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Development of a new functional and discrete finger prosthesis

Esdras S. da Silva

esdras.robotics@gmail.com

Gustavo Valdatti Souza

valdattigustavo@gmail.com

Gustavo Paul Exel

gustavoexelgpe@gmail.com

Leonardo Mejia Rincon

leonardo.mejia.rincon@ufsc.br

Daniel Martins

daniel.martins@ufsc.br

Universidade Federal de Santa Catarina - R. Eng. Agrônomo Andrei Cristian Ferreira, s/n - Trindade, Florianópolis - SC

Abstract. *The hands play a crucial role in numerous daily activities, making the movement of fingers essential. However, incidents resulting in finger or partial finger amputations can severely impact functionality and cause psychological trauma. Prostheses offer a potential solution to address these challenges, restoring both function and self-image. To achieve this feat, the prosthesis needs to efficiently perform the natural movement of Human body in addition to being visually discreet. In this context, this work aims to develop a mechanism for finger prostheses that replicates the natural movement of the human finger using the remaining part of the amputated finger. The mechanism, designed with aesthetics in mind, simulates the planar flexion/extension movement with one Degree of Freedom. The closed-chain mechanism presented in this paper offers an advantage over existing prostheses by considering both natural movement and discreet aesthetics. The development methodology employed follows established principles, ensuring the reliability and effectiveness of the mechanism. Initial analysis presents the Kinematics and functioning of the mechanism developed and shows that in every position, a good transmission quality is maintained within a range considered good and future works are suggested pointing to the direction of optimization.*

Keywords: *Finger Prosthesis, Mechanism, Robotics, Mechanism synthesis, Dimensional Synthesis*

1. INTRODUCTION

The movement of fingers is fundamental in a series of daily activities (Carbone *et al.*, 2020)(Kuret *et al.*, 2019), since these members are the main tool for handling elements. For example, there are many professions, such as programmers, mechanics, musicians, etc., there are activities that depend on the fingers to be performed. According to Kuret *et al.* (2019), apart from the face, hands are the most exposed body part in humans. Using our hands serves as a means of self-expression and gestures facilitate nonverbal communication within our immediate environment (e.g., handshake) (Rybarczyk and Behel, 2008).

However, due to some incidents, there is a possibility of losing these limbs. Among the various types of partial hand loss, finger, and partial finger amputations represent the most commonly encountered cases (Pillet, 1981)(Baumgartner and Botta, 1997). According to Aydin *et al.* (2007), trauma, congenital absence, and malformations stand as the primary causes of these amputations. The complete or partial loss of a finger leads to notable functional impairments. Apart from the immediate effects on grip, strength, and stability, the absence of a finger can induce significant psychological trauma. Beasley has observed that individuals who conceal their hands in pockets due to embarrassment about their appearance experience functional limitations comparable to those of a forequarter (scapulothoracic) amputee (Kolb, 1959). The presence of any deformity, particularly involving the hands which are consistently visible to both the patient and others, can have a negative impact on the socioeconomic status of the individual (O'FARRELL *et al.*, 1996). The process of amputation alters the body structure and significantly affects various activities, participation, and overall quality of life (Pezzin *et al.*, 2000) (Burger and Marinček, 2007). Individuals who have undergone finger amputations often experience substantial impairment in hand function, as well as notable social and psychological dysfunctions (Cervelli *et al.*, 2008). These limitations and restrictions in daily life collectively contribute to a detrimental impact on the individual's quality of life. Davidson *et al.* (2010) affirm that upper-limb amputees demonstrated inferior outcomes across all domains compared

to lower limb amputees. Specifically, upper-limb amputees exhibited reduced vitality and poorer mental health. It is important to note that the study encompassed upper limb amputees at various levels, not limited to finger amputations. The data further revealed that upper limb amputees experience a higher prevalence of pain, which is more severe and persists for longer durations compared to lower limb amputees (Kuret *et al.*, 2019).

A viable solution to circumvent this situation is the use of prostheses. According to Pillet and Mackin (1992), a prosthesis can often restore a near-normal function in distal phalange amputations. In addition to functional issues, existing literature Beasley and de Bese (1986), Beasley (1987), O'FARRELL *et al.* (1996), Pillet and Mackin (1992), and Leow *et al.* (2001) indicates improvements in self-image among individuals who have received a finger prosthesis. Individuals seeking finger replacement typically have elevated expectations concerning the aesthetic aspects of the prosthesis (BUCKNER, 1980). Thus, the role of aesthetics is extremely important as it serves as a crucial factor in addressing the comprehensive functional and psychosocial challenges faced by individuals with amputations (Raghu *et al.*, 2013).

