Mechatronics and Making Mid-Term Project Report Exoskeleton Robotic Hand With Wolf Claw Mechanism

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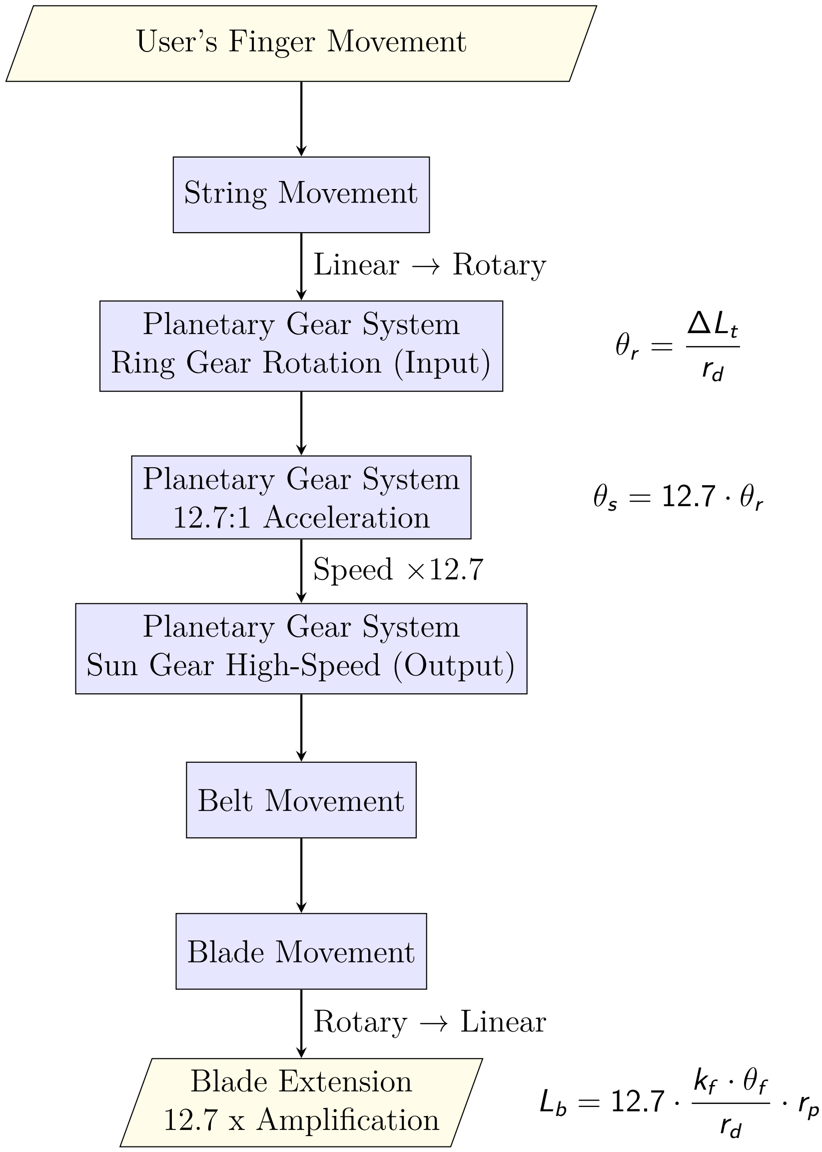
2.1 Drive Method and Transmission

This robotic hand exoskeleton uses an acceleration-based machinery system. Therefore, the movements of the finger will be amplified by this mechanism.

This mechanism can do that through a planetary gear mechanism, whereas a belt system and a string transmission system are also needed.

Details of the transmission process shows below:



2.1.1 Transmission Process Details

User's Input (Finger Movement)

The linear movement of the string that is deployed over the finger is created by the finger's flexion.

