Develeopment of Analysis Techniques for dynamic magnetic resonance imaging

– Master Thesis –

to be awarded

Master of Science in Medical Photonics

submitted by

Aayush Nepal

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Aayush Nepal
aayush.nepal@uni-jena.de
Student ID: 198683
Address:
Schützenggase 2
99423 Weimar

Supervisor

1st: Prof. Dr. rer. nat. med. habil. Jürgen Reichenbach
2nd: Dr. rer. nat. Martin Krämer

Friedrich-Schiller-Universität Jena
Medizinischen Fakultät
Institut für Diagnostische und Interventionelle Radiologie
Philosophenweg 3
07743 Jena

Abstract

Short summary of your thesis (max. 250 words) ...

Acknowledgements

If you want to thank anyone (optional) . . .

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FSU Jena Friedrich-Schiller-Universität Jena

1 Introduction

Some of your text. Maybe with an acronym, such as Friedrich-Schiller-Universität Jena (FSU Jena).

1.1 Background and Rationale

Outline the importance of dynamic knee MRI and its applications in biomechanics.

1.2 Research Objectives

State the goal of developing new analysis techniques for dynamic MRI data.

1.3 Thesis Structure

Explain why this research is a logical next step following the development of the MRI knee loading device.

2 Literature Review

Review existing methods for analyzing dynamic knee MRI data.

2.1 Theoretical Framework

Foundational Theories: Start with the theoretical underpinnings that relate to MRI imaging and biomechanics of the knee. Biomechanical Models: Discuss any relevant biomechanical models or theories that apply to knee movement and loading.

2.2 Review of Related Work

Current Techniques: Within this subsection, critically analyze existing literature on analysis techniques for dynamic knee MRI. This is where you provide a detailed account of what has been done in the field. Comparative Analysis: Compare and contrast different approaches to illustrate the diversity in the field and to position your work in the context of existing research.

2.3 Research Gap

Limitations: Highlight the limitations in current methodologies as a way to show where the gaps in the literature exist. Explain how these limitations could affect the understanding or the application of the biomechanical data from knee MRI. Relevance to Biomechanics: Connect the limitations and gaps directly to their relevance in biomechanics, outlining why addressing these gaps is crucial for the field. This sets the stage for your research to be viewed as a necessary step forward.

3 Methodology

some text

3.1 Data Collection Methods

3.1.1 The Device

A novel MRI-compatible device was integrated into the MRI scanner setup to facilitate guided knee motion in patients (Brisson et al. 2022). This device allowed for a range of motion of approximately 30 degrees, enabling subjects to perform knee flexion and extension cycles under both loaded and unloaded conditions. For loading, the device was equipped with compartments for weight plates (maybe picture here?) and sandbags, providing a physiological load of 10 to 12 kilograms.

Central to this device's functionality is an optical fiber position sensor actual citation needed?(MR3 Y10C10, Micronor, 155 Camarillo, CA, USA), which precisely which measures the ab solute angle from 0° to 360° with a resolution of 0.025°. This measurement capability is critical for synchronizing the knee's movement with MRI data reconstruction. To enhance signal acquisition and the clarity of imaging, two flexible coils (cite the coils here, perhaps also show a picture) were positioned at key anatomical locations: one at the distal femur and another at the proximal tibia, as specified in the MRI protocol. perhaps show a picture outside the scanner of the patient wearing it?

3.1.2 Procedure Details

MRI measurements were performed on four healthy volunteers (aged between 28 and 37 years, body mass between 55 and 90 kg) using a clinical 3 T Siemens Prisma fit scanner. Volunteers had no known musculoskeletal conditions and gave written informed consent in accordance with the guidelines set out by the institutional ethics committee. from device paper For all of these subjects, the left leg was used.

The thigh is secured on a wedge positioner, and the lower leg is attached to an ankle rest, just above the malleoli, using Velcro straps to minimize lateral movement. Once positioned at the scanner's isocenter, the volunteer then engages in a controlled exercise, following a metronome set at 60 beats per minute. This pace dictates a four-beat flexion to extension cycle, where the leg is flexed at the first beat and fully extended by the fourth. This exercise is performed for approximately 2 minutes throughout the duration of the scan, totaling between 100 to 120 repetitions. Initially conducted under a loaded condition with weights, the process is repeated without the added resistance to compare both states.

3.1.3 Sequence Parameters and Reconstruction

3.2 Data Analysis

All the analysis and data visualization were done using the python programming language (v3.11.5). To begin, the data in nifti (Neuroimaging Informatics Technology Initiative) format is loaded using nibabel (v5.1.0) library. It is then visualized using napari(v0.4.18), a multi-dimensional interactive image viewer in Python.

3.2.1 Segmentation

Step 1: Edge Detection Using the Canny Algorithm

The Canny filter (Canny 1986), as implemented in the scikit-image's feature library (v0.21.0), was employed to apply an edge filter to the images. Various parameters of the Canny algorithm were adjusted, including edge thresholds and Gaussian blur, to optimize edge detection. Subsequently, the scikit-image's morphology library was utilized to remove small elements from the binary image. The image was then skeletonized to a one-pixel width, retaining only long and consistent edges. The final selection of the desired edge was accomplished using scipy's label algorithm (v1.11.3).

3.3 Validity and Reliability

Validation Methods: Detail the steps taken to validate the segmentation techniques and the biomechanical parameters you derived. Reliability Measures: Describe any repeat analyses or cross-verifications done to ensure the consistency and reliability of your results.

4 Results

4.1 Segmentation

some text

4.2 Parameter Extraction

some text

5 Discussion

5.1 Technique Evaluation

Assess the effectiveness and accuracy of your segmentation techniques.

5.2 Biomechanical Insights

Discuss the biomechanical parameters obtained and their implications for understanding knee movement.

5.3 Comparison with Existing Methods

Compare your results with current analysis techniques.

6 Conclusion

6.1 Summary of Contributions

Recap the novel analysis techniques developed and their significance.

6.2 Limitations and Challenges

Discuss any limitations encountered and the challenges in the analysis process

6.3 Future Work

Suggest potential improvements and future directions for research

References

Brisson, Nicholas M. et al. (Nov. 2022). "A novel multipurpose device for guided knee motion and loading during dynamic magnetic resonance imaging". en. In: *Zeitschrift für Medizinische Physik* 32.4, pp. 500–513. ISSN: 09393889. DOI: 10.1016/j.zemedi.2021.12.002. URL: https://linkinghub.elsevier.com/retrieve/pii/S093938892100115X (visited on 02/12/2024).

Canny, John (Nov. 1986). "A Computational Approach to Edge Detection". In: *IEEE Transactions on Pattern Analysis and Machine Intelligence* PAMI-8.6, pp. 679–698. ISSN: 0162-8828. DOI: 10.1109/TPAMI.1986.4767851. URL: https://ieeexplore.ieee.org/document/4767851 (visited on 02/18/2024).

A Appendix

If needed for supplementary material, such as detailed description of data collection, tables, or figures.

Statutory Declaration:

I declare that I have developed and written the enclosed Master Thesis completely by myself, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. The Master Thesis was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.

Place, Date

Signature