In this context, this work aims to develop a mechanism to be applied in finger prostheses that use the movement of the remaining part of the amputated finger to generate the complete natural movement of the finger and be aesthetically discreet. In this way, the prosthesis must simulate the planar movement of flexion/extension of the fingers, having one Degree of Freedom, considering the case in which the patient only has the capacity to act on the kinematic pair that unites the palm of the hand and the finger. This effect is possible through a closed-chain mechanism, as explained in Section 3. The main advantage of this mechanism related to the existing prostheses is that the dimensional synthesis was carried out so that, in addition to performing the natural movement of the human being, established in Nagem *et al.* (2007), it takes into account the aesthetic part, in order to be discreet.

There are a series of methodologies for the development of mechanisms as (Hartenberg and Danavit, 1964), (Yan, 1998), and (Tsai, 2000), but all of them have the structure presented in Martins and Murai (2019). Thus, this was the methodology used for the development of the mechanism. In short, the method consists of the following steps: First, a survey of the state of the art is conducted, followed by an analysis of existing mechanisms. Subsequently, the structural and design requirements are defined, and then the synthesis of the number, type, and dimensions is developed. With the mechanism synthesis in hand, the following steps involve prototyping, documentation, and manufacturing.

In this study, section 2 addresses the bibliographic review, section 3 provides an overview of the development process, section 4 presents the derived mechanism and initial analysis, and Section section 5 provides the conclusion of the study, along with a recommendation for future works.

2. BIBLIOGRAPHIC REVIEW

2.1 Synthesis of mechanism process

In the early stages of mechanism design, the development process was almost entirely entrusted to the designer's experience. However, training a skilled, inventive, and imaginative designer can be a time-consuming and ineffective process without a well-defined plan. In these cases, the design process was heavily influenced by the designer's convictions, which do not necessarily guarantee a good or optimal solution. Moreover, the design process itself is not optimized, often requiring more resources (such as time, materials, personnel, and money) than necessary. The first study to develop a structured approach to mechanism design was conducted by Reuleaux and Kennedy (1876), according to Murai (2019). After that, several authors worked on methodologies and methods for the development of mechanisms. One of the most revolutionary that served as a basis for the definition of synthesis types was the one proposed by Hartenberg and Danavit (1964). The methodology proposed by the authors divided the synthesis process into three types: number, type and dimensional. The division proposed by Hartenberg and Denavit (1964), served as a basis for the methodology proposed by several authors who made their adaptations to the methodology Yan (1998), Tsai (2000), Murai (2013), and Ding *et al.* (2022). The number synthesis consists in defining the topological characteristics of the mechanism, such as the number of links and kinematic pairs. The type synthesis consists in determining the type of the kinematic pairs that were defined in the previous step. Finally, there is the dimensional synthesis that consists in determining the dimensions of the bodies, in order to meet a previously determined trajectory (Lee and Russell, 2018).

2.2 Dimensional methods for four bar mechanisms with one loop

The mechanisms are a set of rigid bodies, connected by kinematic pairs, that have a certain degree of freedom between them, forming a system with their own kinematic characteristics. Mechanisms can have infinite purposes, as well as infinite configurations to achieve those purposes. One widely used type of mechanism is the four-bar linkage. Such mechanisms are formed by four links arranged in a closed loop and can perform numerous functions. There are three different types of four-bar mechanisms: Crank-Rocker, Rocker-Rocker, and Double Crank. The behavior of the system depends on the length of the links and which one is the fixed link, and it can be evaluated using the Grashoff criterion Martins and Murai (2019). With a defined inversion, that is, by choosing the fixed link, each link is given a specific name according to its position. The nomenclature presented is given by Martins and Murai (2019). Link "a" is the input link,

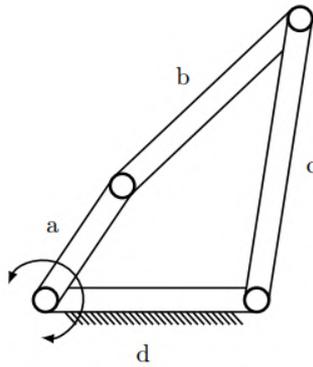


Figure 1. Nomenclature four-bar mechanism

also known as the crank, and it is where the actuator is attached. Figure 1 shows a four-bar mechanism with the named links. Link "b" is called the coupler, connecting the input (a) and output (c) links. Link "c" is the output link, known as the follower. Finally, link "d" is the link that has been adopted as the fixed link.

