking robot has room to move and doesn't hit the NannyBot. The Chassis has 3 omni-directional wheels and has a triangular formation that allows it to travel in all directions. A servo motor is used to pull the strings laid over the pulleys to lift the walking robot. It is placed on the Chassis, so that the center of mass of the NannyBot stays low.

1.4 High-level requirements list

- NannyBot must be able to follow a Robotis OP2 under the user's control, which has a velocity of 24cm/sec.
- NannyBot must be able to lift a Robotis OP2, which weighs 3kg.
- NannyBot must be able to carry the Robotis OP2 and travel at least 4m.

2. Design

2.1 Block Diagram

We will use a microcontroller to send PWM signals to the 3 DC Geared motors and 1 servo motor. The microcontroller will be connected to a Joystick and 2 buttons. The signals sent to the motors will be determined by the signal from the joystick and the buttons. The PWM signals will tell the motors how fast they need to turn, and in what direction they must turn.

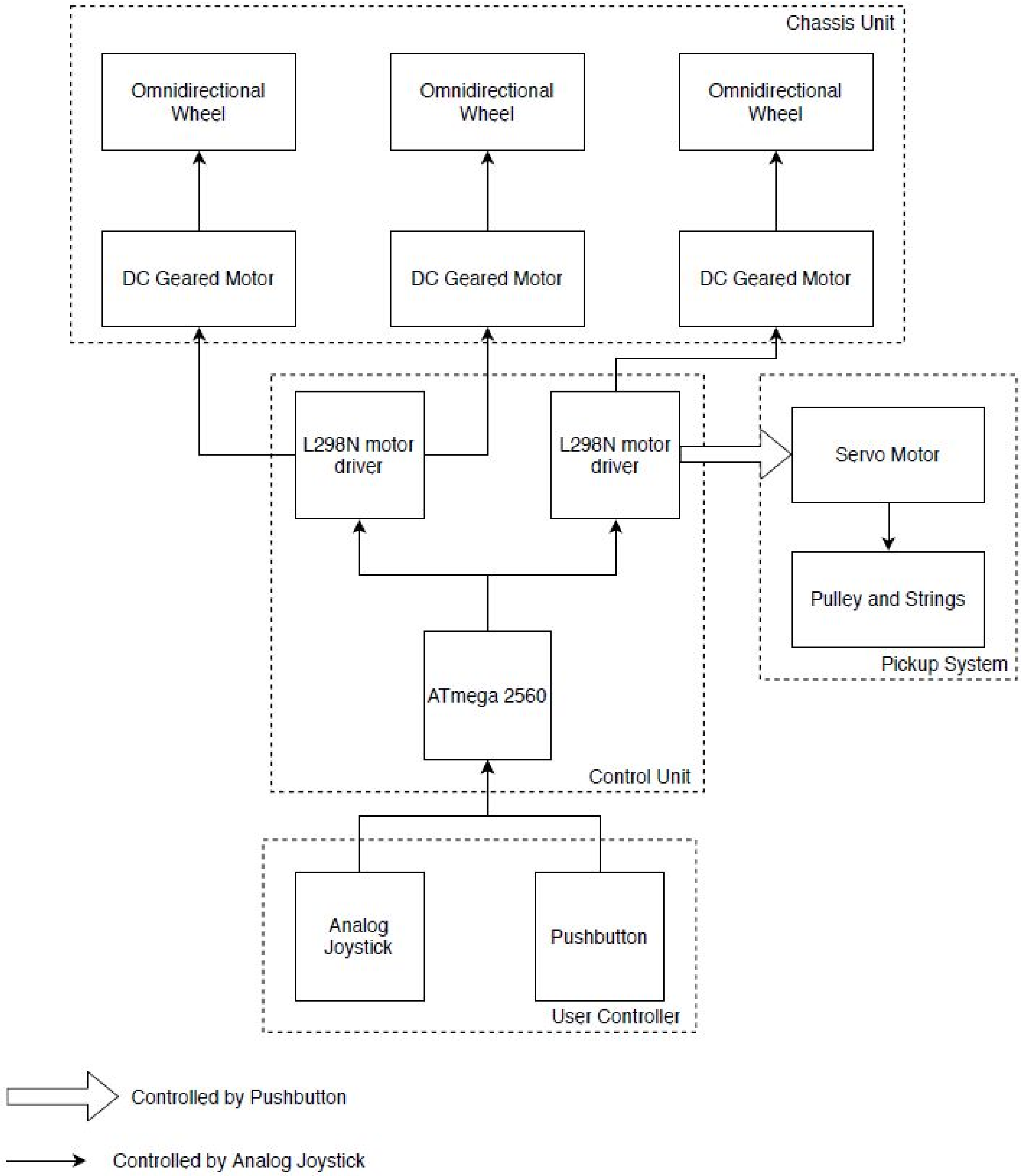

Figure 2

2.1 Functional Overview and Block Requirements

2.1.1 Control Unit

2.1.1.1 ATmega 2560 Microcontroller

For this project we are using 3 DC geared motors and 1 servo motor. In order to control the direction and speed of the motors, we need a microcontroller that has at least 2 PWM pins for each motor. This leads to a total of 8 PWM pins. Further, we are trying to integrate a

User’s controller for this project, we would need at least 2 Analog Input pins for the analog joystick and we also need at least 1 Digital I/O pin for the pushbutton. After taking these requirements into consideration, we decided to make use of the ATmega 2560 microcontroller. This microcontroller has 15 PWM pins, 54 Digital I/O pins and 16 Analog Input pins.

Requirements	Verification
1. 8 PWM pins must be available to send signals to motor drivers. 2. 2 Analog pins to take inputs from the analog joystick 3. 1 Digital I/O pin to take an input from the pushbutton	1. Verify that the pins work by testing motors through the microcontroller

2.1.1.2 L298N Motor Driver

Most microcontrollers, including the ATmega 2560, do not have the capabilities to provide the power that is needed to drive the motors. Further, they are not safeguarded by the back emf that could be created during the functioning of the motors. Therefore, it is necessary to include a motor driver between the microcontroller and the motor. The L298N motor driver has a power rating of 25W and this would be sufficient to drive the motors.

Requirements	Verification
1. It should be drive a 3V-12V gear motor	1. Verify that the motors operate at differents speeds

2.1.2 Chasis

2.1.2.1 DC Geared Motor

