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Updated Bayesian detection of foundation parameter with Jeeves pattern search theory

Key words: Jeeves pattern search theory; Updated Bayesian objective function; Detection; Foundation parameters; Fourier close form solution

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The updated Bayesian objective function can be derived as

$$J = \sum_{i=1}^{n} (\boldsymbol{W}_i^* - \boldsymbol{W}_i)^{\mathrm{T}} \boldsymbol{C}_{\boldsymbol{W}_i^*}^{-1} (\boldsymbol{W}_i^* - \boldsymbol{W}_i) + (\boldsymbol{X} - \boldsymbol{X}_0)^{\mathrm{T}} \boldsymbol{C}_{\boldsymbol{X}}^{-1} (\boldsymbol{X} - \boldsymbol{X}_0).$$

The partial differentiation of updated objective function to the stochastic foundation parameters is expressed as

$$\frac{\partial J}{\partial \boldsymbol{X}} = \sum_{i=1}^{n} 2\left(\frac{\partial \boldsymbol{W}_i}{\partial \boldsymbol{X}}\right)^{\mathrm{T}} \boldsymbol{C}_{\boldsymbol{W}_i^*}^{-1} (\boldsymbol{W}_i - \boldsymbol{W}_i^*) + 2\boldsymbol{C}_{\boldsymbol{X}}^{-1} (\boldsymbol{X} - \boldsymbol{X}_0).$$

The variance of the parameters in Eq.(9) can be written as

$$\boldsymbol{C}_{\hat{\boldsymbol{X}}} = \left[\boldsymbol{C}_{\boldsymbol{X}}^{-1} + \sum_{i=1}^{n} \boldsymbol{S}_i^{\mathrm{T}} \boldsymbol{C}_{\boldsymbol{W}_i^*}^{-1} \boldsymbol{S}_i \right]^{-1}.$$

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(1) The governing differential equations for the Mindlin plate on the Winkler foundation

(2) These variables are expanded in the form of multiple Fourier series

(1)

$$\frac{\partial Q_x}{\partial x}+\frac{\partial Q_y}{\partial y}+q-kw=0,$$

$$\frac{\partial M_x}{\partial x}+\frac{\partial M_{xy}}{\partial y}-Q_x=0,$$

$$\frac{\partial M_{xy}}{\partial x}+\frac{\partial M_y}{\partial y}-Q_y=0,$$

(2)

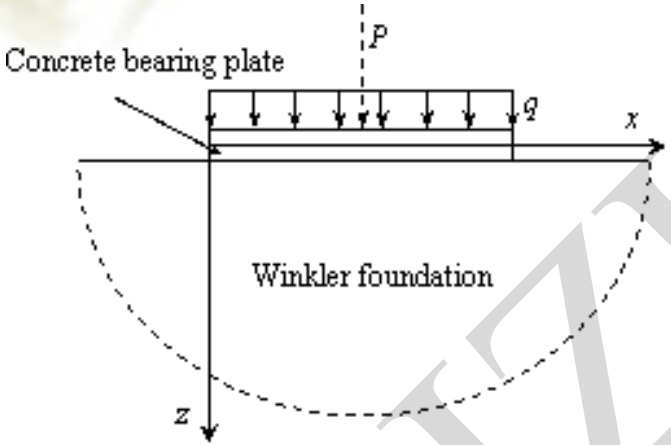
$$\theta_x=\sum_m\sum_n A_{mn}\cos\alpha_m x\sin\beta_n y,$$

$$\theta_y=\sum_m\sum_n B_{mn}\sin\alpha_m x\cos\beta_n y,$$

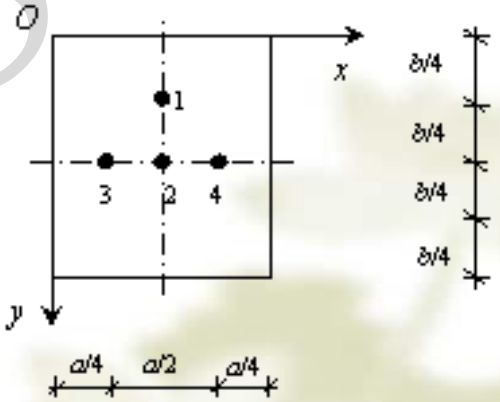
$$w=\sum_m\sum_n C_{mn}\sin\alpha_m x\sin\beta_n y,$$

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Jeeves pattern search analysis of the updated Bayesian detection of the stochastic foundation parameters



Concrete bearing plate on Winkler foundation



Four selected points on a concrete bearing plate

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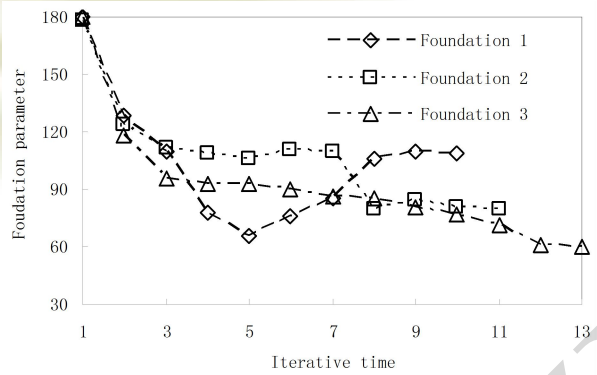
The displacement measurement and the displacement standard deviation/cm

