The Modeling, Construction and Test Process of a 3D Printable Smart Robot Rider

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Abstract

This work aims to present a modeling procedure, manufacturing process, electronic design, programming and communication system of a cyclist robot. The robot rider has the ability to ride a bicycle independently by making decisions on shifts in balance that may occur during its motion by correcting its direction, balance adjust, and stop. Robot decision-making processes were embedded in a shared control system of interactions with the external environment by commands sent through wired serial link or radio frequency (RF), allowing arm and leg- movements. This was achieved using a dual board synchronization powered by Atmel microcontrollers (Arduino) and fed by information from an electronic gyroscope sensor, an accelerometer, and remote radio frequency (RF) receptor. The final prototype was able to pedal from inertia accelerating gradually to its full speed, stop the movement, and move its arms to recover balance.

Introduction

The possibilities of autonomous bicycles and self-controlled or shared controlled robots able to maneuver vehicles have been explored for years (Getz and Marsden, 1995; Buss, 2000). It can be considered a theme driven by urban mobility needs, reduction of human physical effort and aiding people with disabilities. Moreover, modern urban mobility demands echo applications also motivate the green solution for living in large cities. Thus, increasing capacity of robots moving similarly to humans is essential for this purpose.

One of the main goals in Robotics is the automation of tasks done by men (Pazos, 2013). Thus, one of the goals in the field of Robotics is to perform simulation of variety of movements, decision making, hence human tasks performance. Despite intense research activity, large scale implementation of such tasks for daily life routine were not feasible in the early robotics, due to high cost and early development of auxiliary technology, causing to the field a moderate development outside of industrial applications.

Moreover, development of such robotic systems a requires multidisciplinary knowledge. This work involved mathematical modeling, mechanical drawing, manufacture techniques in 3D printing, electronic design, micro-controller programming (Arduino, 2015; Banzi, 2013) as well as access to auxiliary devices including gyroscope, accelerometer, and RF system.

Methodology

The initial phase was the creation of mathematical models for arms and legs. The final step involved the simulation of movements for arms and legs as well as the first real world test for a pedal movement and balance. The construction of the robot was designed upon the use of renewable materials such as plastic which reduced the manufacturing cost. The same plastic was also used to built the 3D printer which has refurbished pass-motors. Moreover, discarded pieces of aluminum compose the frame of the bicycle and the side shields on the legs of the robot.

Modeling each 3D Part

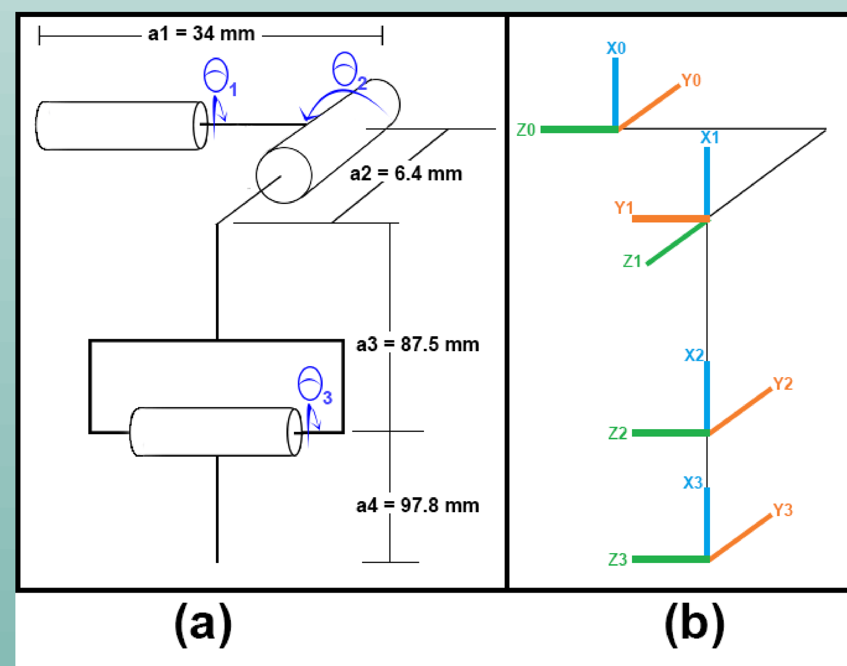

Figure 1: Arm kinematic diagram: (a) link lengths in mm (a1 to a4) and rotation angles, b) four rotation frames for each actuator.