3 DC Geared motors will receive signals from the control unit and be used to turn the 3 omni-directional wheels to move the Chassis in any direction. The gear assembly will allow us to reduce speed and increase torque of the wheels.

Requirements	Verification
1. Each motor must have at least 28rpm or higher. 2. The 3 motors must be able to make the Nannybot travel at least 4m while carrying 4kg of additional weight. 3. The 3 motors must be able to spin around the walking robot, with the	1. Apply tape to the motor, so the tape rotates when the motor is run, but such that the tape doesn’t stick to anything. Run the motor near a microphone, record, and have the tape hit something as it rotates so it makes sounds. Using sound recording software like audacity, it

robot as the center of the turn. The robot makes a full revolution in around 8 seconds.	should be possible to count how often the sound is made per minute by analyzing the sound data. If the count is over 28 in a minute, it passes. 2. Have the Nannybot travel 4m with 4kg on it. 3. Put an object on the ground, and have the Nannybot spin around it once. Time the spin, and check the distance from the Nannybot to the object for both the chassis and the legs.

2.1.2.2 Omni-Directional Wheels

3 Omni-directional wheels will be used to allow movement in all directions. They are spun by the DC Gear motors.

Requirements	Verification
The omni-directional wheels must be able to travel in all directions.	A. Have the chassis travel front and back B. Have the chassis travel left and right C. Have the chassis spin on the spot

2.1.2.3 Chassis

The 3 omni-directional wheels will be installed in a triangular fashion, allowing movement in any direction. The Chassis will have 2 bars to the front, helping weight distribution and acting as support for pickup system’s pulleys.

Requirements	Verification
The legs must be 80cm~82cm apart and 80cm~82cm long, so as not to disturb the movement of the walking robot.	Measure the legs and the distance between them with a measuring tape or a ruler. The exact measurements must be taken for accurate data to use in calculations.

2.1.3 Pickup System

2.1.3.1 Servo Motor

A servo motor will be installed on the Chassis, and connected to 2 strings. These strings each go through a set of pulleys to and are connected to the walking robot’s harness. The motor reels in the strings to lift the walking robot up when the signal is given from the control unit. 2 strings were used so that the walking robot doesn’t spin in the air when it is lifted.

Requirements	Verification
The servo motor must be able to pull 5kg +/- 0.5kg of weight off the ground by at least 2cm.	Have a 5kg barbel strapped onto a string connected to the servo motor, and have the servo motor pull on it to check if it lifts off the ground for at least 2cm.

