Alignment of Plantar Pressure Image Sequences

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Plantar pressure images carry crucial information about plantar diseases and deformations and allow inferring about postural issues. It is important to simplify and maximize the information acquired in plantar pressure measurements in order to help the study of plantar pressure related pathologies. Aiming to achieve such need, the alignment, i.e. the registration, of plantar pressure images has been studied. The alignment of two images can be described as the process of transforming one image in order to correspondent areas or features are optimally overlapped with the ones in a second image.

In this work, sequences of images acquired during steps of individuals were aligned both in space and time. The spatial alignment is performed between peak pressure representative images of each sequence. Thus, a "moving" image is mapped into the "fixed" image by a rigid geometric transformation. The principal axes of both images are found and then the angle between them is calculated. The translation is determined by the differences between image centroids after rotation. An optimization algorithm is used in order to improve the estimated values. After the spatial alignment, the sampling frequency of the sequences is increased by interpolation of intermediate images in order to obtain more continuous data.

Considering the "expanded" sequences, a cost matrix is built containing the mean standard errors (representing the individual matching cost) between all possible image pairs from both sequences to align. Images with the same index from different sequences may not correspond in time because the same person has different pressure patterns between steps. Consequently, a matching algorithm based on dynamic programming is used to establish the matching of minimum global cost. A polynomial relationship between both sequences is established using polynomial degrees up to 10^{th} degree. The polynomial coefficients are found by the least squares technique.

The accuracy of the solution developed was accessed through the mean standard error (MSE) calculation between the aligned and the template sequences. Additionally, control deformations were applied in order to find the residual errors between the original and re-aligned sequences.

The spatio-temporal solution developed obtained high accuracy in the intra-subject spatio-temporal alignment when using high degree polynomials ($p<0.001$) up to 10th degree. Such finding is confirmed both by the mean MSE values and the residual errors. In addition, the temporal alignment algorithm presented fast computational speed. Another finding points to the fact that only a small increase in the sampling frequency influences the accuracy of the spatio-temporal alignment.

Keywords: plantar pressure; spatio-temporal alignment; cost matrix, matching, polynomials.

References

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