Railway switch maneuver segmentation for fault detection and classification

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1 Introduction

A railway turnout system is a key component of the railway infrastructure designed to facilitate the process of guiding the trains. Such a system includes multiple components (such as point machines, switches, and frogs) working together to enable remote rail switching and efficient operation of railway turnouts [1]. The state assessment and the monitoring of the system health of railway turnout systems are nowadays increasingly automated and accurate with the development of new technologies and availability of data [2].

Through an illustrative use case conducted on an industrial dataset, this work focuses on the segmentation of the signal traces collected by sensors within a railway turnout system. The goal of the studied problem falls within the Fault Detection and Classification (FDC) task, with an ultimate aim to monitor the health state of a railway turnout system.

The dataset has been provided by a rail technology company, that describes the mechanical movements of various components related to the switching process. These movements are expressed by the power consumption signal over time, through different phases of operation. The dataset under study contains 97 railway switch maneuver traces, each with its own characteristics. The number of maneuvers per switch varies between 79 and 27,424.

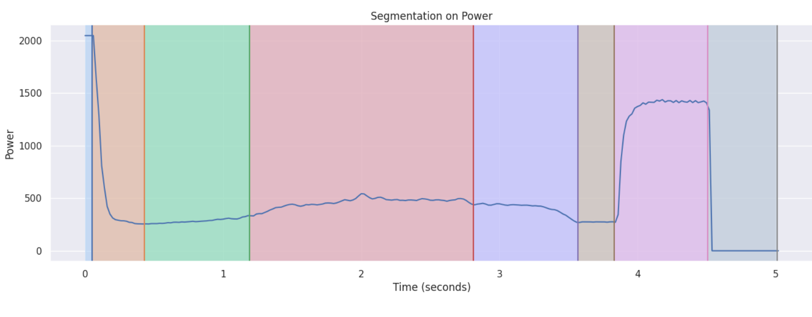

FIG. 1 – An example of a segmentation of a power signal trace

2 Problem description

The considered segmentation problem relies on the identification of distinct phases within a maneuver, including :

— Call phase,
— Mechanism shift,
— Unlocking,
— Needle travel,
— Locking,
— Motor cessation.

These phases must be discerned in the power signal associated with the maneuver, as illustrated in Figure 1. One of the main challenges of the studied problem is to find the unlocking and locking phases, that share similar features, without having any information about the duration of these phases. According to the expert guidelines, the aforementioned main phases are characterized by changes in the trend values of the power signal traces.

3 Solution approach

It is worthwhile to mention that signal traces do not necessarily have the same pattern, each trace having its specific characteristics. No stationary rule-based approach can be derived. To find the best segmentation (i.e., the segmentation that minimizes the variability inside a segment), we applied the change point detection method, a non-supervised approach, given that the signal data can be seen as time series [3] and no labels are provided. The following settings have been considered :

— *Metric :* Several metrics have been applied, including least absolute deviation, least squared deviation, Mahalanobis-type metric. We found that the function, measuring the error when approximation the signals via linear splines, aligns better with the studied problem. This is consistent with the fact that the trend in segments within the signal traces represents the main characteristic feature of the studied traces.
— *Approximation :* To capture the changes in signal traces, a piece-wise linear regression has been applied.
— *Search procedure* is based on dynamic programming [3].

4 Conclusion and perspectives

In this study, we focus on segmenting maneuver power signal traces within the framework of an FDC task. The obtained results conducted on a real-life dataset are industrially relevant. Future work will be dedicated to exploiting them to assess and monitor the health state of a railway turnout system to support remote condition-based maintenance.

Références

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