Intensity Based Elastic Registration Incorporating Anisotropic Landmark Errors and Rotational Information

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PURPOSE: Thin-plate splines (TPS) represent an effective tool for estimating the deformation that warps one set of landmarks to another based on the physical equivalent of thin metal sheets. In the original formulation, data used to estimate the deformation field are restricted to landmark locations only and thus does not allow to incorporate information about the rotation of the image around the landmark. It furthermore assumes that landmark positions are known exactly which is not the case in real world applications. These localization inaccuracies are propagated to the entire deformation field as each landmark has a global influence. We propose to use a TPS approximation method that incorporates anisotropic landmark errors and rotational information and integrate it into a hierarchical elastic registration framework (HERA). The improvement of the registration performance has been evaluated. METHODS: The proposed TPS approximation scheme integrates anisotropic landmark errors with rotational information of the landmarks. The anisotropic landmark errors are represented by their covariance matrices estimated directly from the image data as a minimal stochastic localization error, i.e. the Cramér-Rao bound. The rotational attribute of each landmark is characterized by an additional angular landmark, thus doubling the number of landmarks in the TPS model. This allows the TPS approximation to better cope up with local deformations. RESULTS: We integrated the proposed TPS approach into the HERA registration framework and applied it to register 161 image pairs from a digital mammogram database. Experiments showed that the mean squared error using the proposed TPS approximation was superior to pure TPS interpolation. On artificially deformed breast images HERA, with the proposed TPS approximation, performed significantly better than the state-of-the-art registration method presented by Rueckert. CONCLUSION: The TPS approximation approach proposed in this publication allows to incorporate anisotropic landmark errors as well as rotational information. The integration of the method into an intensity-based hierarchical non-rigid registration framework is straightforward and improved the registration quality significantly.
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