There are four types of dimensional synthesis, namely: function synthesis, path synthesis, trajectory synthesis, and motion synthesis. The function synthesis aims to determine the dimensions of a mechanism so that it can perform a specific predefined function. In path synthesis, the goal is to size the mechanism so that a point of interest travels along a desired path as it moves. Path synthesis is similar to path synthesis, but includes consideration of time on the path or the position that the link must occupy as the point advances along the path. Finally, in motion synthesis, the dimensions are specified so that the mechanism can assume a set of positions that are homologous to a defined plane (Martins and Murai, 2019) The method adopted for the development of this work is motion synthesis, which uses desired positions as reference to design the mechanism. The positions in the plane are defined considering them finitely separated (PFS) (WONDRACEK, 1983). For this type of synthesis, there are two widely studied methods, the analytical method and the geometrical method, introduced by the studies of Beyer *et al.* (1963), Hartenberg and Denavit (1964), Keller (1965), and Filemon (1971), based on the concepts proposed by Burmester (1888). The geometric method is based on graphical resources for determining the dimensional parameters of the mechanisms, it has become more popular with computational resources, which minimizes the dimensional error generated by the method. The analytical or quantitative synthesis, on the other hand, is based on mathematical models that can be solved analytically or numerically Lee and Russell (2018).

2.3 Geometric methods

2.3.1 2 FPS

The synthesis technique for two finitely separated positions involves determining the dimensions of the links in a mechanism based on a set of four input points. These points represent two desired positions of the mechanism's movement. To simplify the terminology, the first pair of points are referenced as C1 and D1, corresponding to the first position, and the second pair of points as, C2 and D2, corresponding to the second position, as it can be seen in (Martins and Murai, 2019).

Once the two control positions are defined, it is necessary to locate the rotation pole of the movement. This pole is determined by the intersection of the perpendicular bisectors of the lines drawn between the displacement points. Next, it is necessary to find the pivots of the output bar. For this purpose, an arbitrary point (B1) is chosen in a plane, with no restrictions on its coordinates, although it is recommended to be close to the points defining the first position. Then, another point (B2) is determined by rotating B1 around the rotation pole by an angle measured between two lines. These lines are drawn from the rotation pole to point C1 and from the rotation pole to point C2. Subsequently, a point (B0), called the fixed pole, is chosen along the perpendicular bisector of the segment connecting B1 and B2.

Once the points delimiting the pivots of the output bar are defined, it is necessary to find the Filemon lines. These lines determine the region where the initial pivot of the input bar cannot be located. The process to define the Filemon lines is based on the angles between the lines formed by the points of the output bar pivots and the initial and final position pairs (C1 and C2, or D1 and D2).

After delimiting the region, it is necessary to define the pivot points of the input bar. An arbitrary point (A1) outside the region delimited by the Filemon lines can be chosen to start the process. The remaining points (A2 and A0) are defined analogously to the process of the output bar pivots.

With all these points defined, it is possible to establish the dimensions and the initial configuration of the mechanism (A0A1, A1B1, B1B0, B0A0).

2.3.2 3 FPS

The synthesis technique for three finitely separated positions involves determining the dimensions of the links in a mechanism based on a set of six input points. These points represent three desired positions of the mechanism's movement. To simplify the terminology, we will refer to the first pair of points as C1 and D1, corresponding to the first position, the second pair as C2 and D2, corresponding to the second position, and the third pair as C3 and D3, corresponding to the third position, as described in (Martins and Murai, 2019).

Once the three control positions are defined, the next step is to locate the rotation poles of the movement. These poles are determined by the intersection of the perpendicular bisectors of the lines drawn between the displacement points from position one to position two, from position one to position three, and from position two to position three. With the points defined, we draw the so-called pole triangle Martins and Murai (2019), which is formed by connecting these three points. From this triangle, we determine the image poles, which are the reflections of each point with respect to the perpendicular bisector drawn based on the side opposite to the point. These three image poles delimit the image pole triangle.

With the image pole triangle established, we draw the circle diagram, which consists of three circles whose diameters are defined by the sides of the image pole triangle. This diagram delimits the region where the movable pole of the output bar pivot (B1) cannot be positioned. The vetoed region is where there is no intersection between the circles or there is an intersection between an odd number of circles.

