

# **Design and Identification of the Train Model in Automatic Train Operation (ATO) Simulation Platform**

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**Abstract:** ATO (Automatic Train Operation) is an important part of the ATC (Automatic Train Control), in which train modeling is the core of ATO. This paper designs a train model including three parts, and identify the train model by PEM method according to data of line 3.

**Keywords-** ATO, Train Model, Simulation Platform

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## **I. Introduction<sup>[1]</sup>**

Recent years, with the development of city modernization, urban rail transit becomes more and more important, which improve the development of ATC (Automatic Train Control). ATC system consist of three parts: ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision). ATO play an important role in ATC system. ATO system can automatic drive instead of drivers to realize velocity monitoring and fixed parking in station, and can ensure the high-quality automation drive.

The main function of ATO is the velocity control and adjustment in order to realize arrive on time and station parking. Because of the limitation of condition and safety, in the early research stage, it is impossible to debug, design and test in train scene. So ATO simulation platform must be designed in order to short the research cycle and protect waste of human and material resources.

For ATO system, train model is the key of the whole system, which can supply entity model of train for other modules. In the control of instructions, train model must give accurate information of velocity, acceleration, time and surrounding.

## **II. The design of the Train Model**

### **2.1 The Frame Of train Model**

According to actual train, there are three courses of train operation: drawing, braking and stopping. In this paper, data of line 3 of shanghai is used to design train model. The structure of model is shown in fig2, and the whole train model include three sub-models: acceleration model, braking model and stopping model.

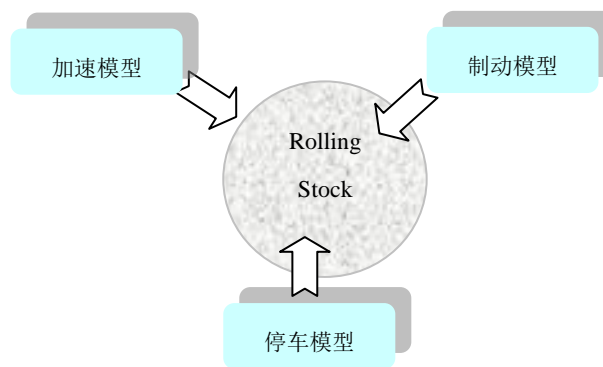


Figure 1 the structure of train model

Acceleration model: it can be identified by operation data of actual shanghai line 3, which includes the input of drawing control instruction and the output of acceleration and velocity.

Braking model: it can be identified by operation data of actual shanghai line 3, which includes the input of braking control instruction and the output of acceleration and velocity.

Stopping model: during the stopping, a serial of instructions are used to prevent traffic accident caused by slipping car. In train model, if the train velocity is zero, and braking instruction are used, train model is shifted to stopping model. Detailed stopping control model of train is shown in figure 2.

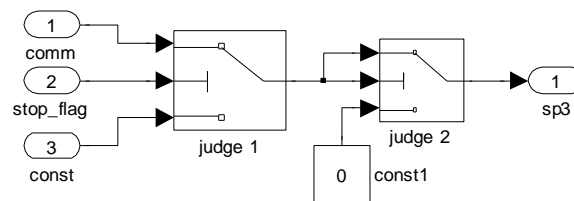


Figure 2 stopping control model

During train control, train model will shift automatically during the different models according to different instructions. The State-flow method is used to design train control train to shift different models, which is shown in figure 3.

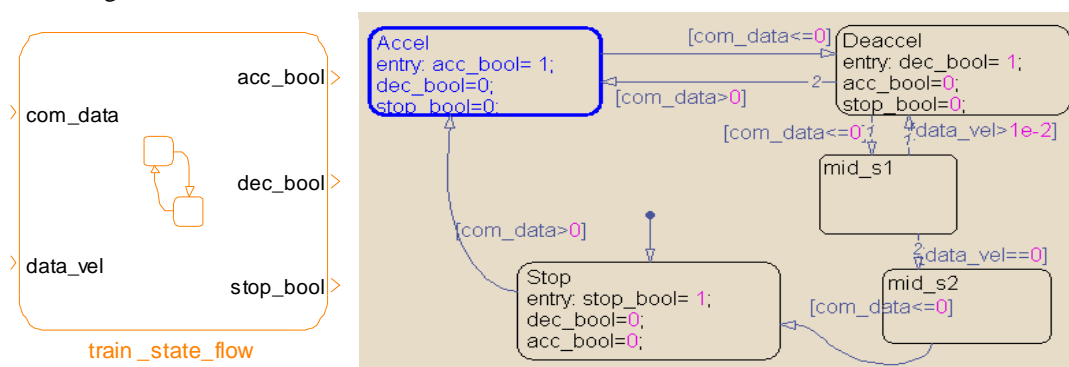


Figure 3 train State-flow model

### III. Identification of the Train Model<sup>[2,3]</sup>

During train operation, Operating characteristic will effected by road condition, so train model need to be accurate by identify the train model.

