# Hand rehabilitation robots for stroke patients

MEC202
Industrial Projects

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**Abstract:** This project aims to design a multimodal **cable-driven** hand rehabilitation robot for stroke patients based on surface electromyography (**sEMG**) [1]. It is specially designed for people with hand dysfunction caused by stroke. It integrates advanced sensors and **CNN-transformer** algorithms to accurately capture rehabilitation movements and realize personalized rehabilitation training programs. Through **diversified** and **personalized** treatment programs and VR game training modes, the rehabilitation process is made more efficient and interesting, helping patients gradually regain hand strength and flexibility and regain confidence in life.

## Background

**Demand surge**: Stroke is one of the leading causes of disability worldwide, and hand dysfunction is a common and serious consequence among stroke survivors [1].
**Traditional bottleneck**: Traditional rehabilitation methods have problems such as low training accuracy and serious homogeneity of solutions, which are difficult to adapt to individual differences of patients and cannot meet diverse rehabilitation needs.
**Technology-driven**: Continuous breakthroughs in cutting-edge technologies such as artificial intelligence and biomedical engineering have provided solid technical support for the intelligent and precise upgrade of hand rehabilitation equipment [2].
**Competitive product analysis**: Currently, most rehabilitation robots on the market use airbag drive solutions, which have a slow response speed, while motor-driven joints have certain safety risks [3].

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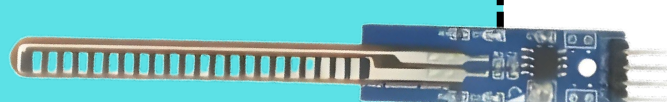
## FLEX Sensor

**Real-time and accurate perception**
The flex4.5 bending sensor is installed at the hand joints, which can accurately perceive the degree of joint bending and movement status in real time.



**Safety monitoring guarantee**
Accurately monitor the bending angle of fingers, as a safety detection device in the rehabilitation process, to protect the rehabilitation training process.

## MYO sEMG Band

Real - time Muscle Status Feedback
The wristband can collect real - time muscle electrical signals, enabling rehabilitation robots to adjust training intensity in real - time according to muscle activity, contraction strength, and fatigue levels, ensuring optimal training effects.
Personalized Rehabilitation Plans
By analyzing SEMG data, robots can understand individual muscle conditions and rehabilitation progress, customizing unique training programs to precisely meet each patient's needs.
Enhanced Patient Engagement
Visualized muscle signal feedback increases patients' active participation in training. It allows patients to self - adjust training efforts, improving training effectiveness.