Subsequently, the pivots of the output bar are sought. An arbitrary point (B1) is selected in a plane, while adhering to the circle diagram. It is advised to choose a point in close proximity to the points defining the first position. The determination of points B2 and B3 can be achieved through a process analogous to the one demonstrated in the two finitely separated positions method (2FPS), with the inclusion of all three positions to ensure the completion of the process.

Another way to delimit points B2 and B3 is through the image pole triangle. In this process, we mirror point B1 with respect to side L1, generating a point Bg. This Bg point serves as a reference for determining B2 and B3 by mirroring Bg with respect to L2 and L3, respectively. Point B0, the fixed pivot, is positioned at the center of the circumference formed by points B1, B2, and B3 Martins and Murai (2019).

After these steps, it is necessary to draw the Filemon lines, as in the 2FPS method, to delimit the vetoed region of the movable pivot of the input bar (A1). The process to specify A2 and A3 is the same as that used for points B2 and B3, as well as the process to find the fixed pivot A0.

2.3.3 4 FPS

The 4FPS method, describes in Martins and Murai (2019), does not have as many analogies compared to the 2FPS and 3FPS methods. While some characteristics are similar, 4FPS involves additional steps. The first step is to define the control positions (C1D1, C2D2, C3D3, and C4D4), then we find the rotation poles (P) by intersecting the mediatrices.

Next, we find the triangle of poles formed by the sub-index 1 poles and the image poles, which are reflections of the poles outside the triangle with respect to the corresponding sides. The choice of sides for reflection is based on the indices of the poles.

In the 4FPS method, three quadrilaterals consisting of image poles are present. One of these quadrilaterals can be chosen to generate the circle point curve, which constitutes the subsequent step. By utilizing two poles and two image poles based on their sub-index relationships, two opposite sides of the pole quadrilateral are selected. These sides are non-adjacent, and the mediatrices of each side are drawn. A point, denoted as M1, is chosen on one of the mediatrices to determine the angle with respect to the first pole of the quadrilateral. Similarly, a point, referred to as M2, is located on the other mediatrice with the same angle relative to the line of the second pole.

Subsequently, circles with centers at M1 and M2, passing through the selected opposite sides, are identified. The intersection of these circles is denoted as C01 and C02, representing the circle points. As M1 is arbitrarily chosen, points C01 and C02 are also arbitrary. The focus lies in the geometric locus of the circle points, signifying all possible positions they can assume depending on the location of M1. The movement of M1 along the generating mediatrice traces a curve with varying forms, known as the circle point curve.

The synthesis using the 4FPS method necessitates an evaluation of two defects: the branching defect and the order defect. Although the process to identify the parameters that define the absence of these problems will not be discussed here, a brief definition of each defect will be provided. Both defects impose restrictions on the points beneath the curve where the mobile pivot of the output bar can be situated. The branching defect confines the sections where the pivots, represented by points Q, T, and U, can be allocated. These points are determined through the three quadrilaterals in the 4FPS method and aid in delineating the regions beneath the curve where the mobile pivot cannot be positioned. To evaluate the order defect, an intersection point between two circles and the curve of points needs to be determined. These circles are constructed based on the poles, followed by an analysis conducted in the order of positions. By employing the delimited points and the proposed method, more restricted regions for the mobile pivot of the output bar can be identified. The determination of pivot points for both the output bar and the input bar follows a process analogous to the methods described earlier.

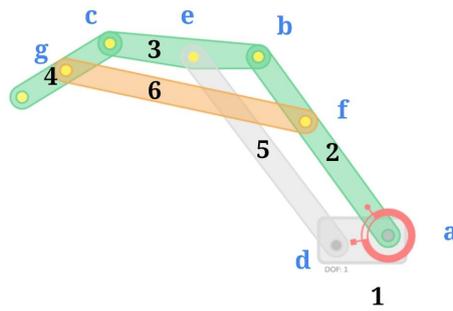


Figure 2. Structural representation of the mechanism

2.4 Analytic methods

Similar to the geometric method, the analytical method endeavors to establish the dimensions of the links within a mechanism, taking into account specific conditions and input data. The method of optimal transmission angle is a viable approach for sizing four-bar mechanisms. It relies on determining the maximum and minimum angles formed between the coupler link and the output link as a reference for dimensioning. Another synthesis technique worth mentioning is the employment of the Freudenstein equation, which entails the vector sum of the link dimensions (Østlie *et al.*, 2012) (Atzori *et al.*, 2014) (Biddiss *et al.*, 2007).

