A Machine Learning Approach for Automated Segmentation of Anatomical Structures from Plantar Pressure Images

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Summary

Plantar pressure has settled as an important tool in biomechanical and clinical research as well as practice for identifying misloading and deformities. Segmentation of the foot can help identify such abnormalities but relies on expert knowledge that may be influenced by subjective experience. Machine learning (ML) gives the promise of finding patterns in a non-subjective way and, when done properly, could potentially reduce the clinicians' time needed in the decision-making process. We propose a ML-workflow for predicting anatomical regions of the foot from multi-centric plantar-pressure data. This workflow shows promising results by predicting areas of interest with good accuracy.

Introduction

ML has been established as a powerful tool in biomechanical research for identifying detailed structures from movements or images [1]. Especially in image segmentation, there are recent advantages over expert-knowledge, since foot-segmentation up to this point is made upon expert ratings or rule- and proportion-based methods [2]. Moreover, ML could potentially handle data from multiple sources (e.g. multiple clinics). Therefore, this study aimed to evaluate whether an ML-approach is effective in automated segmentation of anatomical structures of the foot from plantar pressure images from multi-centric data sources.

Methods

758 plantar pressure samples of 460 subjects of legal age were collected from three measurement systems from static and dynamic measurements. The images were uniformly up-sampled to a consistent size (256 x 256 pixels), uniformly scaled and colorized as well as labeled (handedly segmented) from experts in the field and reviewed by other experts. The depicted areas were the heel, the metatarsal area 1, metatarsal area 1-5 and the hallux. A U-Net model was trained with a 70-10-20 train-validate-test split including data augmentation (rotating, zooming, shifting, flipping, shearing, filling) and grouped cross-validation to find areas of interest from the previously labeled foot areas. Further, a regression head was used in the U-net model to find the interdigital space of metatarsal head 2 and 3, which was used to draw a line between the mid heel and this space as a separation of inner and outer foot. The workflow of these models is shown in Figure 1. The fit of the predicted areas were evaluated with the intersection over union (IoU) and dice coefficient. The predicted points from the regression were evaluated with the Euclidean distance.

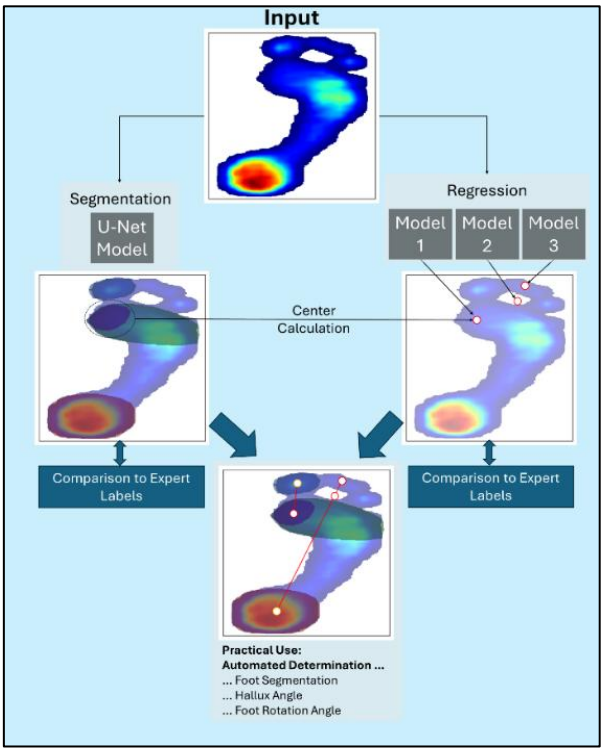

Figure 1: Workflow of the study

Results and Discussion

High overlap between ML and expert-based segmentation areas are indicated by an IoU ranged between 0.78 – 0.92 and dice score from 0.88 – 0.96. Hereby, the heel showed the best prediction results. Median Euclidean distance and median absolute deviation of the predicted to the labeled interdigital space was 10.06 ± 1.04 for the regression, noting the input size 256 x 256. These results indicate that ML methods are useful in the segmentation of anatomical structures of the foot from multi-centric data thus expanding previous work [3].

Conclusions

This study shows promising results in research in the field of plantar pressure, by automating the process of segmentation of the foot from plantar pressure data. Furthermore, it holds the promise of applicability to data from various resources.

References

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