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Estimation of geometric characteristics of three-component oscillations for system monitoring

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The estimation of the geometric characteristics of the three-dimensional elliptical trajectory followed by a three-component sinusoidal oscillation with the objective of system monitoring is addressed in this paper. Multicomponent signals are frequently encountered in system monitoring problems. Most physical quantities are naturally composed of three components, for example three-phase electrical quantities for electrical systems and three dimensional displacements for mechanical systems. In order to obtain efficient fault indicators, such three-component signals can be analyzed with the usual marginal and/or joint analysis tools in the time domain (correlation functions and/or matrix) as well as in the frequency domain (spectra and/or spectral matrix) [1].

This paper focuses on information also contained in such signals, but which is different in nature: their geometric properties. The geometric nature of the trajectory followed by such data in three-dimensional Euclidean space is taken into account by the estimation of its main geometric characteristics, which are intimately linked to the state of the monitored system. This approach has already been proposed for two-component signals [2] by using complex-valued signal processing tools [3]. In this paper, the method is generalized to three-component signals by using basic differential geometry concepts such as the Frenet-Serret frame and related geometric quantities [4].

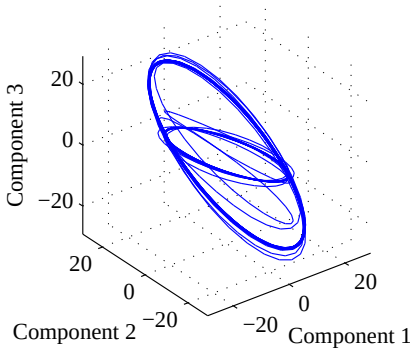

Figure 1: Elliptical trajectory

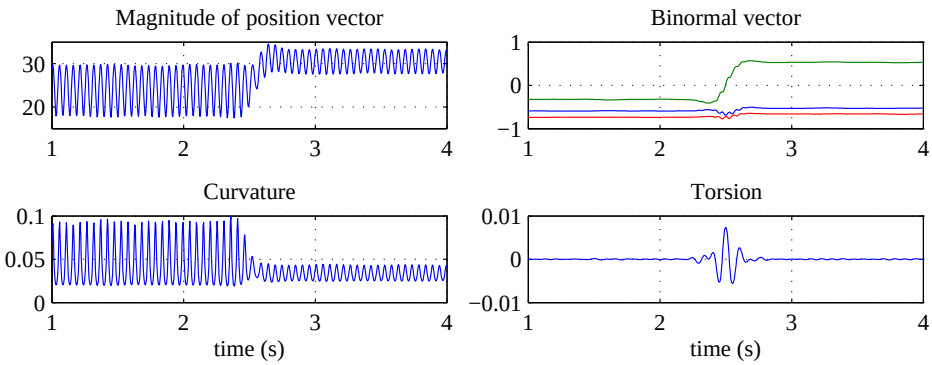

Figure 2: Trajectory characteristics

Three sinusoids of the same frequency follow a trajectory in the shape of an ellipse when plotted in a three-dimensional Euclidean frame, as shown in Fig. 1. The trajectory characteristics considered in the method described in this paper are the position and binormal vectors, curvature and torsion, which can be seen in Fig. 2. Straightforward expressions of these quantities are given which allow the geometric characteristics of the ellipse to be recovered from three-component data. Definition and interpretation of the expressions are also included, followed by a step-by-step explanation of the approach used to estimate these quantities. The method, which has been applied to sinusoids of low frequency [5], is extended to oscillations of arbitrary frequency in this paper. The performance and limitations of the method with respect to various parameters such as noise, frequency of the sinusoids and ellipticity (flatness of an ellipse) of the trajectory are discussed. The usefulness of this method as an informative means of describing three-component sinusoidal signals is illustrated with an application to the vibrations of an electric motor.

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