The 2016 World Congress on
The 2016 Structures Congress (Structures16)
Jeju Island, Korea, August 28-September 1, 2016

Experiment Validation of the New Model Updating Technique based on a Kriging Surrogate Model

*Yongmoon Hwang[1)], Ho-Yeon Jung[2)], Jung-Hoon Lee[2)], Seung-Seop Jin[2)] and Hyung-Jo Jung[3)]

[1), 2), 3), 4), 5)] *Department of Civil & Environmental Engineering, KAIST, Daejeon 34141, Korea*
[1)] *yongmoon@kaist.ac.kr*

ABSTRACT

Recently, a finite element model updating technique has been frequently used to evaluate bridge performance. In order to obtain accurate analysis results, a sophisticated initial finite model is used generally. However, the sophisticated initial model consumes excessive calculation time. In this study, a new model updating technique based on a surrogate model is proposed. The proposed method can not only maintain the accuracy but also save the calculation time. In this study, a Kriging surrogate model is used. In order to construct an accurate Kriging surrogate model and improve its efficiency, a sequential sampling method is adopted. The proposed model updating technique is validated by using the field test data. The proposed Kriging surrogate model improves initial finite element model efficiently and significantly reduces calculation time comparing with the conventional method.

1. Introduction

A finite element (FE) model updating is a method to improve the accuracy of the numerical analysis model using the data from experiment in a target structure. From the method, it is possible to evaluate the overall performance of the structure. However, in spite of development of computing technology, the excessive calculation time is needed to obtain the sophisticated and reliable analysis model because of iterative structure analysis process. In order to solve the excessive calculation time, a surrogate model has been proposed recently.

In conventional model updating technique, analytical model which represents the actual structure system is used. However, the surrogate model uses a mathematical relationship between input and output of the target structure. By constructing the function of the input and output of the target structure, changes of variables in analysis

---

[1), 2), 3), 4)] Graduate Student
[5)] Professor

model can be immediately known. It is important to select the proper basis function which can effectively express the input and output relation of the variables to compose of the surrogate model. In this study, a Kriging model is selected as basis function based on conventional studies. Also, to obtain the more effective and accurate Kriging model, a sequential sampling method is proposed to improve the accuracy of the model. The performance and efficiency of the proposed FE model updating method are validated through experiment data which is obtained by field test in test-bed bridge.

2. Theoretical Background

In this section, the FE model updating based on the Kriging model is introduced briefly. A more detail description can be found in Jin et al (2016).

The Kriging surrogate model is a prediction method which estimates the specific values by using the weighted linear combination with the known values. It is one of the surrogated models originated from Geostatistics, also called Gaussian model. Variables needed in the basis function are selected by the maximum values in the maximum likelihood function. The basis function (ψ^{ij}) can be expressed as

$$\psi^{ij} = \exp(-\textstyle\sum_{p=1}^{k} \theta_p \left\| x_p^i - x_p^j \right\|) \qquad (1)$$

where substructure *'p'* is dimensions of a sample, superstructure *'i'* and *'j'* indicate *i*-th and *j*-th samples. According to the variables involved in basis function, the accuracy and curvature of the Kriging model is determined. Correlation of the function value is defined by the distance of each samples. From this, the function of sample is expressed as the stochastic random variable which has a mean and variance value. Using the log maximum likelihood function and its mean and variance value, prediction value can be estimated. After defining the sample and covariance from the prediction point, least square method is used to calculate the prediction value. In this study, sequential sampling method is introduced to improve the accuracy of surrogate model. Fig. 1 shows the flow chart of construction procedure of the Kriging surrogate model.

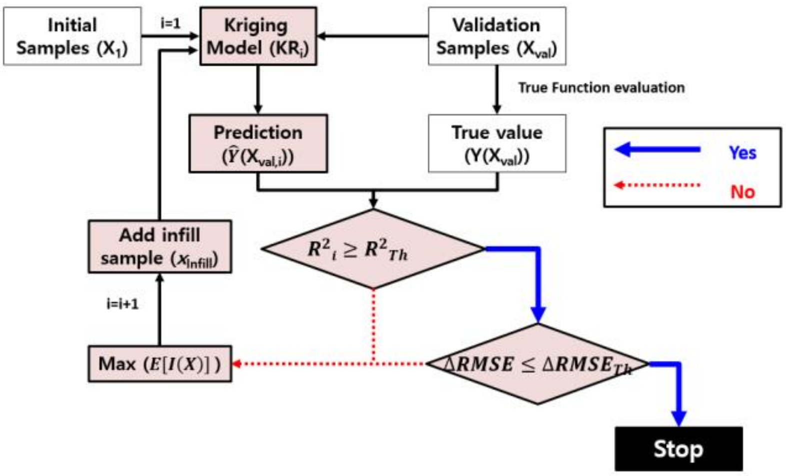
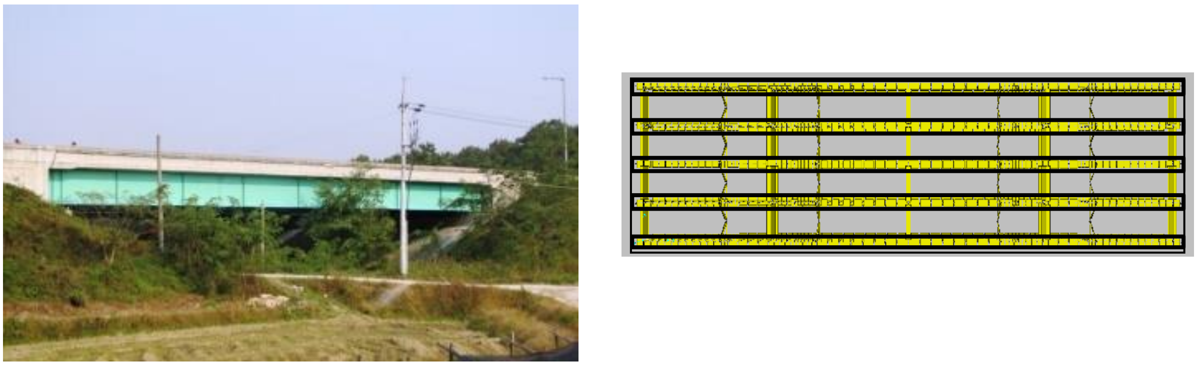


