Model-based Surface Defect Detection and Condition Monitoring in Wire Ropes

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Wire ropes are exposed to huge external powers every day. Unfortunately, this can lead to structural anomalies or even defects in the rope formation. A defective rope bears a high risk for human life. This motivates the strict rules summarized in the European norm [1], which instruct a regular inspection of wire ropes.

Recent approaches to defect detection in surfaces or fabrics mostly are limited to texture analysis [2]. Usually not enough defective samples are available in advance. Therefore texture-based approaches are often combined with one-class classification, also called novelty detection [3]. In [4] anomaly detection in wire rope data was performed using linear prediction as feature extraction combined with a multi-channel one-class classification strategy. However, all these approaches are not able to detect structural changes in the rope structure. Thus, we propose a new approach for model-based detection of surface defects and structural deviations from the normal rope geometry.

A wire rope is composed of strands which itself are composed out of single wires. Every wire can be described by a helix and a mathematical description of the rope geometry can be given by the space curve of the j-th wire in the i-th strand:

$$s_{W_{i,j}}(t, r_W, L_W, n_W) = r_W \cdot \begin{pmatrix} \cos(t\frac{2\pi}{L_W} + j\frac{2\pi}{n_W}) \\ \sin(t\frac{2\pi}{L_W} + j\frac{2\pi}{n_W}) \\ 0 \end{pmatrix} + s_{S_i}(t, r_S, L_S, n_S) \quad (1)$$

with

$$s_{S_i}(t, r_S, L_S, n_S) = r_S \cdot \begin{pmatrix} \cos(t\frac{2\pi}{L_S} + i\frac{2\pi}{n_S}) \\ \sin(t\frac{2\pi}{L_S} + i\frac{2\pi}{n_S}) \\ t + c \end{pmatrix} \quad (2)$$

being the space curve for the i-th strand. r_S is the radius of the strand space curve, r_W the radius of the wire space curve, L_S gives the lay length of the strands, L_W defines the lay length of the single wires and n_S and n_W are the number of strands and (outer) wires in the rope. c defines a time shift resulting in the corresponding part of the rope.

Given this model a comparison of the rope raw data with the ideal rope model becomes possible. By means of an analysis-by-synthesis loop a 2-d synthesized rope image is compared to the raw data in order to estimate the parameters of the rope model given real rope image data. Figure 1 summarizes the projection pipeline used for synthesis. The 3-d model is first converted to a lateral cut for

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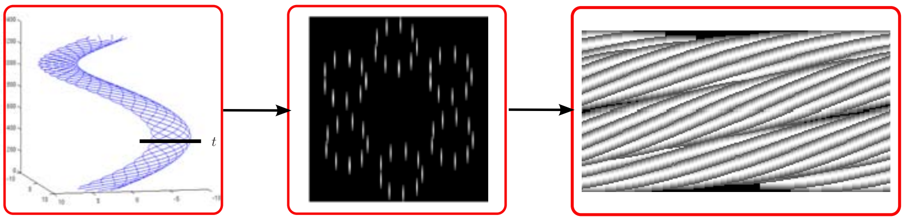

Fig. 1. Pipeline which projects 3-d wire centerline model to 2-d image plane.

every time step t. Then a weighting of the centerline positions is done to take care of the wire diameter. A line projection of the lateral cut then results in a 2-d projection of the rope which is comparable to the real data. Model parameter estimation is done by registration of the synthesized image with the rope image data. The estimated, optimal parameters can be controlled for the whole rope data sequence and major deviations from normality can be reported. To detect surface defects in the rope the ideally fitted 2-d model projection is taken as forecast and is compared to the real signal. As the model contains no information about the grayvalue distribution, it has to be estimated from the data in a calibration step. Another possibility is to extend the parameter optimization problem by further parameters of a graylevel transformation. These parameters then have to be optimized together with the parameters of the rope model. A comparison between raw data and model synthesis based on an adequate distance measure finally results in the localization of possible surface anomalies.

By the described method a combined analysis of the rope structure and detection of surface defects becomes possible. This allows to control the condition of the rope more precisely than it can be done up to now.

References

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