3. DEVELOPMENT

The methodology used for the development of the mechanism is the presented by Martins and Murai (2019), and based on Yan (1998), Tsai (2000), and Hartenberg and Danavit (1964). In sume, The design requirements were established based on studies of human finger movement, mainly referring to Nagem *et al.* (2007). The synthesis consisted of the conduction of two links that must follow the movement of the medial and distal phalanges based on the movement of the proximal phalanx, which is coupled to the first input link of the mechanism. For this purpose, two four-bar mechanisms were constructed, one for the conduction of the link coupled to the medial phalanx (link 3) based on the link coupled to the proximal phalanx (link 2), and the second loop for conduction of the distal phalanx (link 4) based on the link coupled to the medial phalanx (link 3), as shown in Figure 2. These two four-bar mechanisms connected, form the well-known Watt kinematic chain. The functional description of each link for the four-bar mechanism in each circuit is provided in Table 1.

Table 1. Functions of the links of the mechanism in both circuits

Function	Circuit 1	Circuit 2
Fixed link	1 (metacarpus)	2 (proximal p.)
Input link	2 (proximal p.)	3 (middle p.)
Coupler link	3 (middle p.)	4 (distal p.)
Output link	5 (transmission bar 1)	6 (transmission bar 2)

(*) p. = phalanx.

This configuration ensures that all phalanges of the prosthesis and the finger perform a movement similar to that of a human finger. To carry out the synthesis, the length between joints of each link was determined, namely $L_{link_2} = 36 \text{ mm}$, $L_{link_3} = 27 \text{ mm}$, and $L_{link_4} = 15 \text{ mm}$. Those dimensions was based on a specific person who will test the prosthesis. The angles between the phalanges during the finger movement were also defined, and was based on the relative position of the finger bones, presented in Nagem *et al.* (2007). Since the dimensional synthesis was performed using the 4 FPS method, only four positions were used: the initial and final positions of interest, and two intermediate positions. The considered angles are represented in Table 2.

Table 2. Angles for 4 FPS synthesis

Position	MCP	IFP	IFD
1	173°	144°	164°
2	145°	129°	143°
3	121°	103°	112°
4	108°	90°	96°