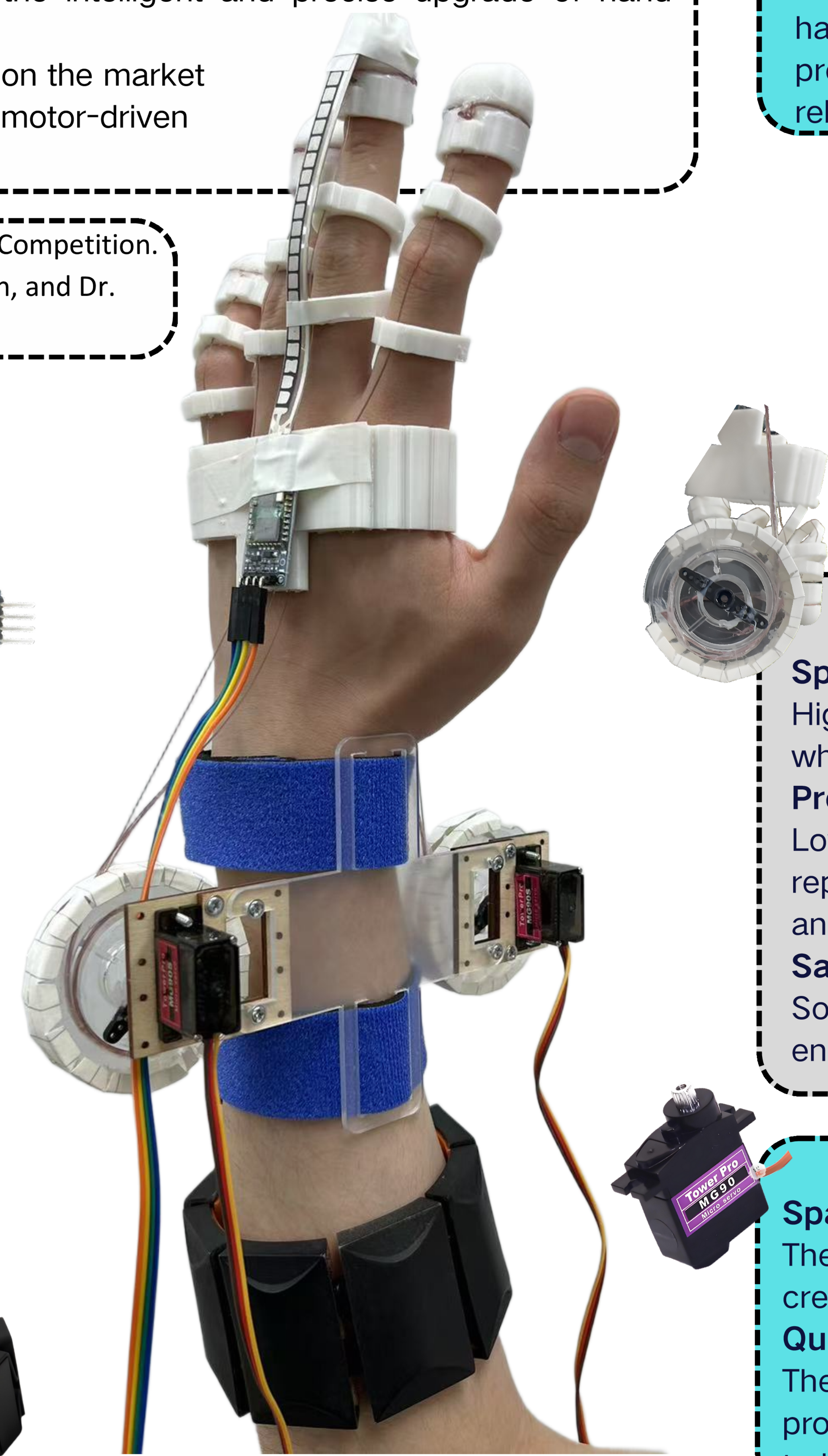


Figure 2. Prototype of hand rehabilitation robot for stroke patients

## Hardware Technology

### 3D printing technology

**Customized Components**
3D printing tailors rehabilitation robot parts to individual hand sizes, shapes, and rehabilitation requirements, ensuring a personalized fit.
**Flexible Material Advantage**
Printing with flexible materials conforms seamlessly to the hand's anatomy, enhancing wear comfort. This allows for precise, patient - specific support and exercise during rehabilitation.

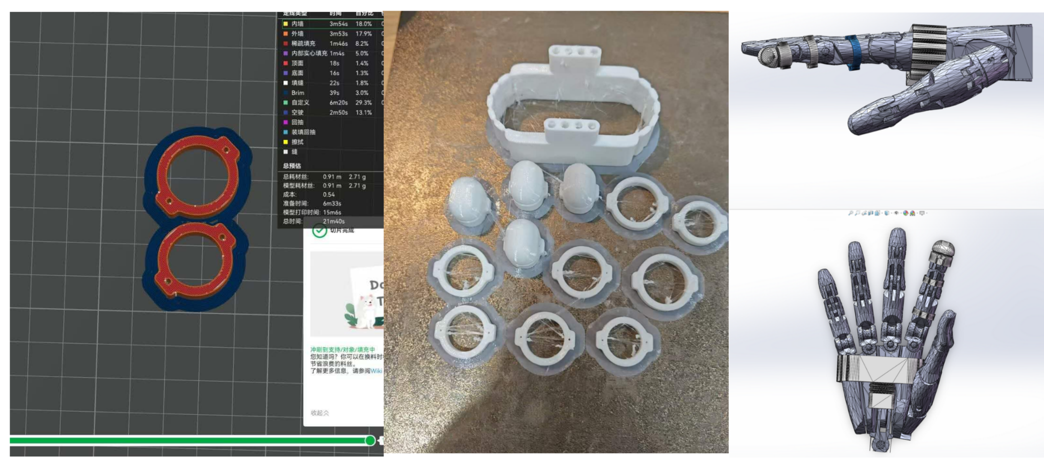


Figure 1. Use 3D printed finger sleeves of various specifications

### Cable Driven System

**Special materials**
Highly flexible and high-strength special ropes are used, which are both lightweight and durable.
**Precision transmission**
Low friction and high-efficiency power transmission, replicating the complex movement trajectory of hand flexion and extension and grasping.
**Safety and comfort**
Soft force feedback technology provides stable support to ensure the safety of the rehabilitation process.

