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Bifurcation control of solid angle car-following model through a time-delay feedback method

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Research Background

Car-Following Model

Traffic Engineering Perspective	Statistical Physics Perspective
➢ Stimulus-response Model	➢ Optimized Speed Model
➢ Safe Spacing Model	➢ Intelligent Driving Model
➢ Physiological Mental Model	➢ Metacellular Automata Model
➢ Artificial Intelligence Model	

Research Background

The proposal of the angle car-following model

Michaels perspective change model:

$$\frac{d\theta_n(t)}{dt} = -W\frac{\Delta V_n(t)}{\left(S_n(t)\right)^2}$$

Bando car-following model:

$$\dot{v}_n(t) = a\left[V\left(\Delta x_n(t)\right) - v_n(t)\right]$$

Speed tends towards optimal speed

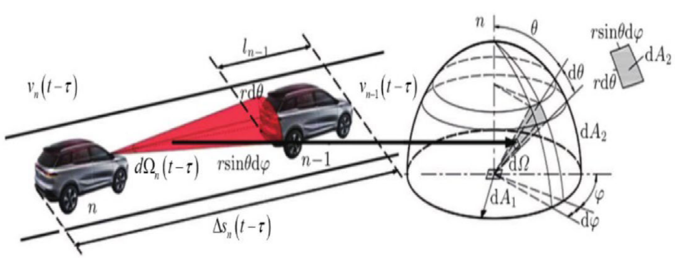
Vehicle conservation

$$a_n(t) = \alpha\left\{V\left[\Omega_n(t)\right] - u_n(t)\right\} - \lambda\frac{d}{dt}\Omega_n(t)$$ **solid angle car-following model**

$$V\left(\Omega_n(t)\right) = V_1 + V_2\tanh\left(C_1\sqrt{S_{n-1}(t)/\Omega_n(t)} - C_2\right)$$

Research Content

Actual scenario



Controlled model

$$\frac{dv_n(t)}{dt}=\alpha\left[V\left(\Omega_n(t)\right)-v_n(t)\right]+\varepsilon M\left(v_n(t)-v_n(t-\tau)\right)$$

$$V\left(\Omega_n(t)\right)=V_1+V_2\tanh\left(C_1\sqrt{S_{n-1}(t)/\Omega_n(t)}-C_2\right)$$

$$M=2A_{n-1}\Big/\left(h-l_{n-1}\right)^3$$

Linear analysis

$$V'(\Omega_0)>\frac{\alpha}{2\left(Mp\varepsilon_1\tau_1+M(1-p)\varepsilon_2\tau_2-1\right)M}$$

Stability conditions of the centerline

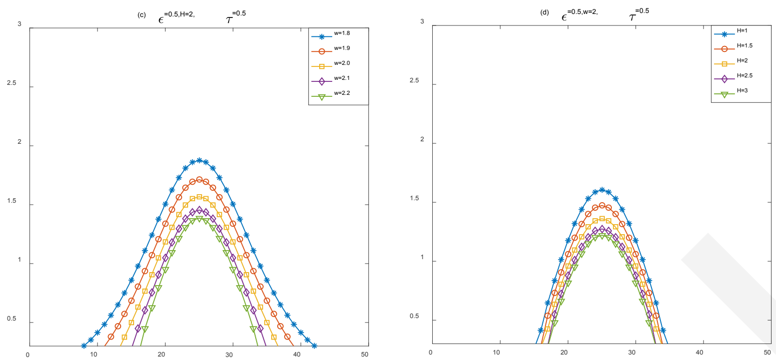
Bifurcation analysis

$$\begin{cases}-\omega^2+\varphi_1\omega s_{\tau_1}+\beta-\varphi_2 c_{\tau_2}=\beta c_k-\varphi_2 c_{\tau_2}c_k-\varphi_2 s_{\tau_2}s_k\\ -\delta\omega+\varphi_1\omega c_{\tau_1}+\varphi_2 s_{\tau_2}=\beta s_k-\varphi_2 c_{\tau_2}s_k+\varphi_2 s_{\tau_2}c_k\end{cases}$$

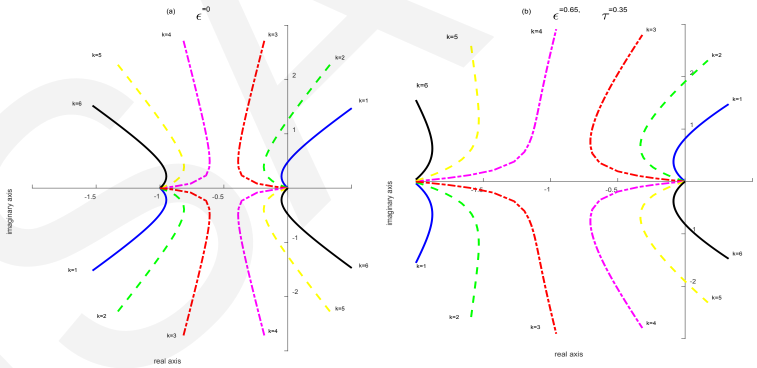
Hopf bifurcation critical condition

Research Results

Numerical simulation



Neutral stability curve

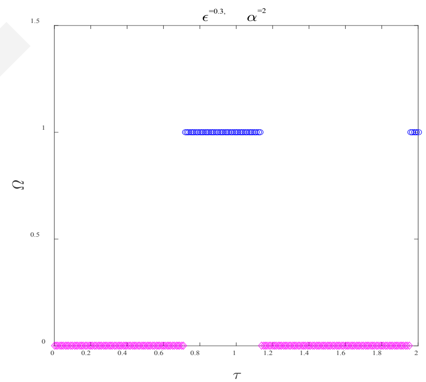


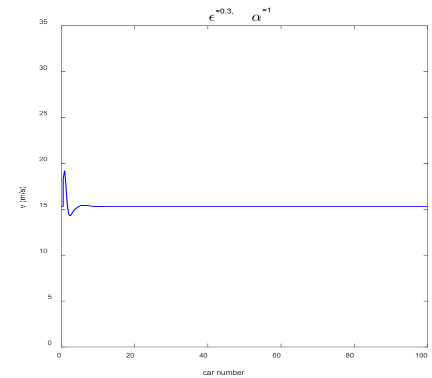
Absolute value distribution curve

Case studies

Table 2 Calibration parameters

parameters	范围	SAM	受控 SAM
$\alpha(s^{-1})$	$[0,2]$	0.5164	0.4823
$h(m)$	$[8,40]$	31.5834	27.0565
$v_{\max}(m\cdot s^{-1})$	$[20,40]$	29.4532	34.4623
$\varepsilon(s^{-1})$	$[-1,1]$	0	0.7746
$\tau(s)$	$[0,2]$	0	0.7179
PI		0.6624	0.6237





Conclusions

- A feedback control with response delay is designed for SAM to suppress bifurcation caused by unstable factors, and suppress traffic flow oscillations;

- Reasonable feedback gain and delay settings can effectively improve the stability of traffic flow.