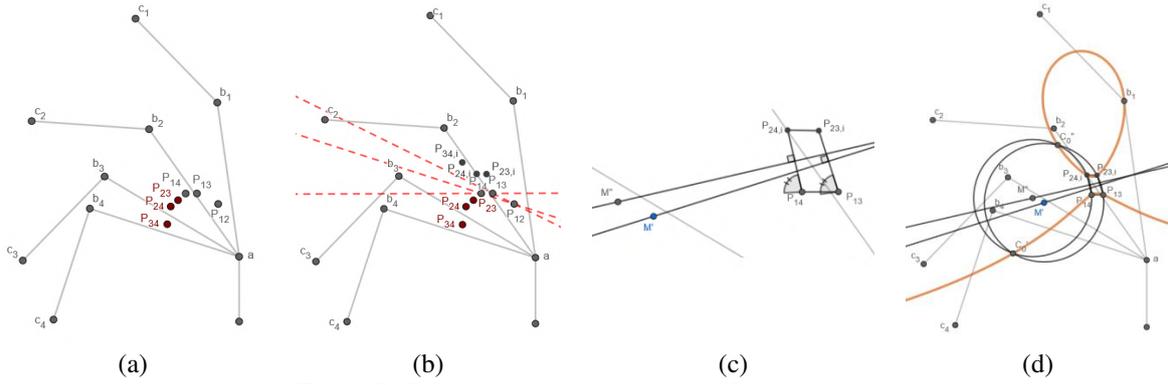


Figure 3. Steps to determine the curve of circle points

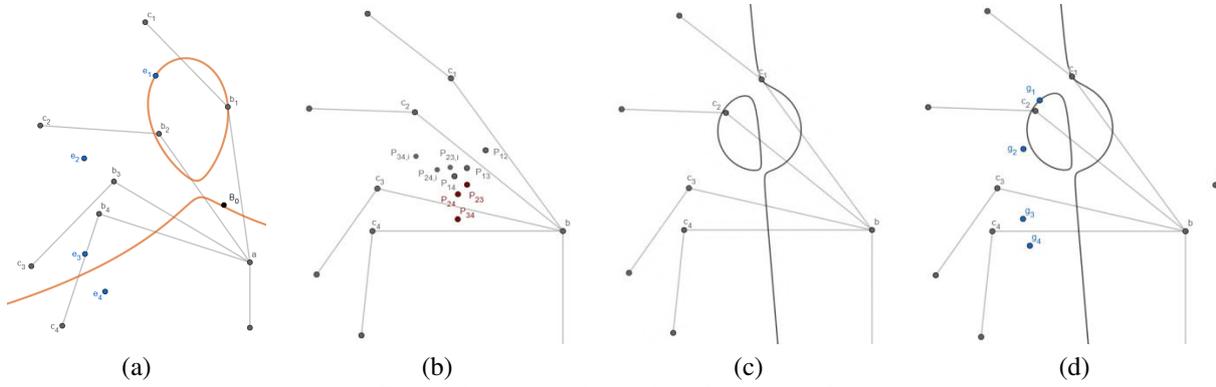


Figure 4. Steps to determine pivots g_n and f

The dimensional synthesis was developed following the method presented in Martins and Murai (2019) and resumed in the section 2. In Figure 3, the points b_n and c_n represent points b and c respectively from Figure 2. The pole points P_{mn} are constructed by the intersection of the perpendicular bisector of $\overline{b_m b_n}$ with the perpendicular bisector of $\overline{c_m c_n}$. Next, the image pole points $P_{mn,i}$ are constructed by reflecting the points P_{mn} with respect to the line $\overline{P_{1m} P_{1n}}$, where $m, n \neq 1$.

The possible points to position e_1 lie on a curve called the circle point curve. To construct it, we consider the quadrilateral formed by points $P_{13} P_{14} P_{24,i} P_{23,i}$. A point M' is arbitrarily chosen on the perpendicular bisector of $\overline{P_{13} P_{23,i}}$, and a point M'' is defined on the perpendicular bisector of $\overline{P_{14} P_{24,i}}$ such that $\angle M'' P_{14} P_{24,i} := \angle M' P_{13} P_{23,i}$, as shown in Figure 3c. Finally, two circles with centers at M' and M'' , passing through the pairs of points $P_{13}, P_{23,i}$ and $P_{14}, P_{24,i}$ respectively, are drawn, and their intersections are marked by C'_0 and C''_0 . The geometric locus of C'_0 and C''_0 for all possible positions of M' forms the circle point curve (shown at Figure 3d, which is also the geometric locus of all possible positions of the movable pivot of the input link of the first circuit e_1).

The point e_1 can be initially arbitrarily positioned on the circle point curve, but then we will optimize its position for optimal transmission quality. The points e_n , $n \in 2, 3, 4$, are determined by rotating e_1 relative to P_{1n} by the angle $\theta_{1n} := \angle b_1 P_{1n} b_n$, and the point d is the center of the circumference passing through the points e_n , as seen in Figure 4a. The mechanism already carries information regarding the size of the human phalanges, and the synthesis consists of finding output links 5 and 6. Once e_n and d are determined, the output link is fully determined.

The synthesis for the circuit formed by links 2, 3, 4, and 6, which drives the movement of the distal phalanx, is done similarly, with the detail that now we represent joint b in a single position, since link 2 is the fixed bar of the circuit, which means that for the second loop dimensional synthesis, the reference system is fixed in the proximal phalanx. Figure 4 represents the synthesis of the second circuit.

In this way, we have found the lengths of all the links that make up the mechanism, but we have arbitrarily chosen two degrees of freedom in the positioning of joints e_1 and g_1 . These two positions independently control the transmission quality of each circuit, where the transmission quality μ is defined by the angle between the coupler link and the output link of each circuit, expressing the ratio between the torque at the mechanism's output and the torque at the input.

$$\mu_I = \angle bed = \arccos \left(\frac{M_{in,I}}{M_{out,I}} \right) \quad (1)$$

$$\mu_{II} = \angle cgf = \arccos\left(\frac{M_{in,II}}{M_{out,II}}\right) \quad (2)$$

Thus, the ratio between the input torque and the output torque of the mechanism is given by Equation 3.

$$\frac{M_{out,II}}{M_{in,I}} = \frac{1}{\cos \mu_I \cos \mu_{II}} \quad (3)$$

Note that the transmission will be maximum when $\mu = 90^\circ$, but the transmission quality depends on the position of the mechanism. Therefore, we seek to minimize $|\mu - 90^\circ|$, adopting the design recommendation of $\mu \in [40^\circ, 140^\circ]$. To determine the position of e_1 and g_1 , we can optimize μ_{min} and μ_{max} for both loops.