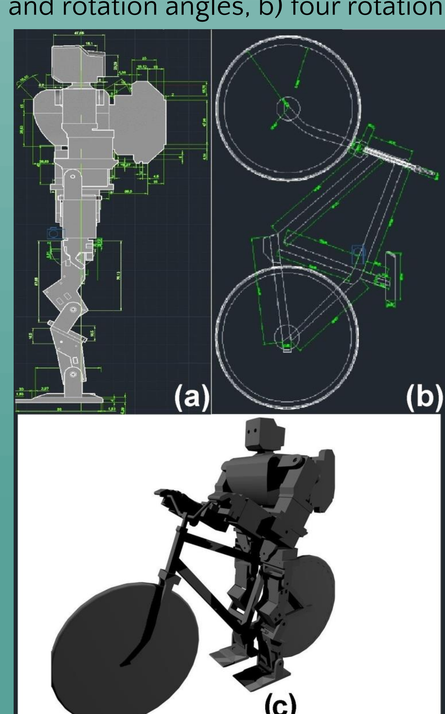

Figure 3: Robot
(a) and its bicycle
(b) both sketched in AutoCAD,
(c) 3D model.

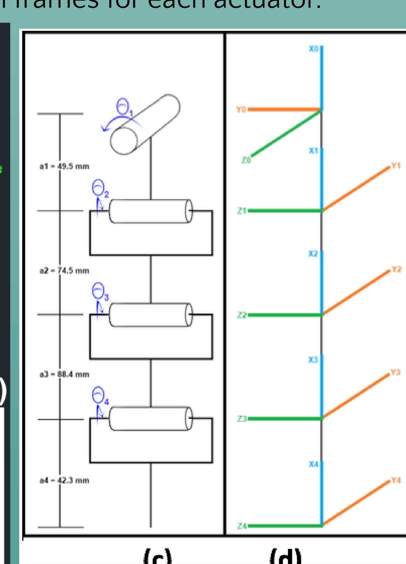

Figure 2: Leg kinematic diagram: c) link lengths and rotation angles, d) rotation frames.

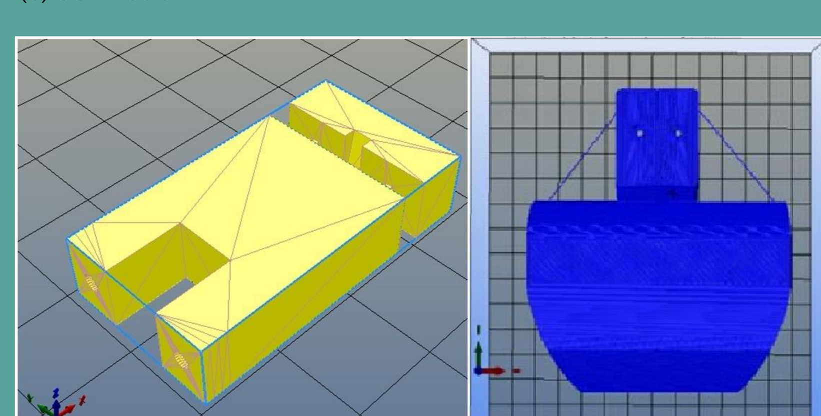

Figure 4: Parts in the printing process servo's socket on the left and the slicing process on the right.

The algorithm cost required two Arduino boards (salver and master) to split the legs routines from the signals to the arms. A status signal allows the master to know if the other Arduino is on stop mode, movement, or whether an error occurred. Moreover, the master board also receives the remote commands from the joystick. When the system is ready, the master Arduino set all initial parameters on the slaver board to avoid code redundancy. After all parameters set, the slaver board flags back a ready signal to the master board.

The communication between both Arduinos allows the master to send stimuli signals to the slaver board when it is in movement mode. When it is in stop mode however, the master board sends only one stop signal. If the master board stops working and the salver board is in movement mode, as it will not receive the next stimuli, the emergency mode will be triggered when the time for the next stimulus is over. On the other hand, if the slaver Arduino board stops working, the master board will notice it by the status signal as it stopped receiving from the salver board. Therefore, the master board will immediately reset its own status and will keep trying to reestablish the link with the other board until it succeed. After reestablishing the link, the master board sends again the initial parameters to the salver board.

