Bio-Inspired Robot

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***Abstract*— The goal of the project is to build a bio-inspired mechanism that would autonomously walk for 4.9m one way and 4.9m back. The project provided an important lesson in robot design, as well as installation and programming of servos. A kangaroo robot was built and it successfully completed the goal.**

I. Introduction

The bio-inspired robot is the final of three projects for MMAE-232. The bio-inspired mechanism in the form of a kangaroo (see Fig.1) was built and it autonomously walked for 4.9m one way and the same distance back. The restrictions for the project were limited to: the whole mechanism must have the ability to be disassembled and no using of tape. All skills learned in previous two projects could be incorporated into this project. Students needed to keep in mind that the low-powered servos being used are not strong enough to do all tasks. In order to combat this, using light weighting techniques such as cutting extra weight was key to incorporate. Students could also use lighter materials for their design to cut weight. There was no restriction on materials used but students were supplied with materials listed below.

Supplied materials:

- 24"x18"x1/4" MDF
- 24"x18"x1/8" MDF
- Wood screws
- Wood glue
- HS-425BB servos
- Arduino Uno or Mega

I. Concept and Evaluation

Two hand-drafted designs of robots were made, one kangaroo-inspired and the other was cat-inspired. A Pugh Chart (see TABLE 1) was generated to determine which design was better of the two. According to the Pugh Chart, both designs would work and be reliable.

Time consumption was the biggest downside for the kangaroo design. If the cat design was chosen to be manufactured it would be powered with a single continuous servo, while the kangaroo would consist of six to seven servos. Even though the cat design was simpler and faster to design and build, the kangaroo was more adjustable and it had more availability for improvement.

The more challenging kangaroo design was chosen in order to expand the learning experience. The first design of the kangaroo had six servos, but the servos plastic axle and 1/8" MDF parts were deflecting. Due to the deflection, a redesign was necessary. The redesigned kangaroo, after additional adjustments, successfully finished trail. It was built of 1/4" MDF and consisted of seven servos. The legs were shortened to make it easier for the servos to move the robot smoothly.

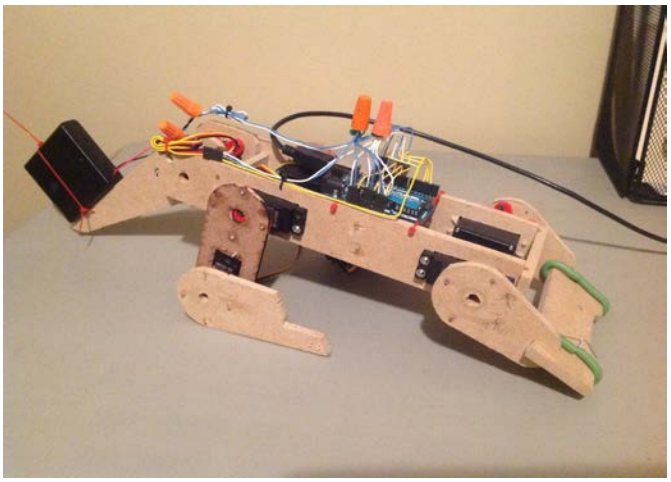
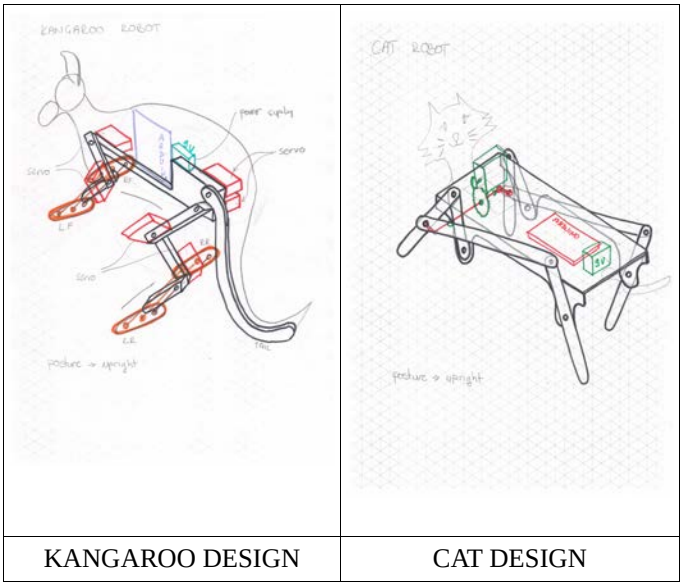


