DESIGN AND OPTIMIZATION OF A SIX-BAR LINKAGE TO ASSIST IN THE REHABILITATION OF THE PULP PINCH GRIP IN STROKE PATIENTS

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Introduction

Stroke usually results in neuromotor disabilities that can affect the movement of the fingers. As finger movement is essential for the most basic activities of daily living, there is a strong motivation to focus on finger rehabilitation after injury or stroke [1]. It is well established that repetitive flexion and extension movement of the fingers, even passively, can facilitate neuromuscular re-education, help prevent spasticity and even control pain associated with patients with hand paralysis due to acquired brain damage [2][3].
Figure 1 shows the 3D scanned hand of a stroke patient in two extreme positions of a pulp pinch grip movement. The initial position of the distal phalanx (DP) is defined by points E_i (MIP joint) and F_i (tip of the finger), and the final position is defined by points E_e and F_e.

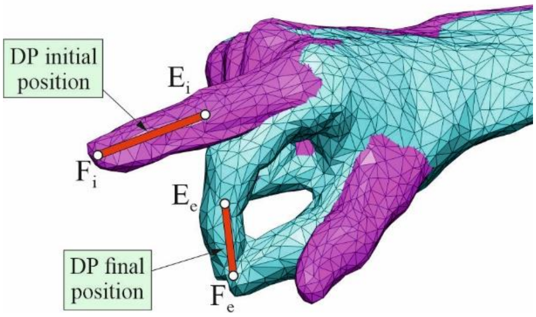

Figure 1: 3D scanned hand of the stroke patient: extended index (pink) and pulp pinch grip (green).

The goal of this work is to design a six-bar linkage intended for implementation in hand-held exoskeletons, which can move the DP from its initial to its final position, mirroring a pulp pinch grip movement.

Methods

Figure 2 shows the six-bar linkage selected for this application, in an arbitrary position defined by the input angle θ_2. The set of parameters that define the geometry of the linkage is shown in Table 1. Some of these parameters are regarded as design variables, whereas others are regarded as derived parameters.

Bar	Design variables	Derived parameters
1	$O_{2x}, O_{2y}, O_{4x}, O_{4y}$	-
2	O_2A, AC, φ_2	-
3	-	O_4B
4	AD, φ_4	AB
5	-	CD
6	φ_6	ED

Table 1: Definition of the geometry of the linkage.

These derived parameters, plus the initial and final value for angle θ_2, can be adjusted in such a way that segment EF of the linkage matches the initial and the final positions of the DP of a 3D scanned finger of a stroke patient, by solving a two-position synthesis problem.

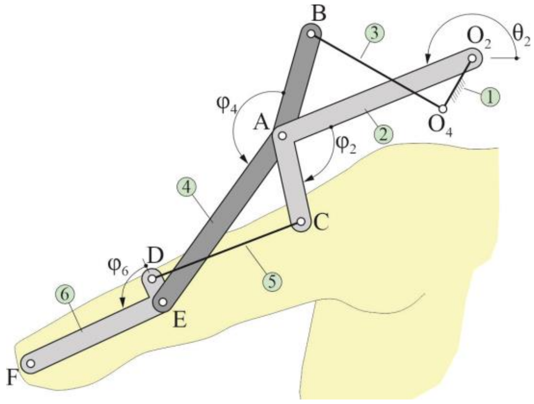

Figure 2: Six-bar linkage under consideration in an arbitrary position defined by input angle θ_2.

Results

The variation of the ten design variables of the linkage using a genetic scheme, and the subsequent calculation of the derived parameters, allows us to achieve an optimum design for this six-bar linkage, which minimizes its dimensions and maximizes its mechanical advantage, so it can be powered by a small actuator.

Discussion

Concern for the quality of life in post-stroke patients and their ability to rehabilitate has gained prominence in recent years. Together, studies on exoskeletons with improved mechanical advantage and ergonomics still need revisions and refinements to adapt them to these special requests. The scanning process and mechanism optimization study shown are tools for the generation of personalized and optimal mechanisms for each patient.

References

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