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

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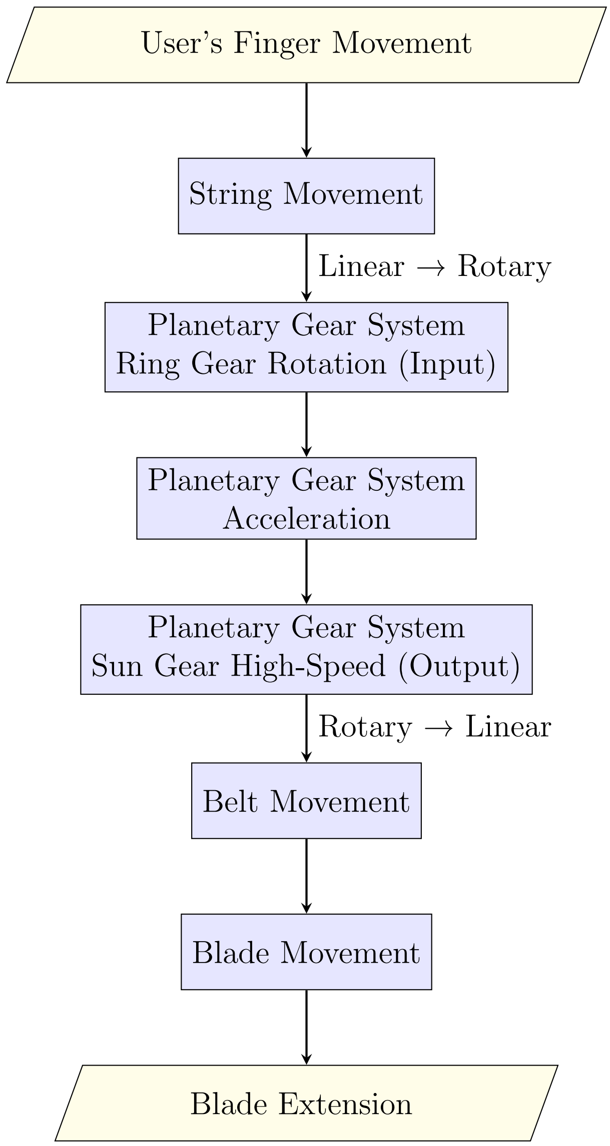
2.1 Drive Method and Transmission

This robotic hand exoskeleton uses an acceleration-based machinery system, amplifying the movements of the finger.

This is achieved using a planetary gear mechanism connected to a string transmission and a pulley and belt system.

Details of the transmission process shown below:



2.2 Hand Exoskeleton Mechanisms

2.2.1 Hand Biomechanics

The human hand comprises 19 bones and 14 joints (excluding the carpal bones).

The exoskeleton design is based on the natural anatomy of the human hand (figure 1), particularly the MCP, PIP, and DIP joints that ensure the finger can flex and extend.

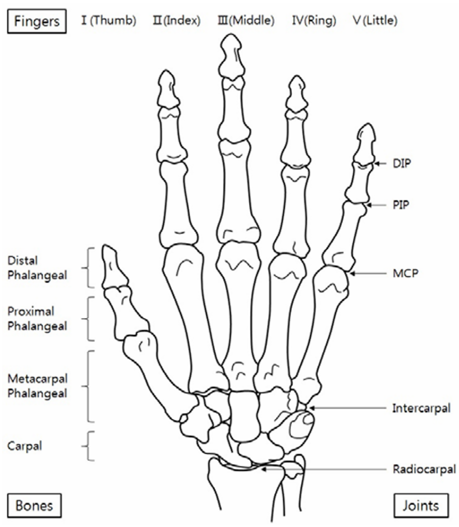


Figure 1: bones and joints of a human hand

The finger joints mainly include:

Metacarpophalangeal Joint (MCP): Has 2 degrees of freedom (flexion/extension, abduction/adduction).

Both Proximal Interphalangeal Joint (PIP) and Distal Interphalangeal Joint (DIP): Has 1 degree of freedom (flexion/extension).

The Carpometacarpal Joint (CMC) of the thumb is a saddle joint with 2 degrees of freedom, granting it greater flexibility.

In the resting posture, the MCP joint is flexed approximately 45°, the PIP joint between 30°–45°, and the DIP joint between 10°–20°. This data is crucial for defining the range of motion and ensuring safety in exoskeleton design.

Wrist Structure Analysis

The wrist has 2 degrees of freedom: flexion/extension and radial/ulnar deviation.

2.2.2 Selection of Mechanism Type

Among the mechanisms illustrated in Figure 2, the direct matching of joint centers (Figure 2.a) was selected for our design because it provides a structurally simple and compact solution without requiring additional linkages or complex actuation. This approach minimizes mechanical complexity, reduces system weight, and simplifies both fabrication and control.

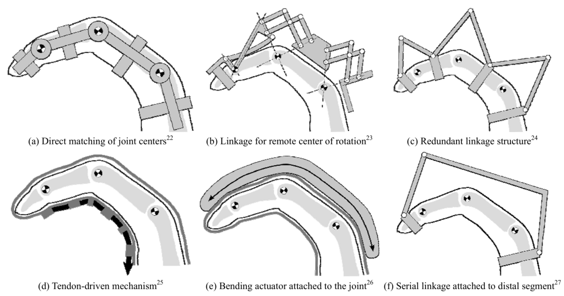


Figure 2: mechanism types

Furthermore, direct alignment of the exoskeleton joints with the anatomical centers ensures high kinematic accuracy and reliability, as no additional compensation for remote or compliant motion is necessary.