4. RESULTS

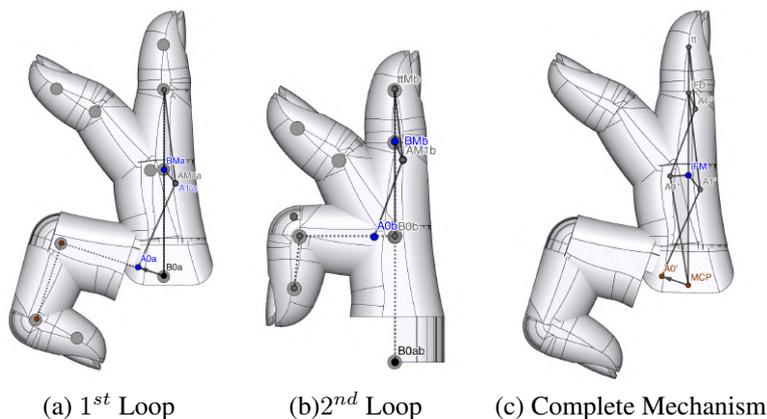
As presented in section 2, each type of synthesis has its own specific characteristics, and the more constraints there are, the less freedom one has in choosing the points' positions. In section 3, the dimensional synthesis of a mechanism using the Watt chain was developed, which achieves four finitely separated positions. However, it was observed that in that case, defining four positions was not possible to obtain a mechanism that respected the dimensional limits of the finger while maintaining good transmission quality. Therefore, a decision was made to seek a balance between functionality and appearance. To achieve this, the dimensional synthesis of the mechanism was considered for three finitely separated positions, thereby providing greater freedom in choosing the positions. The three finitely separated positions were chosen as follows: Position 1 - Fully extended (for pointing at something); Position 2 - Represents the relaxed position (maintains the finger in a natural position when no muscle in the hand is activated); Position 3 - Fully bent finger position (corresponding to a closed hand situation). The angles for those specific positions are specified at Table 3.

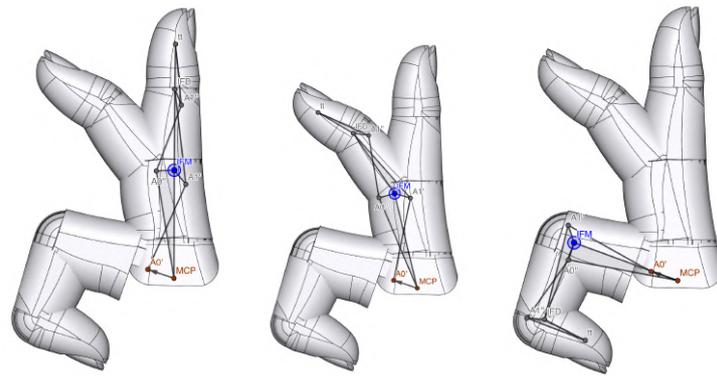
Table 3. Angles for 3 FPS synthesis

Position	Case	MCP	IFP	IFD
1	Fully extended	180°	180°	180°
2	Relaxed	173°	144°	164°
3	Fully bent	108°	90°	96°

The synthesis was carried out in the same manner as presented in section 3. Firstly, the first circuit was considered, with the reference fixed at the metacarpal. The three positions were designed, and then the synthesis for a four-bar mechanism was developed to bring the middle phalanx to the predetermined positions. Subsequently, the dimensional synthesis was carried out for the second loop, which brings the distal phalanx to the three predetermined positions, with the reference system fixed at the proximal phalanx. The results obtained from these syntheses are presented in Figure 5.

In order to achieve a discreet prosthesis, the allowable space was limited, ensuring it does not exceed the boundaries of the human finger contour. The concept entails transmitting the movement through a fine cable for the first loop, and confining the mechanism within the prosthesis for the second loop. The Figure 6 presents the complete mechanism in each of the three position established.





(a) 1st Position (b) 2nd Position (c) 3rd Position
 Figure 6. Three position synthesis.

Preliminary analyses, illustrated in Figure 7, provide an overview of the displacement, velocity, and acceleration of the fingertip in relation to the reference fixed at the metacarpal. As it can be seen, the velocity of the MCP remains constant, and the data acquisition from the three joints was obtained under identical conditions. The greatest displacement at the fingertip indicates natural movement.