#### 3.1 Identification Algorithm

In this paper, iterative prediction-error minimization is used to identify train model. It is a high accurate algorithm and the error is least than the error of Least square method. The principle is shown below:

There are a data model:

$$Y(k) = f(Y(k-1), \dots, Y(1), Y(0), u(k-1), \dots, u(1), \alpha) + e(k) \quad (1)$$

Here:  $u(k)$  denote input vector,  $Y(k)$  denote output vector,  $\alpha$  denote parameter,  $e(k)$  denote noise.

$$\text{If } \begin{cases} Y^{(k-1)} = [Y^T(k-1), \dots, Y^T(1)]^T \\ u^{(k-1)} = [u^T(k-1), \dots, u^T(1)]^T \end{cases} \quad (2)$$

$$\text{Then } Y(k) = f(Y^{(k-1)}, u^{(k-1)}, \alpha) + e(k) \quad (3)$$

According to (4.3), the Optimal forecasting of k time output will be obtained.

$$\text{If } \hat{Y}(k | \alpha) = E\{Y(k) | Y^{(k-1)}, u^{(k-1)}\} \quad (4)$$

Then  $E\{\|Y(k) - \hat{Y}(k | \alpha)\|^2 | Y^{(k-1)}, u^{(k-1)}, \alpha\}$  will be minimum.

#### 3.2 identified train model

Because of the interference noise of data of Line 3, Savitzky-Golay filter is used to process data in order to improve the data precision before identification.

In this paper, processed train data is used to identify acceleration model and braking model. Considering that any complicated system can be approximated as a 2 order system, so acceleration model and braking model use two order model and integrating element to identification.

The sample time of line 3 is 0.1 second. After identification, discrete acceleration model and braking model is listed below:

acceleration model:  $G_{acc}$  (Ts=0.1s)

$$G_{acc}(z) = \frac{0.00184 z^3 + 0.00184 z^2 - 0.001839 z - 0.001839}{z^3 - 2.936 z^2 + 2.872 z - 0.9358} \quad (5)$$

braking model:  $G_{dec}$  (Ts=0.1s)

$$G_{dec}(z) = \frac{0.002012 z^3 + 0.002012 z^2 - 0.002011 z - 0.002012}{z^3 - 2.933 z^2 + 2.867 z - 0.9333} \quad (6)$$

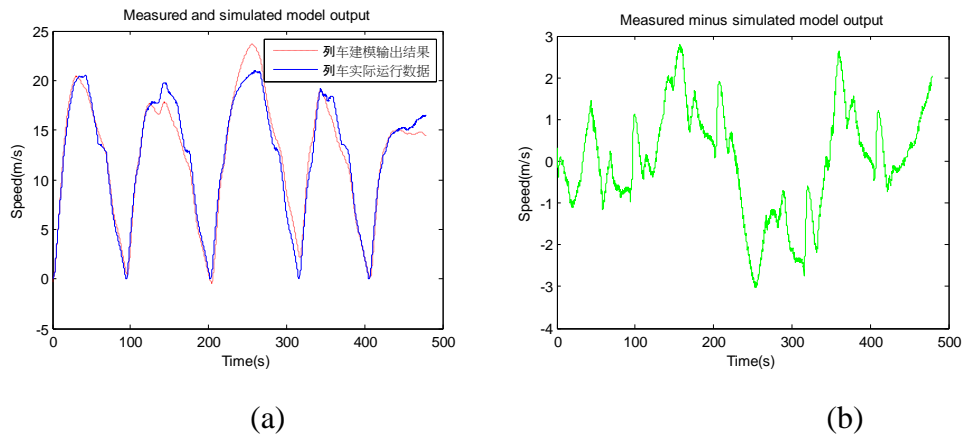


Figure 4 model identification

(a) identification result; (b) identification error

The identification result and error are shown in figure 4, the identification precision is 79.4% .

#### IV. Conclusion

ATO system is an important part of STC system, and control simulation of ATO has many advantages. The key core of ATO simulation is train model. In this paper, a train model is designed, and the model is identified by PEM algorithm according to actual data of shanghai line 3.

#### References

- [1] Xu zhanding. Research in automatic train operation system based on fuzzy neural networks[D]. Xinan JiaoTong university. 2010.
- [2] Zong ming, zhang guohou. Development of automatic driving simulation platform in rail transit[J]. Rail Transit Research. 2012(6):52-55.
- [3] Liu Hewen, Zhao Haido ng , Jia Limin. A Study on the Control Algorithm for Automatic Train Operation[J]. China Railway Science. 2000,21(4):38-43.