# Realization of a Measuring Device for Recording the Relative Movement between Residual Limb and Prosthetic Socket

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# Academic Abstract

A functional model for a system to measure the relative motion between lower limb prosthetic socket and protective liner was previously developed. This master's thesis deals with its improvement and expansion into the proposed measurement device with a sensor array.

The functional model's microcontroller is replaced by one with superior specifications and the performance difference between the two evaluated. Maximum data transmission frequencies when running the original code are determined and the maximum data reception frequency of the original Matlab GUI is measured.

Subsequently, the microcontroller code and Matlab GUI are analyzed and optimized for speed. For the microcontroller, an alternative method for reading the sensor's registers is implemented, extraneous sections of code removed, and on-board processing reduced to the minimum. Similarly, real-time processing is minimized and extraneous functionalities removed in the Matlab GUI. The quantity of data transmitted to the PC is reduced and its format changed from strings to binary. As Matlab's serial input buffer begins to overflow at frequencies below the system's maximum capability, a terminal program is added as an interface between Matlab and the incoming data. After speed optimization, the system is expanded to accommodate up to eight sensors.

The system's performance is then evaluated on a bi-axial test rig. The calibration process and resultant factors are examined. Dependency upon surface texture, sensor-liner alignment and direction of motion with respect to the sensor are noted. Favorable calibration factors are used to evaluate the system's accuracy and precision over various paths. With few exceptions, both accuracy and precision are found to be within the required range. A systematic drift is also identified.

Finally, the system is prepared for use in a future pilot study. A custom 3D-printed box is made to house the microcontroller and wiring, with the space to accommodate additional components for wireless capability. The previously developed sensor housings are modified to accept new cables. The Matlab GUI is expanded to perform as a comprehensive measurement controlling tool.

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## General Audience Abstract

In lower limb prosthetics, the amount of relative motion between the prosthesis and residual limb is considered an indicator of the quality of fit. As existing methods for measuring this motion are generally difficult to use, a simpler system is desired. The task for this master's thesis is to develop an existing functional model into a measurement system with multiple sensors and validate its performance.
The first step is to upgrade the microcontroller responsible for reading the sensor data and transmitting it to the PC. The original codes for both the microcontroller and PC-side Graphical User Interface (GUI) are then examined and optimized for maximum speed. The system is expanded to accommodate multiple sensors and its performance evaluated using a test-rig. Finally, the completed system is prepared for use in a future study by creating the appropriate component housings, wiring, and software functionalities.

# Research Project

This research project was carried out at the Institute for Mechatronic Systems at Technische Universität Darmstadt. The work was supervised by Veronika Noll.

The research project was carried out according to the requirements for the Dual Degree Master Program between Technische Universität Darmstadt and Virginia Polytechnic Institute and State University. The published version of the master's thesis can be found via Universitäts- und Landesbibliothek Darmstadt:

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