Preliminary study on the optimization of settings of an automatic smoke control system for tunnel fires by system identification and genetic algorithm

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Abstract

In order to prevent the smoke back-layering in tunnel fires, the concept of automatic smoke control, based on longitudinal ventilation with variable ventilation velocity as obtained from a PID algorithm, has been proposed and the potential of good performance has been demonstrated in a numerical study [1]. Temperature measurements beneath the ceiling are used as input parameter for the controller. However, the PID controller parameters (the proportional, integral and differential coefficient) have been determined by trial-and-error in the previous work. In the present study, an approach of combining system identification (SI) and genetic algorithm (GA) is investigated for optimizing the PID controlled ventilation system. Figure 1 provides an overview.

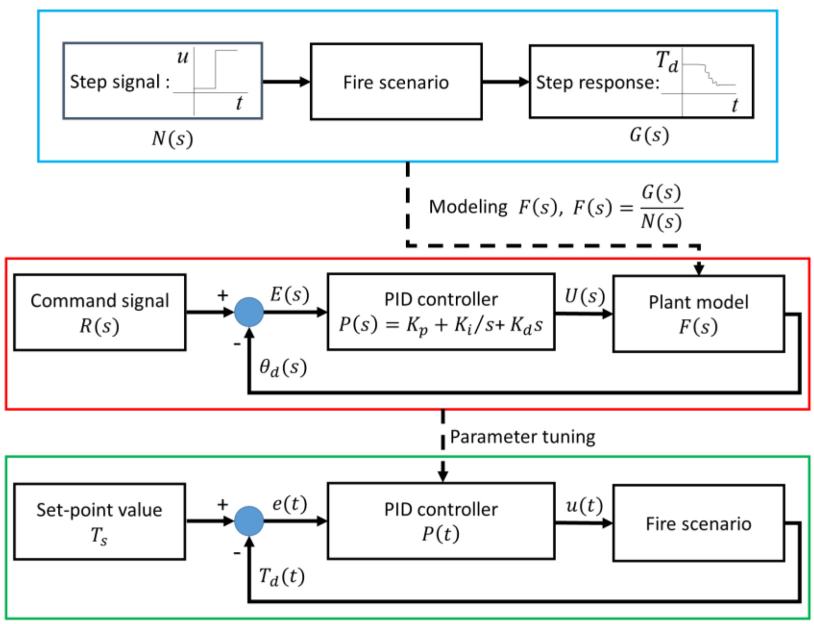
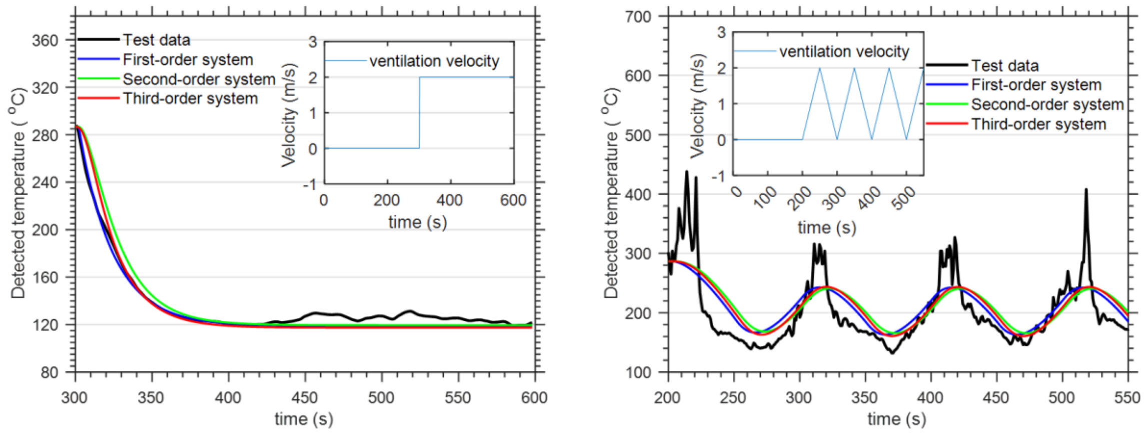


