Development of a Graphical User Interface for Personalized Transfemoral Prosthesis Design

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ABSTRACT

1 Introduction

Multiple factors can lead individuals to undergo surgical operations that result in amputation, defined as the removal of an extremity or part of it [1]. Given the personalized nature of surgeries involving extremities, along with variations in individuals' anatomical structures and desired post-surgical activity levels, customized prosthetic solutions are often required. Focusing specifically on transfemoral (above-knee) amputations, one of the most critical parameters to address is stability during the stance phase, which ensures user safety. Additionally, ease of flexion during the swing phase is vital for enhancing usability. Ongoing research and development in this field, along with efforts toward commercialization, are driven by the demand for high-quality, accessible and personalized prosthetic solutions that enable easy adaptation.

Stance phase of the gait cycle demands stability while the foot is on the ground, achieved in polycentric prosthetics through an increased instantaneous center of rotation (ICR) in the sagittal plane, providing a natural locking mechanism. Conversely, during the swing phase, ICR should align with the knee's natural center to ensure smooth flexion. Radcliffe's studies [2, 3] evaluated performance criteria for stance stability across various prosthetics, which have since been adopted in other works [4, 5] for assessing and comparing the stability of different kinematic designs.

Authors aim to contribute to the field by developing a novel transfemoral prosthesis using an analytical kinematic synthesis procedure for a single-degree-of-freedom polycentric mechanism, personalized to individual needs for both stance and swing phases [6]. Two modular designs are proposed for each phase, synthesized using kinematic principles with the objective of integrating them. Design method allows for various ICR trajectories through analytical approaches, but parameters like the polycentric mechanism's center and precision points on the ICR are challenging to define without appropriate tools or interfaces. Thus, this work advances by implementing a user-friendly graphical user interface (GUI) developed in MATLAB App Designer, designed to automate the process of optimizing parameters and defining individual ICR trajectories or precision points as specified by the user, due to the fact that it is thought the personalized solutions would be one of the future perspectives in such designs. Inclusion of stance stability models provides objective performance metrics for comparison. Additionally, the GUI's visualization capabilities enhance the personalization of prosthetic designs, enabling clearer insights into their customization and suitability for individual needs.

2 Development of graphical user interface

In previous work [6], kinematic synthesis methodology was implemented through MATLAB scripting, allowing manual input of precision points and optimization parameters. To maintain software consistency, a graphical user interface (GUI) is developed in MATLAB App Designer, enabling users to easily customize their ICR trajectories and precision points. It is important to note that multiple sets of precision points can yield different mechanisms, so GUI incorporates constraints and requirements to ensure that the generated designs adhere to predefined criteria. This ensures that users can explore various configurations and limitations while maintaining design accuracy.

To enable motion visualization in relation to human anatomy, it is necessary to integrate a visual model of the human body. Given the individual variability in anatomy, anthropometric data are generally used in the design process [7]. In developed GUI, visualization relies on such data, but users can customize specific parameters, including buttock depth and lateral femoral epicondyle height, allowing for a more personalized representation of the anatomical structure during prosthetic design.

Figure 1 illustrates GUI for visualizing the human lower extremity in the sagittal plane, featuring versatile user input options and the capability to upload pre-generated ICR trajectories with detailed data points and corresponding flexion angles. This interface enables users to view, add, delete and modify trajectory points as needed. By comparing figures 1a and 1b, users can also observe modifications to body dimensions, specifically adjustments to buttock depth values as an example. A slider and text input control are provided to adjust the flexion angle, offering real-time updates to the lower extremity movement visualization. Additionally, different stance trajectories, based on real prosthetic models, are available for visualization in the sagittal plane. Users can select each data point, along with associated flexion angle, for further modification or deletion. Figure 1c highlights the interface's capacity to customize trajectories by adding specified points, which appear both on the human visual and in the trajectory list. GUI allows users to save modified trajectories and precision points to a local ".mat" file and supports uploading and adjusting natural swing phase trajectories for the second part of the design.

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3 Conclusion and future works

A graphical user interface has been developed using MATLAB App Designer to facilitate the input of specified ICR trajectory and optimization parameters, enabling kinematic synthesis procedures aimed at creating an innovative transfemoral prosthesis. This interface provides visualization that aids in kinematic simulations, allowing for comparisons of different mechanisms based on Radcliffe's performance criteria. Future developments will incorporate dynamic simulations to determine the required torques for these mechanisms. This approach presents a significant opportunity to automate the design process for personalized transfemoral prosthetics.

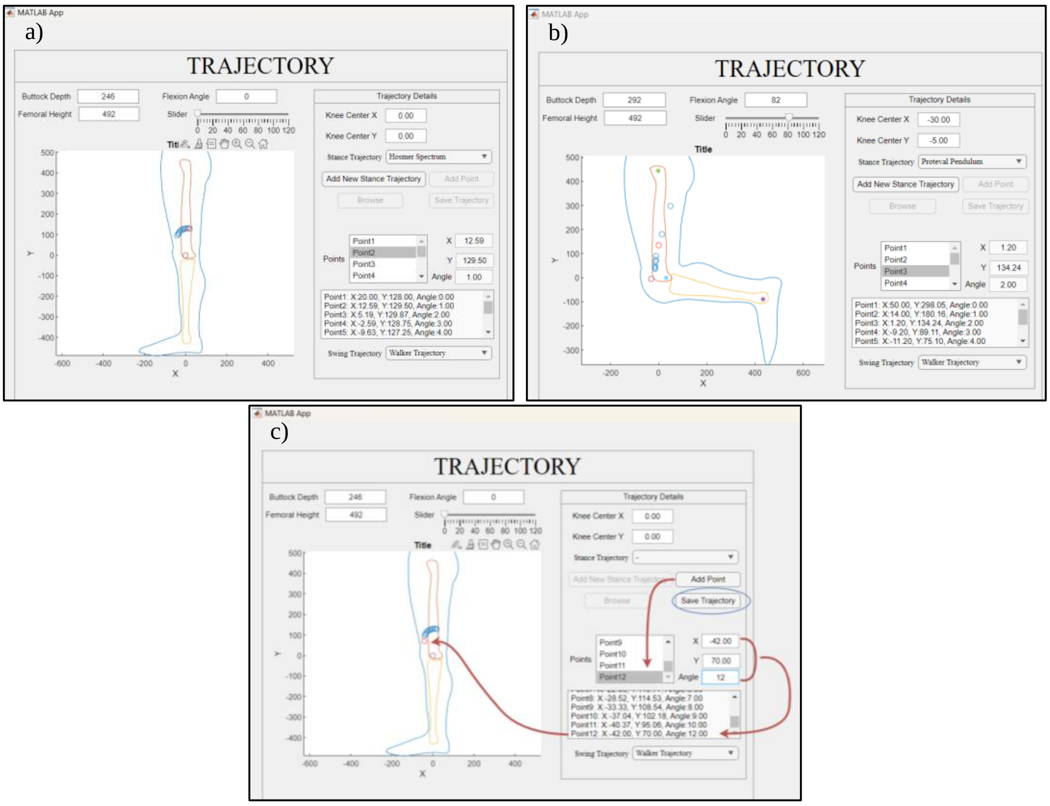

Figure 1: (a) ICR trajectory with zero flexion angle and default antropometric data. (b) ICR trajectory with non-zero flexion angle and increased buttock depth in visual. (c) Customized ICR trajectory with features.

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