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SIGNAL SYNTHESIS BY MEANS OF EVOLUTIONARY ALGORITHMS

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Abstract. In this paper we investigate a procedure for generating a signal with genetic algorithms. This signal can be related to driving mission or system environmental information. Signals are obtained from elementary patterns characterized by different degrees of freedom. These patterns are repeated and combined in order to reach specific signal shapes. The whole signal parameterization has to be determined by solving a difficult inverse problem of high dimensionality and strong multimodality. This can be carried out using evolutionary algorithms with the aim of finding all pattern configurations in the signal. The different signal synthesis schemes are evaluated, tested and applied to the generation of particular driving profiles for railway locomotives.

Keywords: Signal synthesis, niching genetic algorithms, electrical vehicles, driving mission, inverse problems

INTRODUCTION

The design of complex electrical devices requires taking into account at a system level couplings between architecture, sizing, energy management strategy and environment [1]. For typical systems such as electrical vehicles (EVs), the system environment is associated with specific power driving profiles that have to be provided by all energy sources. These profiles contain a large number of features related to the system design, as for efficiency and lifetime which can be represented by specific indicators (e.g. maximal and average mission powers, statistical indices associated with the mission power distribution). Integrating these indicators in the design process is not straightforward because of the important number and heterogeneity of driving missions than can be imposed to the vehicle. This can be done by identifying the most representative mission from a clustering analysis with respect to the different indicators in compliance with all driving missions [2]. This can also be performed by finding a “fictitious” mission profile that fulfills specific values of these indicators (typically critical or average values). In this case, this results in solving an inverse problem which consists in determining a particular signal shape (i.e. the fictitious power profile) in accordance with a given number of constraints. Thus, a signal synthesis approach based on evolutionary algorithms (EAs) has been developed for solving the corresponding inverse problem.

SIGNAL SYNTHESIS BASED ON EVOLUTIONARY ALGORITHMS

Signal models

In our signal synthesis approach, signals are represented by combining elementary pattern characterized by different degrees of freedom (typically magnitude or frequency variables). Three kinds of pattern are considered (see Fig. 1).

- The first signal model (Fig. 1a) is obtained by combining and aggregating elementary segments defined with two parameters (the magnitude and the temporal variations).
- The second model (Fig. 1b) is based on a Fourier series expansion [3]. It consists in adding elementary sines defined in phase ϕ_n and amplitude A_n with a frequency f_n multiple of the inverse of the signal duration $\Delta\tau_s$.
- The third model (Fig. 1c) uses the same approach but is obtained by adding cardinal sine functions parameterized in terms of location (t_n), amplitude A_n and frequency f_n .

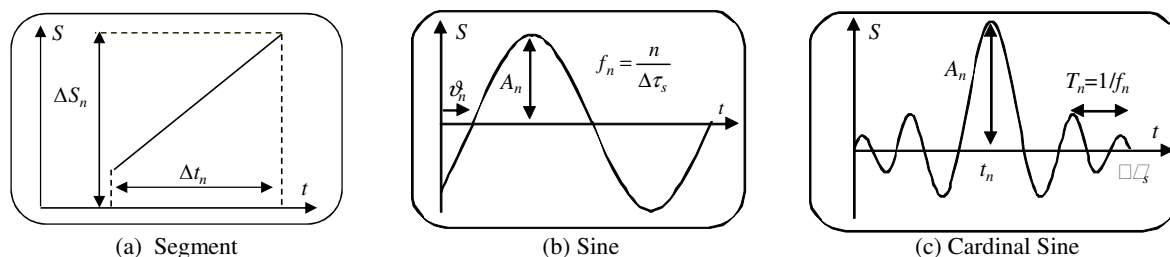


Figure 1. Elementary patterns for the signal representation

Signal synthesis schemes

The investigated signal synthesis approach leads to an inverse problem which consists in finding the characteristics of all elementary patterns in order to fulfill some specific constraints on the whole generated signal. The problem dimensionality depends on the number and the type of elementary patterns. It equals $2n$ for the sine and segment models and $3n$ for the cardinal sine model (n denoting the number of pattern). Finding a complex signal with high variability requires the increase of n and thus the difficulty of the inverse problem. Moreover due to the particular oscillating shape of the proposed patterns (especially sine and cardinal sine patterns), the resulting inverse problems are strongly multimodal. This justifies the use of EAs for solving this kind of problems.

