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EX/P3-33: Modeling Fusion Data in Probabilistic Metric Spaces for the Identification of Confinement Regimes and Scaling Laws

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Any measurement is in essence a sample from a latent probability distribution. Hence, measurement uncertainty is an intrinsic property, rather than a side-effect, of the measurement process, and it should be taken advantage of. In this contribution we show that an inherent probabilistic description of fusion confinement data drastically improves the capability to discriminate between confinement regimes and considerably reduces the prediction error for scaling laws for the energy confinement time. We model measurements of physical variables from the International Global H-Mode Confinement Database by independent Gaussian probability density functions (PDFs) using information on the respective error bars. In the framework of information geometry a family of PDFs forms a Riemannian manifold with the Fisher information serving as the metric tensor. We map the confinement data on a probabilistic Gaussian product manifold and we use the geodesic distance (GD) as a natural similarity measure between the PDFs. Via multidimensional scaling (MDS) we next carry out a projection of the confinement data into a lower-dimensional Euclidean space. The projection respects the distance geometry on the original manifold, hence allowing a faithful visualization of the confinement data. Cluster structure can be observed in the data corresponding to confinement regimes. This is confirmed in a k-nearest neighbor classification task, yielding an excellent discrimination capability between confinement regimes. In comparison, the Euclidean distance, which neglects the inherent probabilistic structure of the data, performs significantly worse with respect to visualization and classification.
Our observation that information on the measurement uncertainties is most valuable for the classification task, is the starting point for a regression analysis using data projected via MDS into a Euclidean space. We show that, compared to the Euclidean distance, using the GD in the original space leads to significantly reduced discrepancies between the predicted and experimental energy confinement time. This inherent probabilistic derivation of scaling laws will be further explored in future work.

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