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CORRELATION ANALYSIS BETWEEN THE VIBROACOUSTIC BEHAVIOR OF STEERING GEAR AND BALL NUT ASSEMBLIES IN THE AUTOMOTIVE INDUSTRY

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Abstract: The development and incorporation of novel technologies in the automotive industry such as autonomous driving or steer-by-wire systems have accelerated technological change, increasing the system complexity significantly and posing new engineering challenges. The simultaneous increase in quality standards requires strict specifications to be propagated across the supply chain, from the carmaker companies down to the automotive component suppliers. This challenge is exacerbated in domains where the quality of a product can be subjective, such as in automotive acoustics. In particular, the design and production of steering systems thus ceases to be a matter of simple functionality, with considerable efforts dedicated to the understanding of the vibroacoustic interaction of steering components. In the current work, we use optimization techniques to deal with a situation encountered in the daily operations of one of the world's leading steering system suppliers, ThyssenKrupp Presta AG, where quality requirements imposed on the vibroacoustic quality of the steering gear need to be passed down to its subcomponents. Furthermore, only one subcomponent, the ball nut assembly (BNA), is subject to an own vibroacoustical quality test, equivalent to the one of the steering gear. In our work we quantify the BNA influence on the assembled steering gear by finding optimal, low dimensional representations of their respective vibroacoustic signals in the equivalent quality test. This is achieved by iteratively maximizing the correlation of projections of BNA and steering gear order spectra under orthogonality constraints. The new, maximally correlated representations for their characteristic order spectra allow an analysis of the BNA's contribution to the steering gear's vibroacoustic behaviour. A first estimate on the attainable correlation is achieved by linear Canonical Correlation Analysis (CCA). The estimate is updated using non-linear methods, such as Kernel CCA (KCCA), which uses the kernel trick to solve the non-linear KCCA optimization problem. Due to their high suitability as non-linear function approximators, deep neural networks can also be used to find new, maximally correlated representations which are not restricted to reproducing kernel Hilbert spaces with the corresponding kernels. We explore the performance of different neural network architectures, optimize their hyperparameter via the Tree-structured Parzen Estimator approach and establish the superiority of the Deep CCA technique in terms of attainable correlation. Furthermore, the weight visualization enables the identification of key influence areas for which BNA quality thresholds can be set, leading to a joint optimization of the monetary costs originating from misclassified parts in both quality tests.