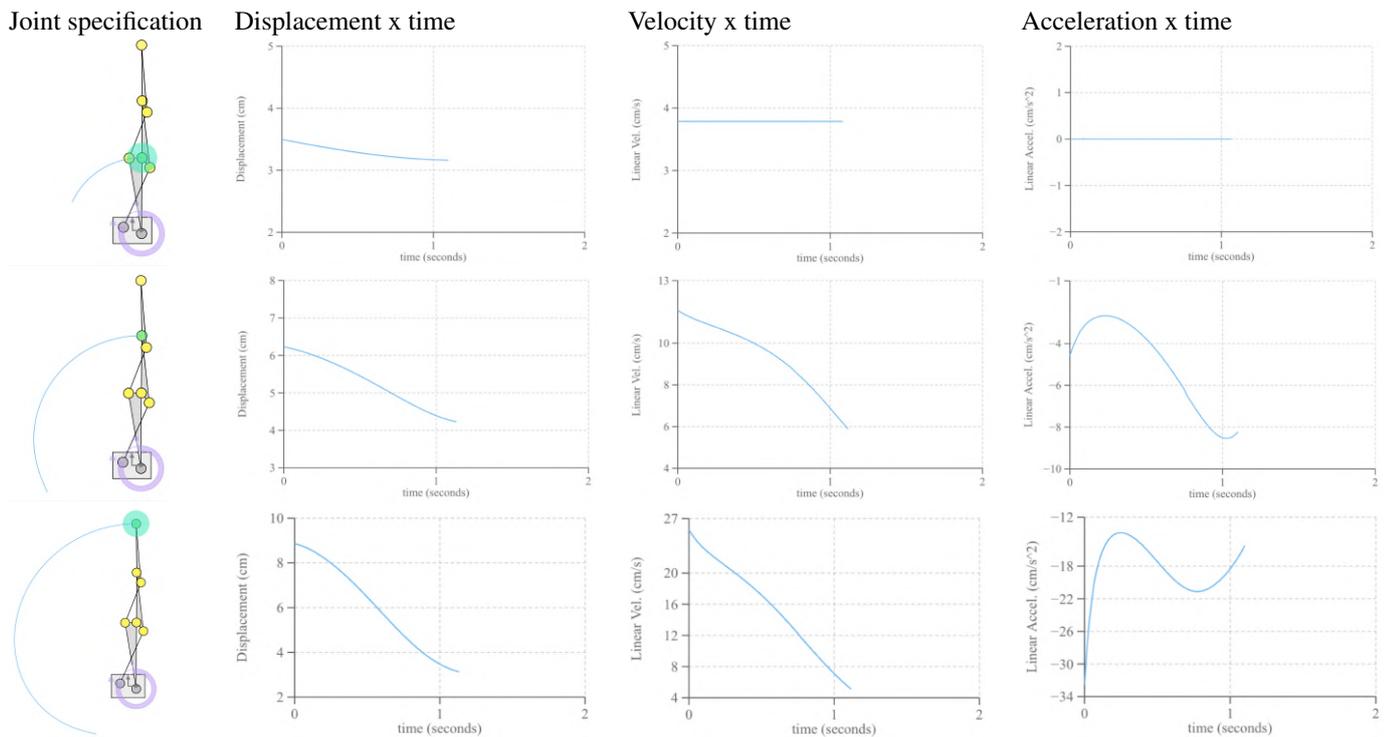


Figure 7. Preliminary Analysis Data

The synthesis development was executed employing the mathematical tool Geogebra, available on <https://www.geogebra.org>, while the preliminary calculations of velocity and acceleration were performed utilizing the Motiongen tool <https://motiongen.io>.

5. CONCLUSION

In summary, the developed mechanism for finger prostheses represents a significant achievement in the field of prosthetics. It successfully addresses the challenge of simulating the planar movement of flexion/extension in a finger prosthesis with one Degree of Freedom, particularly when the patient can only act on the kinematic pair connecting the palm of the hand and the finger. The mechanism is designed to replicate the natural movement of a human finger while maintaining appropriate proportions and dimensions. This distinguishes it from existing prosthetic solutions and offers several notable advantages. The mechanism allows individuals with finger amputations to regain a significant level of functionality by leveraging the remaining capabilities of the hand. This enables users to exert control over the prosthesis and perform

tasks with improved dexterity, enhancing their ability to carry out daily activities. Furthermore, the aesthetic discreetness of the prosthesis contributes to the wearer's overall satisfaction and acceptance. By seamlessly blending with the natural appearance of the hand, the mechanism reduces attention and potential social stigma associated with visible prosthetic devices. This facilitates their integration into society.

The development of this mechanism signifies progress in the field of finger prosthetics, demonstrating the potential of technological advancements to positively impact the lives of individuals with limb loss. Further research and development are necessary to optimize the mechanism in order to obtain a greater force capability on the tiptoe, based on the torque promoted on the MCP joint.

6. ACKNOWLEDGEMENTS

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