### MG90 Drive Servo

**Space-saving and powerful**
The MG90 motor is perfectly combined with the cable drum to create an ultra-compact cable winding structure.
**Quick response and precise assistance**
The MG90 motor responds with only a 0.12 second delay, providing timely assistance or resistance during rehabilitation training, greatly improving the rehabilitation experience.

## Software Technology

- **sEMG Data Collection Process**

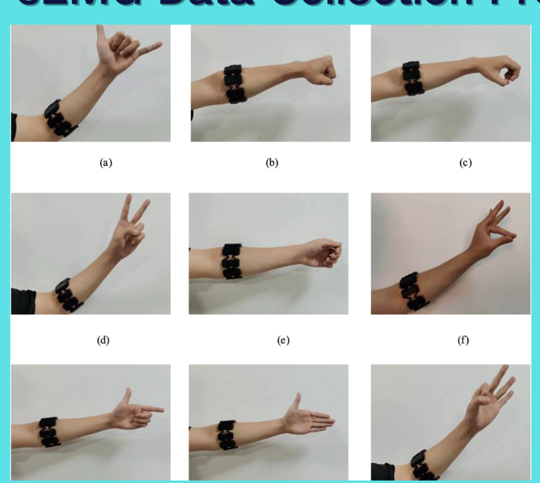


Figure 3. Hand movements for data collection

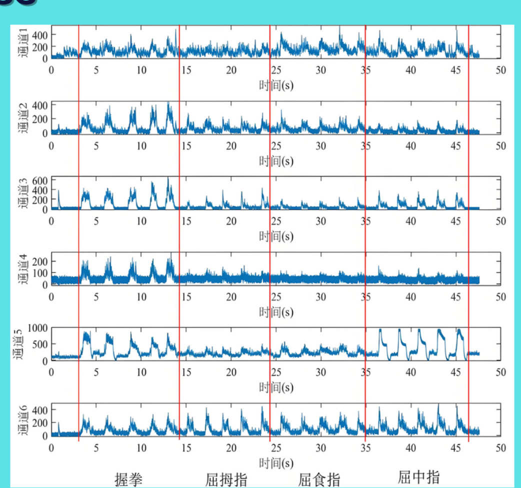


Figure 4. The collected sEMG signal

- Figure 4 shows the sEMG data during multiple hand movements.
- The data was labeled during the hand movement and a Butterworth filter (20Hz to 450Hz) was used to reduce noise and retain signal features.
- The collected data was used for CNN-transformer model training.

TABLE I
COMPARISON EXPERIMENTAL RESULTS OF DIFFERENT RECOGNITION MODELS

| Method | Parameters $(MB)$ | FLOPs $(G)$ | Accuracy | Precision |
|---|---|---|---|---|
| VGG16 | 165.76 | 40.50 | 84.64% | 87.86% |
| Googlenet | 6.28 | 4.30 | 87.91% | 89.73% |
| ResNet50 | 23.53 | 10.73 | 93.79% | 93.96% |
| DenseNet121 | 6.96 | 7.48 | 92.48% | 93.58% |
| ShuffleNet | 0.92 | 0.36 | 96.40% | 96.79% |
| ResNeXt50 | 23 | 11.12 | 94.44% | 94.44% |
| MobileNet | **3.23** | **1.52** | 93.14% | 93.36% |
| ViT | 43.31 | 22.13 | 87.25% | 87.15% |
| SwinT | 27.53 | 14.16 | 93.79% | 93.80% |
| **Proposed** | 32.03 | 14.82 | **99.02%** | **99.02%** |

- **A CNN-Transformer Hybrid Recognition Approachfor sEMG-Based Dynamic Gesture Prediction**

- Figure 5 shows the framework of the CNN-transformer model. The hybrid recognition network consists of two networks: a deep CNN and a convolution and transformer (CAT) [4].
- First, the multi-channel sEMG signal is transformed into a time-frequency map as input through CWT transformation.
- The deep CNN branch introduces AFB (adaptive frame buffer) to extract local features; the CAT network branch is combined with the transformer to capture global information and learn cross-channel interactions.
- After connecting and fusing the features of the two branches, the MFA block is used to extract multi-scale attention features and filter out irrelevant scale information.
- Finally, the classification layer outputs the predicted category through the global average pooling (GAP) layer and the fully connected (FC) layer.