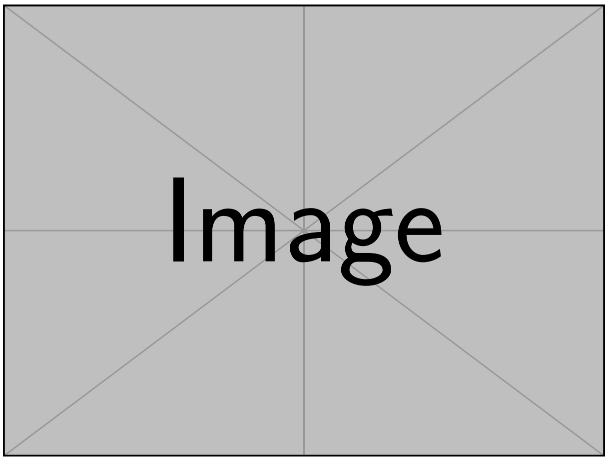


Figure 1: figure exoskeleton design

Total displacement of the string overhead by calculation:

$$r = 0P = 0$$

Biomechanical Input (Finger Flexion): Natural finger flexion creates geometric displacement through overhead tendon routing on the finger dorsal side.

Using Smith et al's tendon displacement equation:

$$\Delta L_t = k_f \cdot \theta_f \tag{1}$$

and substituting typical finger geometry data ($k_f = 0.8$ mm/degree for index finger), we then get approximately 24 mm tendon displacement for 30 degrees of flexion. Finally, this linear displacement provides the input to the transmission system.

Tendon to Rotary Conversion: The tendon wraps around a drum connected to the ring gear, converting linear displacement to rotational input. Using the drum conversion equation:

$$\theta_r = \frac{\Delta L_t}{r_d} \tag{2}$$

and substituting our drum radius ($r_d = 5$ mm) and previous tendon displacement (24 mm), we then get 4.8 radians of ring gear rotation. Finally, this rotational input drives the planetary gear system.

Planetary Gear Acceleration: The ring gear serves as input in an unconventional configuration where planet gears transfer motion to the sun gear. Using the planetary gear ratio equation:

$$\theta_s = 12.66 \cdot \theta_r \tag{3}$$

and substituting our ring gear rotation (4.8 radians), we then get 60.77 radians of sun gear rotation. Finally, this represents the 12.66:1 acceleration that enables significant blade extension.

Pulley and Belt Transmission: The sun gear shaft drives dual synchronized pulleys with timing belts maintaining parallel blade alignment. Three blades are mounted perpendicular between the belts. Using the pulley-belt transmission relationship, the rotational motion is converted to linear blade movement with the pulley radius ($r_p = 3$ mm) determining the final extension.

Final Blade Deployment: Belt movement translates to linear blade extension through the complete kinematic chain. Using the comprehensive deployment equation:

$$L_b = 12.66 \cdot \frac{k_f \cdot \theta_f}{r_d} \cdot r_p \tag{4}$$

and substituting all our parameters ($k_f = 0.8$, $\theta_f = 30°$, $r_d = 5$ mm, $r_p = 3$ mm), we then get 182.3 mm total blade extension. Finally, this demonstrates how subtle finger movements (30°) result in significant tool deployment (182 mm).

The complete transmission system achieves:

$$\text{Overall Ratio} = \underbrace{\frac{k_f}{r_d}}_{\text{Tendon}} \times \underbrace{12.7}_{\text{Planetary}} \times \underbrace{r_p}_{\text{Pulley}} = 12.7 \cdot \frac{k_f \cdot r_p}{r_d} \tag{5}$$

Where small finger movements (θ_f) result in proportionally larger blade extensions (L_b), making the system both responsive and precise for its intended applications.

This acceleration-based transmission represents an innovative approach to exoskeleton tool deployment, leveraging planetary gear mechanics to amplify natural human movements into effective tool operations.

2.2 Fingers and Wrist Mechanisms

2.3 Wolf Claw Mechanism Comparison

2.3.1 Version 1: Planetary Gear

2.3.2 Version 2: Compound Gear Train

3 Mathematical Modelling and Analysis

3.1 Fingers and Wrist Modelling

3.2 Wolf Claw Mechanism Version 1: Planetary Gear

3.3 Wolf Claw Mechanism Version 2: Compound Gear Train

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