Figure 1 Overview of the process of the parameter optimization

First, the response curve of the detected temperature to the step signal of the ventilation velocity is tested. Second, the interaction of the detected temperature and ventilation velocity is modelled, so the so-called plant model is established. Figure 2 shows comparison between the plant model and the test data. Next, the complete feedback system with the plant model and the PID controller is mathematically described. Finally, the GA, based on the principles of natural selection, is used to find the (near-)optimum solution of the PID ventilation system. The optimization objects in this work are reduced overshoots of the smoke front and shorter stabilization time: the smoke is controlled not to exceed the set point much, and the smoke is controlled faster at the set point. The preliminary results show that the optimized system has better performance, i.e., faster stabilization time and shorter back-layering length (before it is fully controlled), as shown in Figure 3. In the future, the trade-off between shorter stabilization time and reduced overshoot needs to be further studied.



(a) (b)

Figure 2 The plant model is obtained by system identification:(a) identification of the plant model; and (b) the validation of the plat model. The test data is the response curve with the input signal of ventilation velocity, which is calculated in FDS. Three systems of different orders (mathematically expressed) are used to approximate plant models.

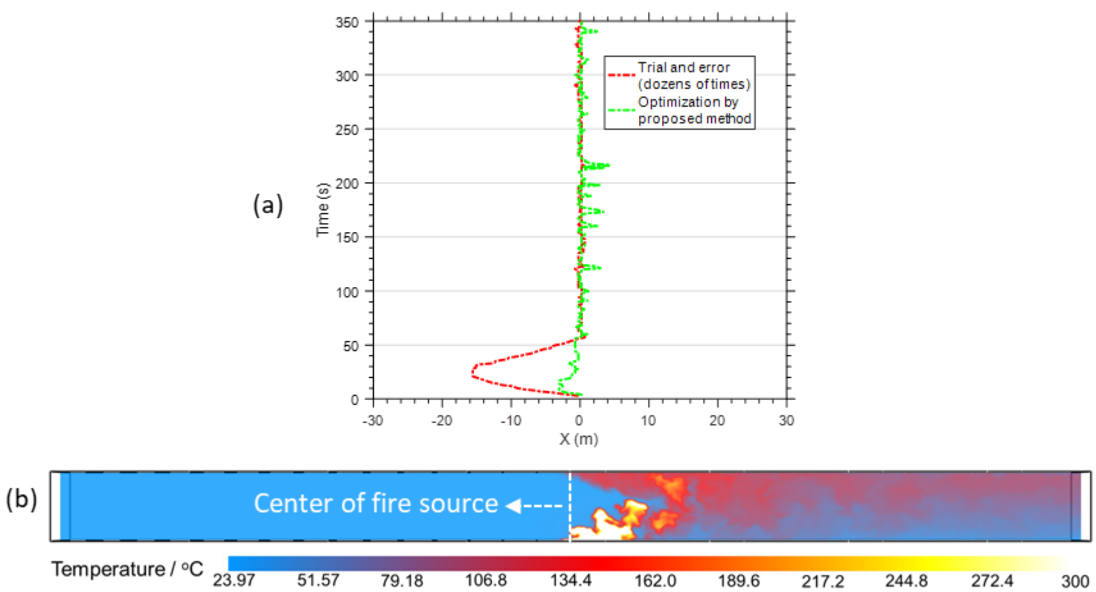


Figure 3 (a) The evolution of the smoke front in two smoke identification methods: a comparison between the trial and error and the optimized approach. (b) an instantaneous result for the smoke in the quasi-steady period.

Keywords: Tunnel fire, Smoke control, PID, Ventilation, System identification, Genetic algorithm

References

[1] Hong, Y., Kang, J., Fu, C., 2022. Tunnel fire smoke control based on the PID method: A numerical study. Tunn Undergr Sp Tech, in press. https://doi.org/10.1016/j.tust.2022.104450