2.1.3.2 Pulleys

4 pulleys will be used to lay the strings from the servo motor to the robot above the robot's head. There are 2 sets of 2 pulleys, and there is a string going through each set. The 2 strings bring the walking robot up

Requirements	Verification
1. The pulleys much not impede the string movement. 2. The pulleys must be strong enough to withstand 5kg +/-0.5kg of weight.	1. Lay a string across the coil, with a weight attached to it. Pull the string to lift the weight, and see how well the pulley turns. 2. Repeat the above procedure with 5kg barbel as the weight.

2.1.3.3 Strings

2 strings are used to connect the servo motor and the walking robot. Using pulleys, the strings one end of the strings are attached to the walking robot's harness from above. When the servo motor turns, the strings are reeled in, thereby lifting the robot via the harness and strings.

Requirements	Verification
1. Strings must be long enough to reach the robot, and have enough slack to let the robot lean 30 degrees. 2. String must be strong enough to withstand at least 5kg of weight.	1. Measure the string. If the string is shorter than required, get a new string, as it is preferred to have a longer string, which we can cut to adjust the length. 2. Tie a 5kg to a string, and pull it up. Confirm it does not snap.

2.2 Calculations

For a continuous servo motor to lift a load of 5kg with a servo arm length of 1cm, the motor should have a stall torque of at least 5kg/cm. This would be sufficient to lift the Robotis OP2 which weighs 3kg.

The DC gear motors should be able to provide enough speed to the NannyBot so that the NannyBot can follow the walking robot. When choosing the motor, the radius of the omniwheels must be taken into consideration. In our case, the smallest possible radius that we would be using is 5.08cm. Since the wheels have to cover a larger distance in a shorter time when the walking robot is rotating about a point, this situation would be considered when choosing the motor with the required RPMs.

The OP2 rotates at 8RPM. The radius of the circle that the NannyBot's outer wheel would circumscribe is 40cm+69.28cm = 109.28cm. This means that we would need the wheel to move at $8*2\pi*109.28$ = 91.55cm/s. Therefore the motor would have to provide an angular velocity of $\frac{91.55}{5.08*2\pi}$ =27.4RPM.

2.5 Risk Analysis

Since we are going to design two modules for our project, the movable wheeled structure that follows the walking robot and the servo that pulls the strings to lift the walking robot, one of the main problems could be to effectively integrate both of them into a single structure.

For the wheeled structure, one of the main problems we will have to address is to be able to follow the walking robot without interfering with its regular walk. Firstly, we are going to move the NannyBot with human interaction by using a remote control with a joystick. In the future, if we accomplish our basic goals, we will try to introduce sensors to the NannyBot so that it can be autonomous and that human interaction is no longer needed.

However, the main problem we have to face is to lift the walking robot effectively without harming it or interfering with its walking. For that reason, we will design a specific harness for the walking robot that is attached to two lifting points that will be placed on the shoulders of the robot. By doing that, we can create a universal NannyBot that can work with different walkingbots and the only thing we will need to change is the specific harness for the walking robot.

All these problems represent the challenges and risks to the successful completion of the project. If at some point we are stuck with some of those problems, we would try to focus on the main goals: to lift the walking robot with the help of the NannyBot.

3. Ethics and safety

As engineers from the University of Illinois at Urbana-Champaign, we are committed to create a project that is aligned with the values of the IEEE and ACM Code of Ethics. For that reason, these are our main ethical statements:

Since we are working with a moving robot that can hit someone, we will work in a safe environment in which we can avoid harm to any of the group members or other people while working. We will use a small fence during the testing of the motors and wheels to protect all the members from the possible acceleration of the walking robot. The fence will also be covered by a thin layer of neoprene, which is soft enough to provide protection to the robots in case they hit the fence.

We all have completed the laboratory training and we are aware of the risks that working in a project with machines and electricity imply. When working on the chassis and implementing all the modules given by the machine shop, we will make sure that there are no risks for any of the members by using the lab equipment safely and avoiding electrical shocks and burns.

We believe that working in an engineering project involves two risks, plagiarism and misinformation. We are going to respect the ideas and inventions of others. Whenever we use an idea that does not belong to us, we will mention the original author with a proper citation. Also, we are going to be honest about our work and results. If we do not get the expected results on a specific test, we will try to find out why and report the issue. We want to be engineers working with integrity and strong values because we know that our work affects people's lives.

We want to maintain high standards of professional competence, conduct, and ethical practice. We will learn the technical knowledge required to develop the project and we will upgrade our skills through independent study, attending conferences with professors, and asking experts on the matter.

References