APPLICATION TO THE SYNTHESIS OF RAILWAY DRIVING PROFILES

Generation of a reference railway driving profile

In order to validate the proposed signal synthesis schemes, we investigate as case study, the generation of a typical railway driving mission for BB 63000 locomotive (see Fig. 2). Note that this profile can be viewed as a complex signal of large duration (≈ 14 min) and high variability. The inverse problem is solved by minimizing the mean error between the reference signal (i.e. the reference driving mission) and the generated signal. Three different EAs are applied in association with each signal model: a standard anisotropic Evolution Strategy (ES) [4], the restricted tournament selection (RTS) and the clearing (CL) method [5]. The number of patterns for the segment and the sine signal models is $n = 75$ and that of the cardinal sine model is $n = 50$, which leads to the same number of unknowns (i.e. 150). Five independent runs are performed for each algorithm. Best runs are indicated in Fig. 3. It is shown from this figure that CL outperforms ES and RTS in all cases. However, the mean error after 100 000 generations is still higher than 10 kW. These results will be analyzed in more details in the final paper.

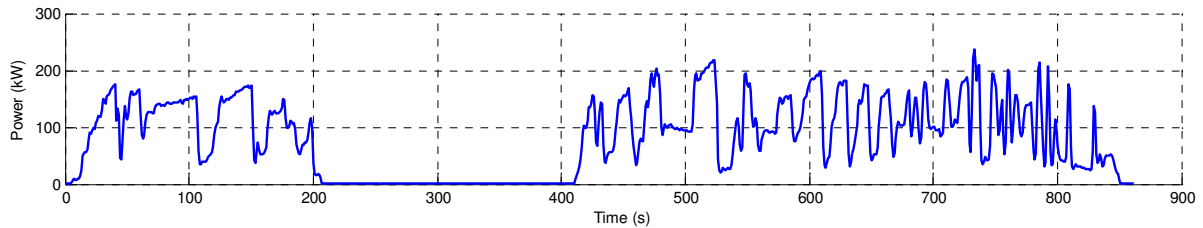


Figure 2. Typical BB 63 000 railway driving mission profile

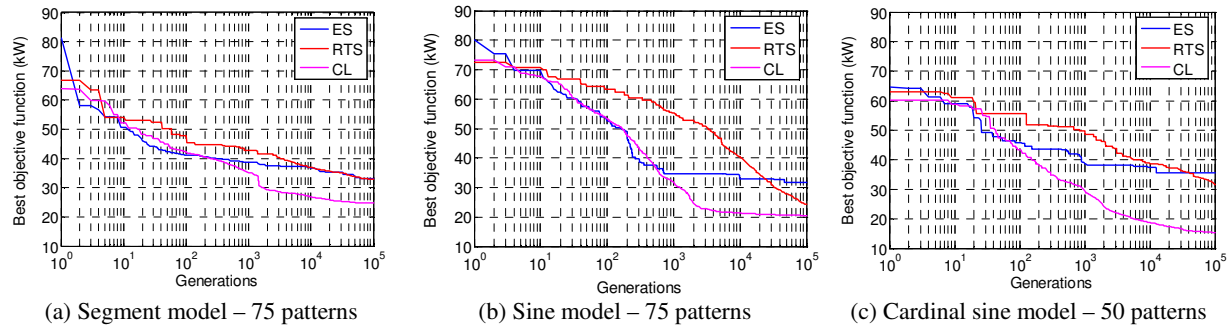


Figure 3. Reference mission “inversion” with each signal model – best run plots

Generation of fictitious railway driving profiles with specific characteristics

The generation of “fictitious” railway driving profiles for design purpose has also been studied. It consists in finding power signal shapes that fulfill several constraints (maximal and average powers, maximal energy, statistical and cyclability indices). Results are not given in this digest as a reason of space limitation but will be discussed in details in the final paper.

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