Fig. 1. Final kangaroo design



KANGAROO DESIGN	CAT DESIGN

Fig. 2. Sketches of two designs

TABLE 1. Pugh Chart for two designs

Criteria	**KANGAROO**	**CAT**
RELIABILITY	1	1
CHALLENGE	1	0
ADJUSTABILITY	1	0
TIME	0	1
TOTAL	**3**	**2**

II. ANALYSIS

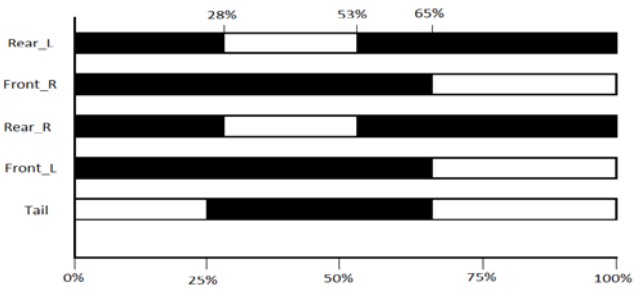


Fig. 3. Hilderbrand Gait Plot for Kangaroo Walk

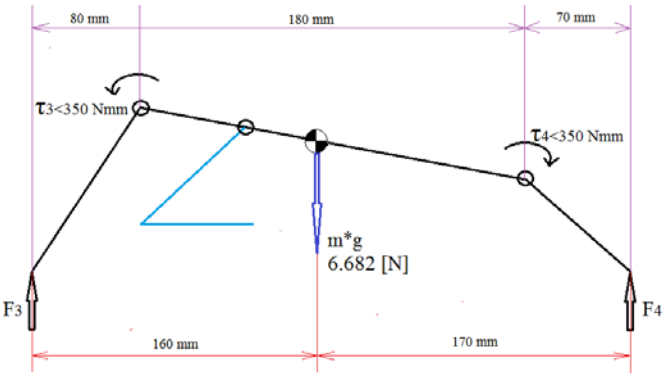


Fig.6 . Free Body Diagram 2nd Case

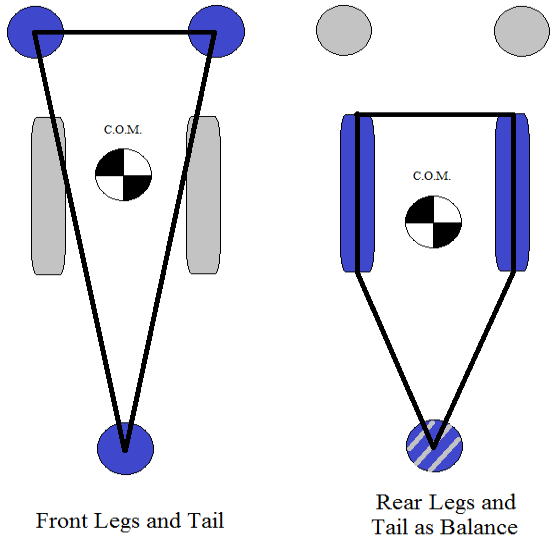


Fig. 4. Convex Contact Poligon for Kangaroo Walk

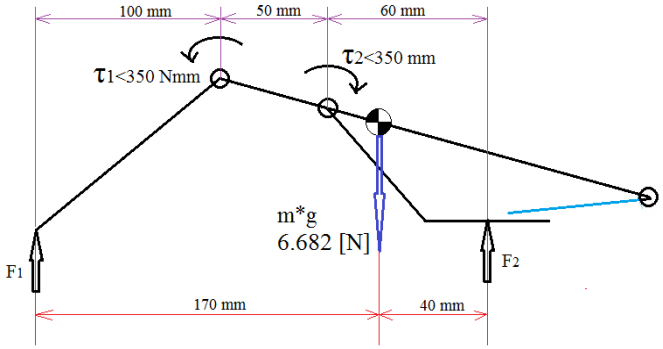


Fig.5 . Free Body Diagram 1st Case

Robot body mass = 245g = .0245kg
Arduino Uno mass = 25g = 0.025kg
HS-425BB Servo mass x 7 = 7 x 45g = 0.315kg
Battery pack mass = 250g = 0.25kg
Wires mass = 50g = 0.05kg

Total Robot mass = 0.885kg
m*g = 6.682 [N]

Stall torque of servo = 350 Nmm

For first case we can calculate support forces F1 and F2:
F_1 = (40mm/210mm)*6.682 [N] = 1.273 [N]
F_2 = (170mm/210mm)*6.682[N] = 5.409 [N]

Now τ_1 and τ_2 are:

$\tau_1 = F_1 * 100mm = 127.3$ Nmm < 350 Nmm

$\tau_2 = F_2 * 60mm = 324.54$ Nmm < 700 Nmm (due to two servos)

Both τ_1 and τ_2 are lower than maximum allowed torque and it is proven that servos could do the task.

For second case we can calculate support forces F3 and F4:
F_1 = (170mm/2330mm)*6.682 [N] = 3.442 [N]
F_2 = (160mm/330mm)*6.682[N] = 3.240 [N]

Now τ_3 and τ_4 are:

$\tau_3 = F_3 * 80mm = 275.4$ Nmm < 350 Nmm

$\tau_4 = F_4 * 70mm = 226.8$ Nmm < 700 Nmm (due to two servos)

Both τ_3 and τ_4 are lower than maximum allowed torque and it is proven that servos could do the task.

III. EXPERIMENTAL RESULTS

The first design was fabricated using 1/8” MDF board and a laser cutter. It ultimately failed because servos are fragile and unsuitable for tall designs. The final kangaroo design was fabricated by tracing the designed pieces onto the 1/4” MDF board and using a jigsaw tool to cut out the individual pieces. Due to the shorter leg length in the design and additional servo, the kangaroo moved forward quickly and finished the trail, totaling 9.8m, in two to three minutes.

IV. DISCUSSION

The first design of the kangaroo was moving, but not well enough to complete the trail. It was unstable and fragile so the decision was made to make redesign. The new design was solid and heavier. Adjustments were made to the redesign by shortening the limbs even more, to make it easier for servos to operate smoothly. During testing for the second design, it was concluded that the battery connected to tail was producing friction. Due to this friction at the tail, the kangaroo was not moving forward as well as possible. The battery pack was re-positioned to the front, between the arms of the kangaroo. After this, the kangaroo moved as expected. The only minor improvements that could be made were to make it walk faster, which was not the focus of the project.

V. CONCLUSIONS

The bio-inspired robot kangaroo was designed and fabricated to walk autonomously for 4.9m one way and 4.9m back. After two redesigns, the kangaroo successfully finished the trail.