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Combining Warping Functions and Functional Principal Component Analysis to enhance Profile Monitoring of Signal data

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Abstract

Profile monitoring of signal data is gaining increasing importance for in-line monitoring of manufacturing processes, because of the increasing availability of reliable and miniaturized sensors and computational power at low cost. Signal data can be interpreted as spatially or time ordered data, called “profiles”, which can be treated as random realizations of functional objects characterized by amplitude and phase variability. In monitoring such a kind of data, curve registration plays a key role, as it provides a separation of the two types of variability, by reducing, at the same time, any undesired inflation of the natural phase variability. In the literature, control charts are usually applied on registered profiles only, without any explicit inclusion of the registration coefficients into the monitoring process, even though this may cause a significant information loss. Furthermore, under some circumstances, basic segmentation and re-sampling techniques are used to reduce the misalignment effects, but they are not sufficient to guarantee a proper registration of monitored data. We discuss the main issues related with functional curve registration in profile monitoring, and we highlight the need for a novel method that allows one to properly characterize both the variability sources. A key idea in our recent research activity is to jointly monitor the stability over time of the registered profiles and the registration coefficients. This allows improving the capability of detecting unnatural pattern modifications, with respect to the mainstream approaches. The benefits of a proper management of functional data registration are demonstrated by means of both simulated and real industrial data.