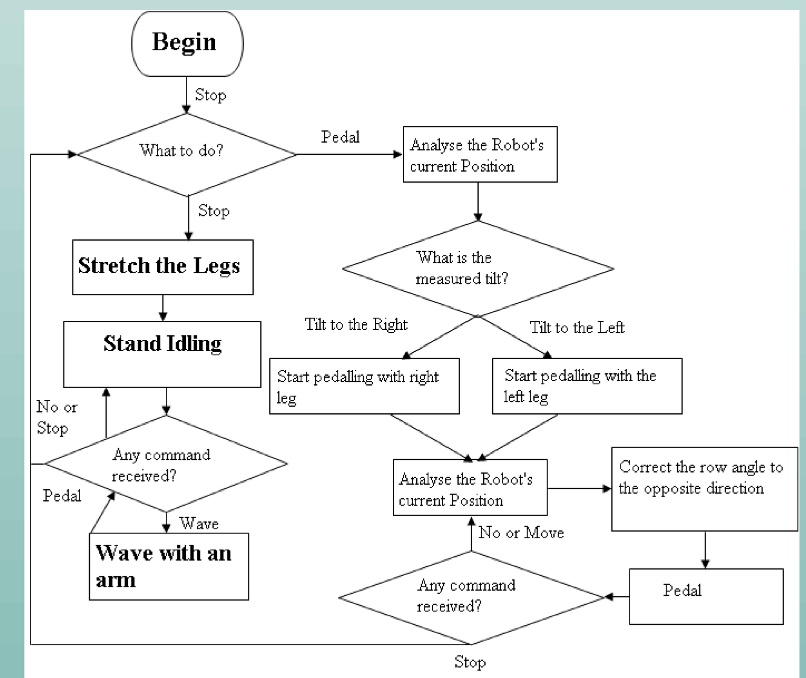

Figure 5: Algorithm's flowchart demonstrating the decision steps the robot may take.

Results

Process of 3D printing

The majority of the parts of the robot (approximately 70%) were made by 3D printing. The 3D printers were also assembled using reusable materials. It works with plastic wires (3 mm or 1.75mm) made of polylactic acid (PLA) which is melted to make the layers of the 3D printed parts. After every part was finished by the printer, it was measured in order to check if its dimensions would met the designed project. Symmetry, and layer size were measured. Some parts which should be coupled to servomotor had density increased by 90% in order to bear forces applied to them. Other parts were redesigned for their size were not feasible to be printed as a single piece or they had inner connections that would not able accessed such as chest, battery case, and head). Because of lack of precision for small parts, some parts had to be adapted, such as the hands.

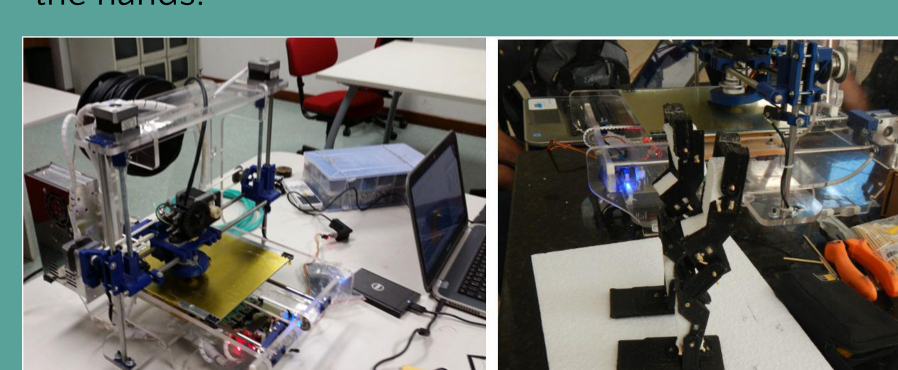

Figure 6: Printer and the first prototype printed legs.

The Assembling Process

A total 15 servo motors of 13N each with were used to move all members of the robot. This phase involved 40% of the project budget. The servo motor were also disassembled to add a 3mm steel axis to the opposite side the servo axis.

The bicycle assembling

In the process of construction of the bicycle, we used a 5mm solid aluminum bar to let the robot lighter and balance the weight / power ratio. TIG welding was used to reinforce the frame and with center of gravity for the suitable robot. The wheels are made of acrylic of 10 mm which were cut using the laser process to stay closer to the CAD model. After the assembling phase was complete, the prototype, as well as its remote control, as shown in 7, were ready for testing.

Simulation and Tests

Legs were tested to check their movement while pedaling. Tests had shown a balanced structure and well synchronized servomotors. After first tests, current measurements had shown consumption of 1.2A for each leg, in which every servomotor consumed 400mA. On a standby state the robot consumed 370mA. The first pedaling movement had to have fine tuning on tilt coupling, angular speed on each servomotor and low rotation setup to perform the desired movement.