Fig. 1 Flowchart of the Kriging surrogate model with the sequential sampling strategy (Jung et al 2016a)

3. Experimental Validation

To verify the utility of the proposed method, experiment data obtained through field test is used to validate. The test structure is one-span steel composite girder bridge which consists of 5 main girders, 5 cross girders and 4 diaphragms. Fig. 2 shows the test bed bridge and FE model.



(a) Test bed Bridge (b) FE model

Fig. 2 Experimental model (Jung et al 2016a)

First, acceleration data is measured under ambient vibration of the structure. Natural frequency and mode shape of the structure are estimated by using stochastic subspace identification (SSI) method. Also, Young's modulus of the main girder and cross girder, which mainly effect on the behaviors of structures, are selected as the updating parameters and 6 low-order frequencies are considered as target output. After constructing initial Kriging surrogate model from 30 initial samples selected by Latin hypercube sampling, the surrogate model is improved by sequential sampling method. Additional 300 samples are used to validate the Kriging surrogate model. As shown in Fig. 3, the Kriging model precisely expresses dynamic characteristics of target output.

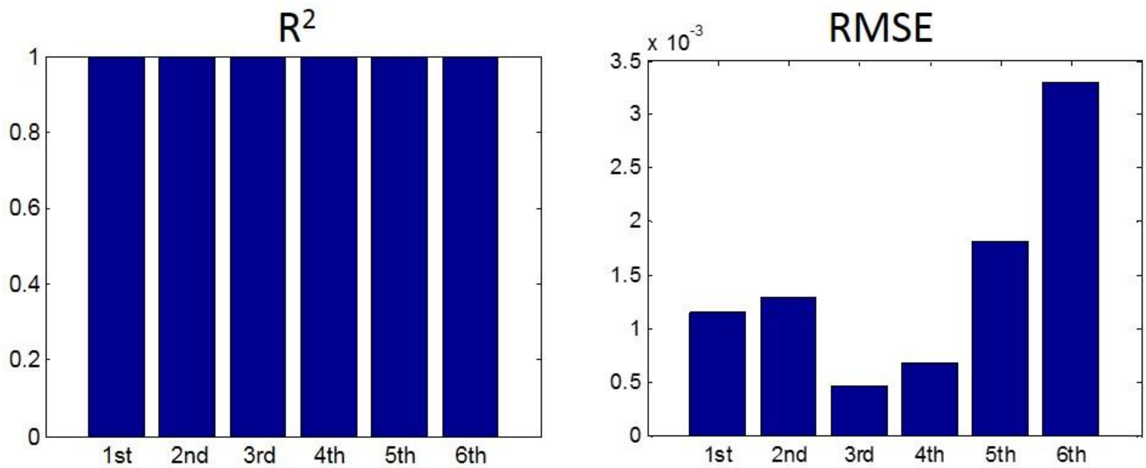


Fig. 3 R^2 and RMSE of the 300 sample points (Jung et al 2016a)

The conventional FE model updating methods, generic algorithm and Nelder-Mead's simplex algorithm, are used to compare the efficiency. Table 1 shows the model updating results using the Kriging surrogate model. From the table, the accuracy of the target outputs (natural frequencies) is increasingly improved. Only 14 hours are consumed with the Kriging surrogate model. However, the conventional method needs about 330 hours to model updating.

Table 1. FE model updating results (Jung et al 2016a)

Target Output	Experimental Result (Hz)	Initial FE model		Kriging model	
		Value(Hz)	Error(%)	Value(Hz)	Error(%)
f_1	3.909	3.109	20.5	3.992	2.1
f_2	4.727	3.457	26.9	4.476	5.3
f_3	10.759	9.025	16.1	11.309	5.1
f_4	13.494	10.262	23.9	12.516	7.2
f_5	14.950	12.220	18.4	14.958	0.05
f_6	19.173	15.226	20.6	18.528	3.3

4. Conclusion

In this study, the FE model updating method composed of the Kriging surrogate model and sequential sampling method is introduced. After brief description of the Kriging surrogate model and sequential sampling method, the proposed FE model updating method is validated by experiment in the existing bridge. As a result, the proposed FE model updating method can precisely estimate the target output (dynamic characteristic of bridge). Also, its calculation time is significantly reduced compared with conventional method. Therefore, the proposed FE model updating method can replace the conventional method which needs excessive time to analysis.

REFERENCES

Jin, S.S., and Jung, H.J. (2016) Sequential Surrogate Modeling for Efficient Finite Element Model Updating, *Computers and Structures*, **168**, pp.30～45.

Jung, H.Y., Lee, J.H., Jin, S.S., and Jung, H.J. (2016a) Finite Element Model Updating based on a Kriging Surrogate Model for Bridge Performance Evaluation, *The ANCRiSST Workshop*, Cambridge, The United Kingdom.

Jung, H. Y, Lee, J. H, Jin, S.S, and Jung, H.J. (2016b) A Kriging Model based Finite Element Model Updating Technique for Performance Assessment of Bridges. Computational Structure Engineering Institute of Korea.