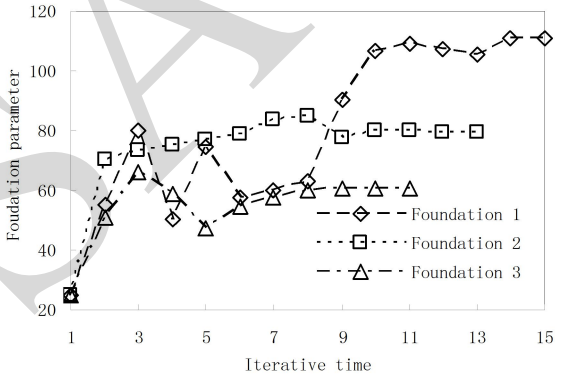
Number of foundation	Number of selected points	w_1	w_2	w_3	w_4	w_5	σ_{w1}	σ_{w2}	σ_{w3}	σ_{w4}	σ_{w5}
I	1	0.877	0.873	0.879	0.871	0.872	0.013	0.016	0.015	0.011	0.018
	2	1.175	1.171	1.179	1.173	1.172	0.025	0.023	0.028	0.022	0.027
	3	0.849	0.843	0.846	0.842	0.845	0.012	0.016	0.018	0.010	0.015
	4	0.850	0.853	0.848	0.855	0.856	0.015	0.018	0.012	0.016	0.019
II	1	0.216	0.213	0.215	0.212	0.219	0.007	0.011	0.012	0.009	0.008
	2	0.299	0.293	0.292	0.297	0.294	0.011	0.008	0.009	0.006	0.012
	3	0.220	0.224	0.223	0.227	0.217	0.012	0.005	0.007	0.010	0.009
	4	0.218	0.223	0.214	0.215	0.213	0.010	0.006	0.008	0.004	0.007
III	1	0.281	0.283	0.284	0.278	0.277	0.011	0.008	0.009	0.008	0.010
	2	0.728	0.723	0.725	0.732	0.731	0.041	0.045	0.036	0.039	0.043
	3	0.397	0.393	0.395	0.403	0.402	0.006	0.010	0.009	0.008	0.011
	4	0.401	0.404	0.398	0.397	0.403	0.013	0.006	0.007	0.011	0.008

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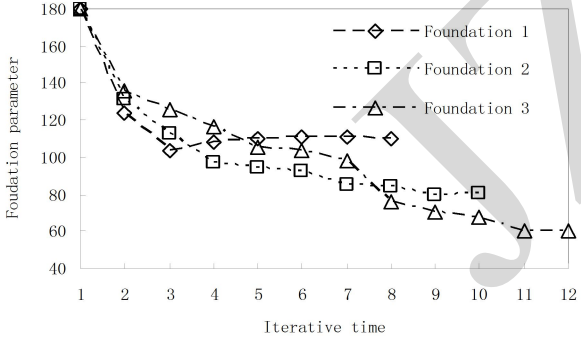
Iteration results of Jeeves pattern search analysis of the foundation parameters

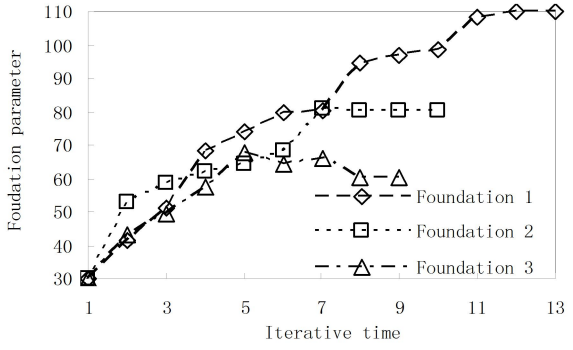
Case 1





Case 2





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Conclusions

(1) An updated Bayesian detection model of the stochastic Winkler foundation parameter based on Jeeves pattern search theory is derived. The Jeeves pattern iterative processes are steadily convergent to the true values, which indicate that the derived detection model is correct and reliable.

(2) Unlike the Kalman filtering theory and the conjugate gradient theory, the partial derivatives of the systematic responses to the foundation parameters are irrelevant in the Jeeves pattern search process, which indicates that the Jeeves pattern theory is of higher computational efficiency.

(3) Searching for the optimal movement step length is a fairly complicated problem in parameter detection. The derived *quadratic* parabolic interpolation method can automatically determine the interval of the optimal step length and then search the significant step length.

(4) The derived updated Bayesian detection model based on the Jeeves pattern search theory has universal significance for different kinds of foundation parameters if the corresponding foundation model should be considered and substituted for the discussed Winkler foundation.

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