Prosthetic exo-leg: A multi-functional robotic leg-suit to support the patient with transfemoral amputation

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ABSTRACT

According to an article posted on the website of La Trobe University, Bangladesh is a lower-middle-income country with a population of over 167 million where around 60% of the population is participating in labor force such as agriculture, constructions incorporating a high chance of workplace injuries.[1] Among the various types of workplace injuries or motor vehicle injuries, the most common is lower limb amputation. Moreover, considering the world population, about 7% to 10% of the world's population have different kinds of limb-related issues where lower limb amputation has been marked as the most common. The National Limb Loss Center has estimated that only in the United States there are an estimated 1.9 million amputees.[2] So our main intention is to solve the problem of :

- ✓ **Lower limb Amputee Patient**
- ✓ **Monoplegia Patient**
- ✓ **Fatal accident**
- ✓ **Unavailability of Cost-Effective Prosthetic.**
- ✓ **Limited user-friendly prosthetics in the Market**

OBJECTIVES

Our main objectives through this research work are:

- The exo-leg is committed to enhancing patients' capacity to walk freely by focusing on functional results
- The project considers the patient's safety by ensuring comfortable and easy movements as he can use a portable battery.
- To provide the lower limb amputation patient with prosthetic exo-leg as a walking aid at a reasonable cost. This project includes actuation or spring stabilization as an alternative to expensive hydraulic servo valves. Incorporating the adjustment as per as the leg size
- Simple and a lightweight wearable robotic leg for the patients.
- Construct a similar system as assistive exoskeletons to function for different types of patients with lower limb amputation and patients diagnosed with monoplegia.

This research will open the future aspect of prosthetic legs related researches globally.

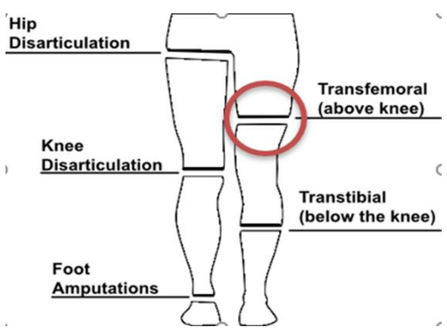

Figure 1: Types of lower limb amputation

METHODS

C- leg is one of the existing solution in the market.

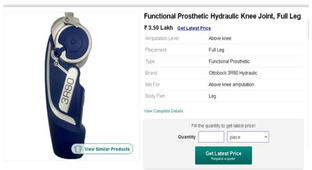

Figure 2: C-leg

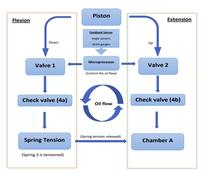

Figure 3: Workflow of C-leg

But we came up with another cost efficient solution and introducing Prosthetic Exo-leg. In this design, we are using Servo Motors, GYRO Sensors, Hall effect Sensors, EMG Sensors. After taking values from sensors, system will analyze those data's and servo motor will work accordingly.

Figure 4: Prosthetic Exo-Leg

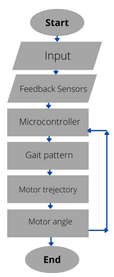

Figure 5: Flow chart of our prosthetic Exo-Leg

Comparison with Existing Solution

A theoretical comparison of existing C-Leg with our Prosthetic Exo-Leg and green highlighter shows which one is better.

Criteria	Design 1:C-leg	Design 2: Prosthetic Exo-leg
Cost	Very High	Low
Complexity	High	Medium
Component Availability	Very low	High
Requirement	Fulfilled	Fulfilled
Repairability	Difficult	Easy
Repairability Cost	Very High	Low
Battery Life	High	Medium (Portable)
Operating Time	High	Medium (Changeable)
Activity Mode	2	2
Weight	Low	Medium (Variable)
Width	Compact	Hefty

Figure 6: Comparison between existing C-Le and our Prosthetic Exo-Leg

Components	Minimum current consumption (mA)	Maximum current consumption (mA)	Battery (mAh)	Maximum Run-time (hours)	Minimum Run-time (Hours)	Minimum With 90% efficiency (Hours)	Minimum with 90% efficiency (Hours)
Servo	410	510	5600	13.541	10.855	12.187	9.77
Gyro-Sensor (2)	0.3	0.5					
Hall Effect Sensor	3	5					
esp32	0.24	0.35					
Total	413.54	515.85					

Figure 7: Power calculation of Prosthetic Exo-Leg

RESULTS

In this section we have shown the noticeable efficiency through simulation and real time data collection and analysis.

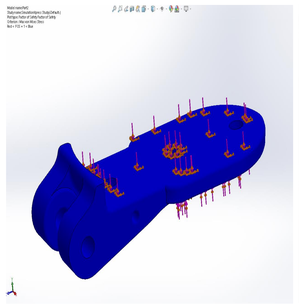

Figure 8: Load analysis Prosthetic

Figure 9: One of our friend using Exo-leg and we collected data from him

Figure 10: Normal walking X-axis value of our subject with his previous prosthetic leg, normal people and our subject with Prosthetic Exo-Leg

We can see that the Prosthetic Exo-Leg tries to replicate the normal people normal walking value. Accordingly, Y-axis and Z-axis shows the same pattern.

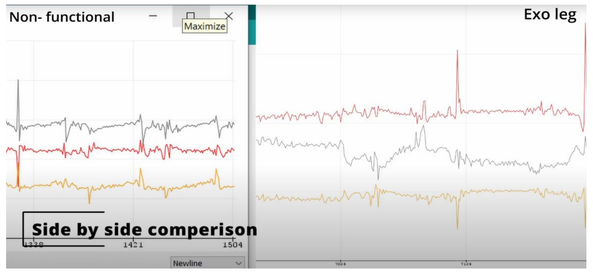

Figure 11: Side by side comparison of Non Functional Leg and Prosthetic Exo-Leg while walking by our subject.

Requirement	Yes	No	Reason
Cost Effective	✓		
Efficiency	✓		
Power Consumption	✓		
Weight		✓	Stainless Steel Pipe Usage
Width	✓		
Comfort		✓	Lack of Training
Safety	✓		
Fully-Functional	✓		

Figure 12: Criteria check-up

Risk Management And Analysis

- ✓ Technical
- ✓ Non-Technical
- ✓ Health

Safety Consideration And Ethical Consideration

Safety considerations has been taken like below:

- ✓ Water-resistant System
- ✓ Measure against Slippery areas
- ✓ Monitoring Voltage
- ✓ Use of Kill switch
- ✓ Ethical Considerations are taken like below:
- ✓ Approval from Institutional Review Board (IRB): Dept of Biomedical Research Foundation Bangladesh (BRF).
- ✓ Presence of Qualified and Experienced Researchers: Brac Limb Center, Dynamic Limb Centre
- ✓ Safety Measures: Ensuring tested and good quality components
- ✓ Participants' Agreement, Reimbursement issue and Trial Exit Arrangement

Future Aspects

- ✓ Transtibial amputation, Ankle Amputation & Monoplegia
- ✓ Water Resistant System
- ✓ Injection molding
- ✓ User's Training & Support System (App Development)

CONCLUSIONS

To conclude, we can say that the project is more efficient than the non-functional prosthetic leg. We are planning to upgrade our servo motor and some small changes needed to be done. That will increase the efficiency even more. Undoubtedly, we can say that we have come long way in the first attempt. Further research, modification and advancement will be done.

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