A new automatically generated metric for evaluating the spatial precision of deformable image registrations: the Dose Discordance metric

Uncertainties in deformable image registration have an implication on the accuracy of the deformed dose [1, 2]. These uncertainties are due to errors (inverse and transitivity errors) which can be attributed to lack of features in homogeneous regions and to misaligned edges in heterogeneous regions [3, 4]. There is currently a critical lack of understandable, automatically generated metrics useful for evaluating the spatial accuracy of deformable image registrations. Several metrics have been used to evaluate the performance of intra and inter patient image registration such as dice similarity index and mean distances. These metrics often rely on the availability of contoured structures which are predisposed to inter- and intra-observer variability. Needless to say, these metrics becomes less relevant for inter-patient registration due to wide range of variability in anatomical structures and the lack of ground truth.

We suggest new metric called distance discordance (DD). The procedure to compute this metric is illustrated in Fig 1. Two points A & B from Pt(J) and Pt(k), that are mapped to the same voxel C on Ref(i), will be located at A’ and B’ when mapped to Ref(p). The distance |A'B'| is called distance discordance. DDM = { |A'B'|, |A'B'| ... } 

![Fig 1. Simple diagram to illustrate the concept of DDM.](image)

Fig 1 shows the mean value of DDH for the reference software phantom [1] using the B-Spline image registration algorithm. The results in left panel are generated by Elastix while the results in right panel are for Plastimatch. The DDM metric is minimal throughout the solid box (top) since it will undergo translation. Maximum DDM values are observed at the edge of the phantom due to larger deformations.

The proposed distance discordance (DD) metric is a quantitative tool that can be used to evaluate the effect of inter-patient variability on the goodness of the registration in different parts of the patient anatomy across a patient cohort. In addition, this metric does not rely on ground truth or presence of contoured structures. The DDH is useful, for example, for evaluating a longitudinal series of CT scans registered to track the total accumulated dose distribution during radiotherapy.

![Fig 2. The mean value of DDH generated by Elastix (Left) and Plastimatch (Right)](image)

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