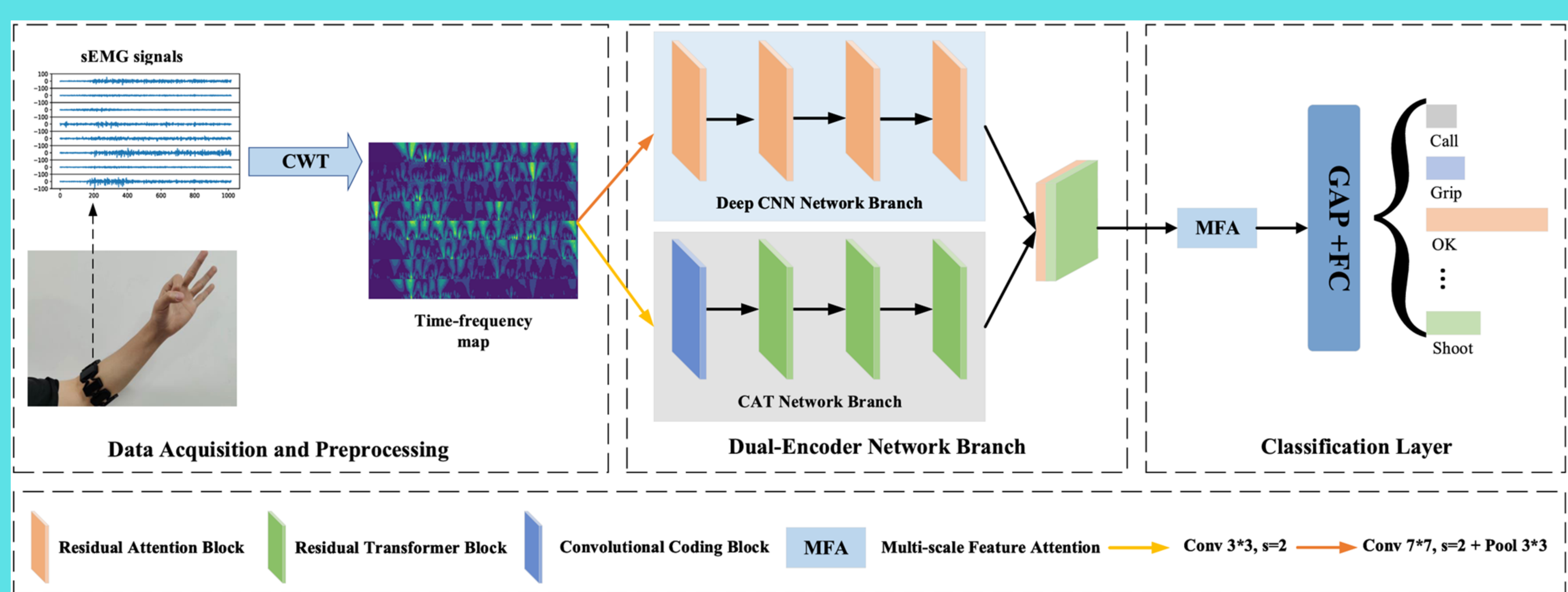



Figure 5. The network structure of the CNN-Transformer hybrid recognition network.

## Conclusion

The cable driven hand rehabilitation robot has outstanding artificial vitality and can accurately control finger joint movements, simulate real hand activities, and help patients recover their neuromuscular function. It can improve the range of motion, muscle strength, and motor coordination of hand joints in stroke.
With its lightweight, compact, and comfortable to wear characteristics, this robot is easily accepted by patients. With the increasing number of patients with hand dysfunction, it is expected to be popularized in medical institutions and rehabilitation centers, and gradually enter the home rehabilitation market.

## References

[1]J. J. A. M. Junior, C. E. Pontim, T. S. Dias, and D. P. Campos, "How do sEMG segmentation parameters influence pattern recognition process? An approach based on wearable sEMG sensor," Biomed. Signal Process. Control, vol. 81, 104546, 2023.
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