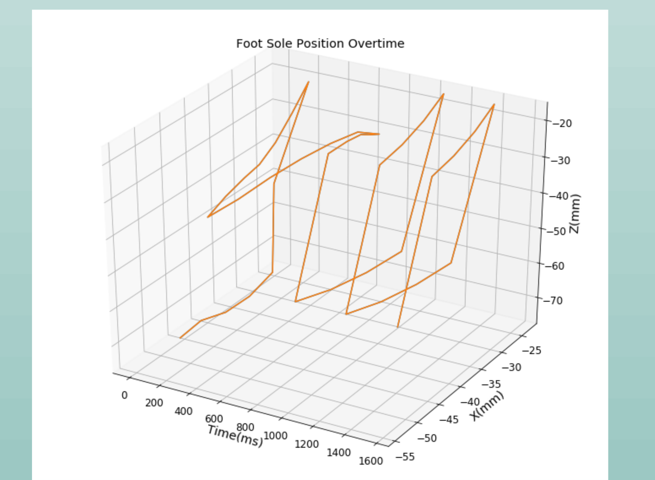

Figure 8: Foot movement simulation based on hip-to-foot displacement vector.

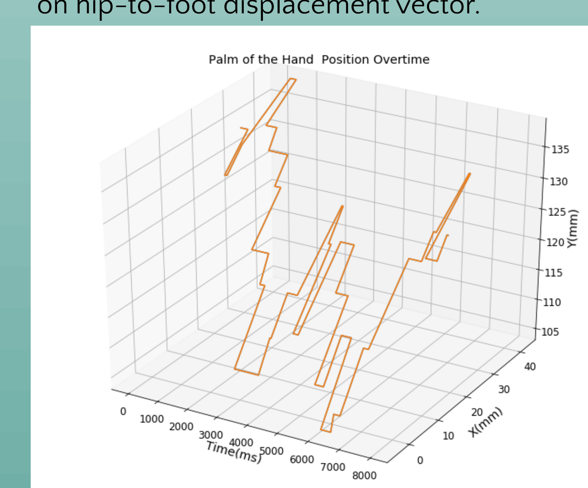

Figure 9: Movement for the palm of the hand resulted from the transformation by shoulder-to-hand displacement vector.

Assembled Final Prototype

The assembled prototype is shown on Figure 7. All 3D printed parts are in black as well as the servomotors. The bicycle is mainly made of aluminum bars and the wheels are made of acrylic. Next to the robot is the RF controller which was partially manufactured in the 3D printer. The controller is used to send the commands to set which movements the robot must perform.

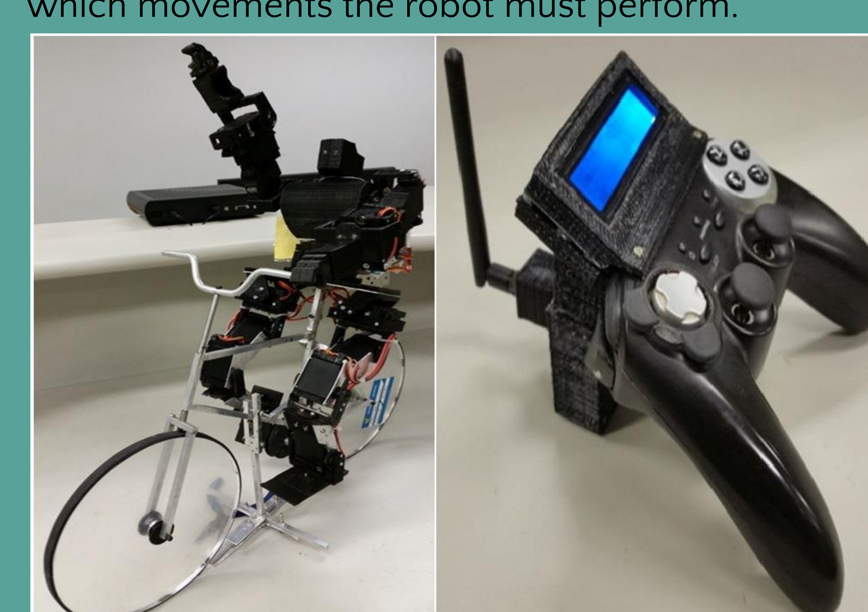

Figure 7: Assembled robot (second prototype) and joystick remote control.

Conclusion

This work presented the process of modeling, design, construction and test of 3D printable robot rider. The algorithm developed in C++ enable robot to move its arms and legs to perform desired actions such as pedaling, turning direction bar, start, and stop movements. The mathematical model proved to reach the proposed movement, although it required fine tuning to smooth the movement. All parts of the bike rider were designed to fit the servomotors. In order to a better performance, a second Arduino board had to be added to split the movements from legs to arms. Future work will include a free run test without a tripod that supported the initial test of the robot. Moreover, a forward kinematic system based on neural network can also be compared to the current algorithm.

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