Therefore, the direct joint-center matching method offers the most efficient and practical solution for this application.

2.3 Wolf Claw Mechanism Comparison

2.3.1 Version 1: Planetary Gear

2.3.2 Version 2: Compound Gear Train

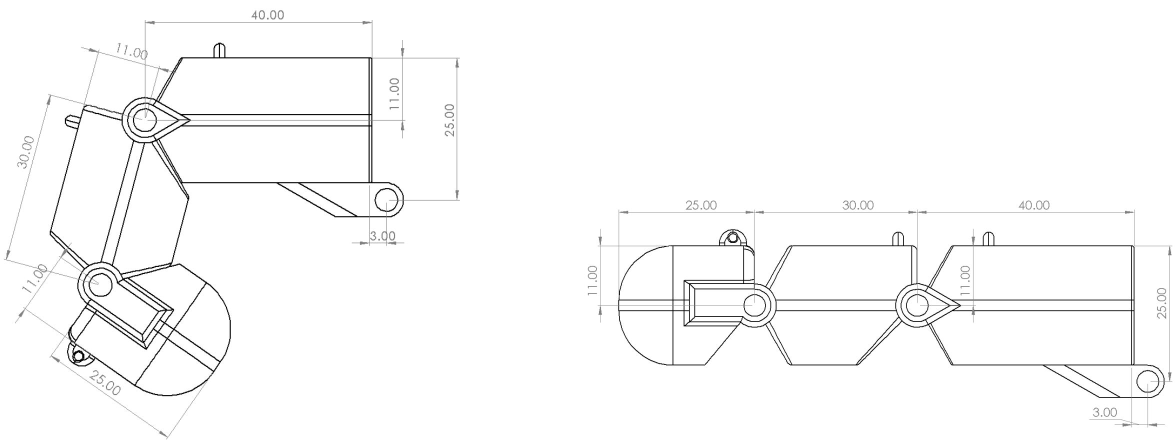
3 Mathematical Modelling and Analysis

3.1 Fingers and Wrist Modelling

Finger and Overhead String Movement

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

Figure 3 has two sub-figures, Figure 3a describes the details and data when finger curved, Figure 3b describes the details and data when finger extended.



(a) mid-finger curved

(b) mid-finger extended

Figure 3: mid-finger exoskeleton design

Total displacement of the string overhead by calculation:[1]

$$
\begin{aligned}
\Delta L &= L_{DIP} + L_{PIP} + L_{MCP}, \quad \text{where} \\
L_{DIP} &= 11 \times \frac{45}{360} \times 2\pi \approx 8.64, \\
L_{PIP} &= 11 \times \frac{60}{360} \times 2\pi \approx 11.52, \\
L_{MCP} &= (25 - 11) \times \frac{85}{360} \times 2\pi \approx 20.77 \\
\Rightarrow \Delta L &\approx 8.64 + 11.52 + 20.77 = \boxed{40.93\text{mm}}
\end{aligned}
$$

Wrist Movement

In hand exoskeletons, the wrist section is relatively complex due to its two degrees of freedom (DOFs) for upward-downward and left-right movements, with their rotation centers almost coinciding. This poses a challenge for the design of the mechanical structure. We have designed a special mechanism, functionally similar to a universal joint, to serve as the exoskeleton for the wrist, as illustrated in the figure 4.

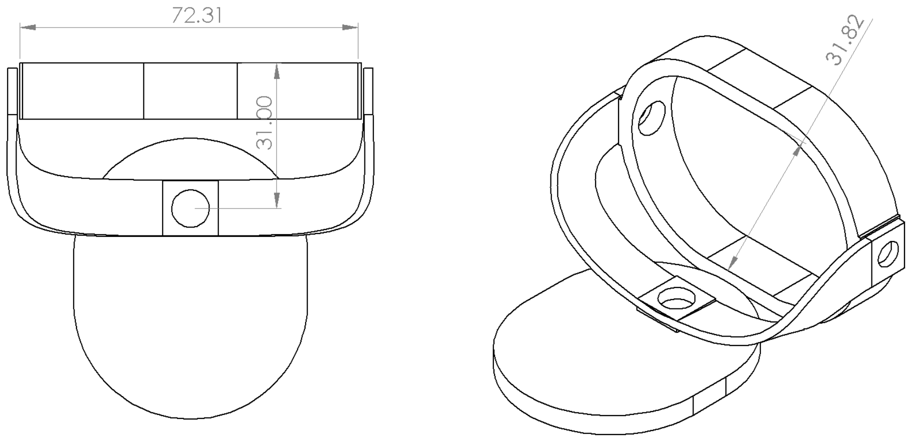


Figure 4: demostration of wrist

The palm is represented by an oval in the diagram, and the linkage structure connecting the palm and fingers still requires careful design due to the constraints of the narrow aperture space.

3.2 Wolf Claw Mechanism Version 1: Planetary Gear

3.3 Wolf Claw Mechanism Version 2: Compound Gear Train

4 Conclusion and Future Work

References

[1] author. title. In editor, editor, *booktitle*, year.