Towards the State-of-the-Art of the Use of Genetic Algorithms to Solve Energy-Conscious Train Control Problem ⋆

Mohand Mezmaz, Daniel Tuyttens, Hongying Fei and Jad Jalwan

MathRO Department, University of Mons, Belgium
{Mohand.Mezmaz,Daniel.Tuyttens,Hongying.Fei,Jad.Jalwan}@umons.ac.be

Introduction

Compared to other means of transport, rail remains the less "energivorous" one. However, the cost of energy used for traction remains high. Indeed, the cost of energy, for the traction of passenger trains, is estimated at ∼100 million euros during 2006 in Belgium, and at ∼850 million euros during 2008 in France.

In our research, we are interested in developing a state-of-the-art about the optimization methods used to reduce the energy consumption of trains. Two categories of methods are used to minimize the consumed energy: Mono-train and multi-train methods. In multi-train methods, a train cooperates with the other trains to reduce energy consumption. This cooperation allows to avoid conflicts and synchronize traction and braking operations.

This paper focuses on mono-train methods, and gives a brief overview on genetic algorithms (GAs) part of our state-of-the-art. After this introduction, Section 1 describes the energy-conscious train control problem. Section 2 presents the GA part of our state-of-the-art. The paper ends with some conclusions.

1 Energy-conscious train control problem

Energy-conscious train control problem (ECTCP) consists in driving a train from one station to another in an efficient way. The objective is to minimize the energy consumption. The journey duration, the train and the railway are the three main elements that describe the problem. The journey duration is fixed and known. A train is defined mainly by its weight, length, traction and braking efficiency curves, and its maximum speed, acceleration, deceleration and jerk. The railway is characterized by its geometric structure and resistance environment. More details can be found in [5].

2 Resolution with genetic algorithms

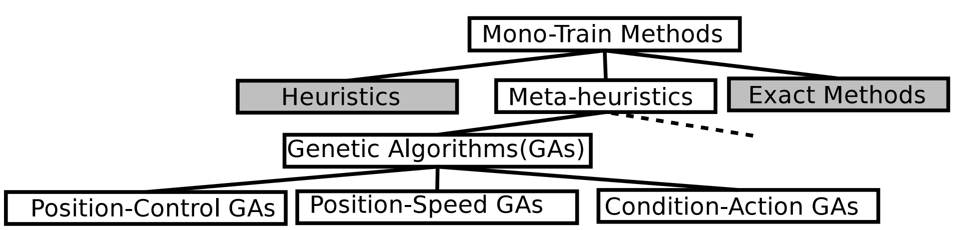

Fig. 1. Différents AGs used to solve ECTCP

As shown in Fig. 1, mono-train methods may be either exact methods, heuristics or meta-heuristics. The exact methods are (1) inapplicable when the train model is realistic, (2) inadequate

⋆ This work is supported by the Walloon Region through the GreenRail project.

when the data of the problem exceeds a certain size, and (3) unsuitable for real-time optimization on board a train. Therefore, GAs are good alternatives to exact methods. GA is the main method used in the literature to solve ECTCP. In this paper, only the GA part of our state-of-the-art is presented. We have identified three categories of GAs in the literature. These categories differ according to the semantic of chromosomes.

- **Position-control GAs:** [8], for example, belongs to this category. A gene, in the GAs of this class, is composed of a position and a control. A gene POS-CNTRL means the driver applies the control CNTRL starting from the position POS. A control can be, for instance, a full traction, a coasting or a full braking. The coasting is when a driver stops the traction and lets the train run using its kinetic energy. In a train model, a control can be a continuous (i.e. values in an interval) or a discrete (i.e. values in a finite set) variable. The position can be expressed by a location on the rail or by time.
- **Position-speed GAs:** [3, 4, 9], for instance, belong to this category. In this class of GAs, a gene is composed of a position and a speed. A gene POS-SPD means the train runs with the speed SPD at the position POS. All position-speed genes (i.e. chromosome) constitute a speed curve. It is not necessary to have the speed at every moment. Indeed, all we need is to have the points where the speed curve changes its direction, in other words, points where the derivative of the speed curve varies. The driver drives the train trying to follow this curve and applying the less "energivorous" controls.
- **Condition-action GAs:** [1, 6, 7], for example, are part of this category. A gene COND-ACT means if the condition COND is true then the driver executes the action ACT. In this category, each gene is a an if-then driving rule. All of these genes constitute a rule base.

Conclusions

The paper presents the GA part of our state-of-the-art. We identifie three classes of GAs used to solve the energy-conscious train control problem. These classes are position-control, position-speed and condition-action GAs. Besides the GAs, we note that certain avenues of research are not sufficiently exploited, like the other meta-heuristics, hybrid methods and parallel methods. Therefore, we intend to exploit these methods in our future work.

References

1. P. Bonissone, Pratap, S. Khedkar and Yuto Chen, Genetic Algorithms for Automated Tuning of Fuzzy Controllers: A Transportation Application, Proceedings of the 5th IEEE International Conference on Fuzzy Systems, Pages 674-680, 1996.
2. C.S. Chang and S.S. Sim, Optimising train movements through coast control using genetic algorithms, IEE proc. Electr. Power. Vol. 144, No. 1, Pages 65-73, 1997.
3. R. Chevrier, An Evolutionary Multi-objective Approach for Speed Tuning Optimization with Energy Saving in Railway Management, Evaluation des Systèmes de Transports Guid's et leur Sécurité - ESTAS - INRETS, Mars, 2010.
4. S.H. Han, Y.S. Byen, J.H. Baek T.K. An, and S.G. Lee and H.J. Park, An optimal automatic train operation (ATO) control using genetic algorithms (GA), TENCON 99. Proceedings of the IEEE Region 10 Conference, vol. 1, 1999.
5. P. Howlett, The optimal control of a train. Annals of Operations Research. 98, Pages 65–87, 2000.
6. H.S. Hwang, Control strategy for optimal compromise between trip time andenergy consumption in a high-speed railway, IEEE Transactions on Systems, Man and Cybernetics, Part A, Vol. 28, Number 6, Pages 791–802, 1998.
7. M. Khanbaghi and R.P. Malhamé, Reducing Travel Energy Costs for a Subway Train Via Fuzzy Logic Controls. Proceedings of the 1994 IEEE International Symposium on Intelligent Control, Pages 99-104. 1994.
8. L. Wei, L. Qunzhan and T. Bing, Energy Saving Train Control for Urban Railway Train with Multi-population Genetic Algorithm, International Forum on Information Technology and Applications, IFITA '09, Volume 3, Pages58-62, 2009.
9. Yinping FU, Ziyou GAO, Keping LI, Optimization Method of Energy Saving Train Operation for Railway Network, Journal of Transportation Systems Engineering and Information Technology, Volume 9, Issue 4, Pages 90-96, 2009.