Comparison of Multivariate Regression Methods Used for Predictive Cardiac Motion Modelling and Correction
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Introduction

In cardiovascular magnetic resonance (CMR), the management of acyclic motion due to respiration is important to the assessment of cardiovascular anatomy and function with higher image resolution. While the effects of cardiac motion may be dealt with by acquiring data at mid-diastole when the heart is relatively stationary, respiratory motion is more difficult to control. Although the use of breath-holding effectively freezes respiration, the need to limit the duration of data acquisition to that of a comfortable breath-holding period imposes significant limitations on the image quality. The performance of imaging under normal physiological conditions of patients requires the monitoring of respiratory pattern and its induced cardiac deformation. Understanding the intrinsic relationships between 3D cardiac deformation due to respiration and multiple 1D real-time measurable surface intensity traces is fundamental for predictive cardiac motion modelling and correction. In this work, several multivariate regression methods employed for extracting the intrinsic relationships are compared.

Method

The goal of regression analysis is to establish a predictive model between response variables Y and input variables (predictors) X. When X is full rank, to predict Y from X can be achieved by using ordinary multilinear regression (MLR). In practice, X is likely to be singular due to multicollinearity of predictors or the number of observations is significantly less than the observed variables as in this study. Then the regression approach is no longer feasible. The possible solution is to use principle component analysis (PCA) to reduce original variables to some smaller number of factors first. The problem with PCA is that some principle components are not relevant for prediction, but only relevant for discribing X. So a good prediction is to find factors using information from both X and Y.

The predicted deformation field was compared to the reference deformation vectors derived from the free-form registration method to identify residual errors in these predictive methods. The prediction errors from different regression analysis as the number of traces used increases are shown in figure 4. Here we choose Gaussian kernels for kernel-based methods.

Multivariate linear regression methods and kernel-based techniques for predictive cardiac motion modelling are performed. Compared with the ordinary MLR, multivariate regression methods that eliminate the multicollinearity of predictors can reduce the prediction errors greatly. CCA shows better results than other linear methods because it is focused on extracting optimally correlated scores, while PCR and PLSR are intent to use scores to summarize variability in either of the two scatters. Although kernel-based algorithms explore the non-linear relationships between predictors and responses, good results rely on the proper choice of kernel function and kernel parameters which is non-trivial for practical applications. Further experiments using more data sets and different kernel functions will be employed to provide a more valuable comparison.

Results and Discussion

In partial least squares regression (PLSR), we seek the direction in the space of X, which yields the biggest covariance between X and Y.

Canonical correlation analysis (CCA) aims to simultaneously seek two sets of basis vectors in the space of X and Y to ensure the correlations between the projections of the variables onto these basis vectors are mutually maximized. All these linear regression analysis can be extended to kernel-based methods to employ the nonlinear relationships between predictors and responses. Kernel methods first map the input space X into a high dimension space by non-linear function \( \phi(\cdot) \) and then perform linear regression in this space. A kernel function \( \phi(\cdot) \) which satisfies the Mercer’s condition. If algorithms only depend on the kernel function, then we never have to know or compute the actual mapping function \( \phi(\cdot) \).

Fig.3 The implementation of PLSR prediction

Reference