

A new approach to generate Approximation model for CAE analysis using Isight

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Abstract: A product development and evaluation using the simulation technology now is a standard process. Approximation models are now frequently used as an efficient design tool. Isight, an automation and optimization tool of SIMULIA, offers a several methods to generate Approximation model. Using Approximation model, as it is well known, the exploration time can be shortened, especially when a simulation takes long time for a single run. Generally, it is important to provide effective sampling points as Teacher data. In most of methods, a sampling matrix is generated taking no account of any response and the more parameters one has, the more Teacher data one needs. If an analysis is time consuming, like crash analysis, then we cannot perform all the sampling in a limited time and cost. In this paper, we propose an efficient approach to generate more accurate Approximation model using less Teacher data. In this approach, Isight will search peaks and valleys of current response surface using optimization drivers, add them to Teacher data, and update the response surface automatically. Moreover, new sampling points will not duplicate the existing ones. First, the approach is applied to a mathematical function, and then applied to a vehicle crash analysis. We succeeded to create more accurate Approximation model compare to conventional methods in both cases. The effectiveness of this approach is confirmed.

Keywords: Approximation model, CAE analysis, Process automation, Teacher data.

1. Introduction

FEM simulation for a product development, it needs to reduce a computation time of a best practice for achieving a short development term. Approximation model, which is one of process components in Isight, is quite helpful to fill this demand, because the model can calculate output values without a solver execution. However, one should pay an attention for getting enough model accuracy of output. Generally, following requirements should be considered to create approximation model with a reasonable accuracy.

- Create an enough teacher data by sampling points.
- Add the data by manually-operated if it must improve the accuracy.

If there is a time to create the model and/or sufficient computer resources, the above problem can be solved easily. However, in many cases, simulations must be done in time and/or limited resources. In addition, a crash simulation requires more computation costs than others. Therefore, it is difficult to execute a solver so many times for exploring good result.

This document proposes an approach to generate Approximation model with accuracy by minimizing the cost in a simulation stage.

2. Concept

This approach provides a method to generate automatically Approximation model with good precision. A comparison of work flow between current and proposed methods is shown in figure 1.

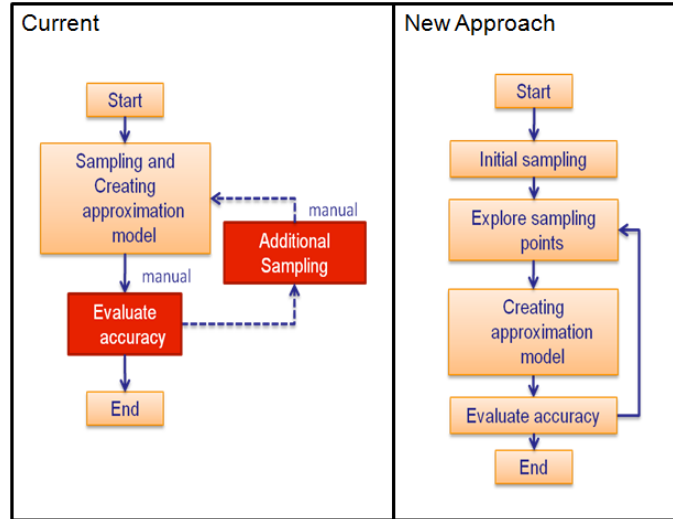


Figure 1. Comparison of current and proposed approaches

The most significant difference between both approaches is a mechanism of additional sampling to Approximation model. Typically, evaluation of the model accuracy and arrangement of additional sampling points for a teacher data are done manually. On the other hand, in the new approach, it will automatically search for next sampling points, update the model and evaluate its accuracy continuously. If accuracy of Approximation model reaches criteria that are defined by user, a calculation will finish. Thus, this technique supports to create Approximation model with good accuracy efficiently and automatically in less time.

To explore new sampling points, Screening of Fitness function (M. Arakawa, C70-697, 2004) is applied. It is calculated by multiplying Basic function and Tunnel function as shown in below formula.

$$\text{Screening of Fitness function } S(x) = \text{base}(x) \cdot \text{tunnel}(x)$$

$$\text{tunnel}(x) = \max(\alpha, 1 - G(x))$$

$$G(x) = \sum_{j=1}^K \text{Exp} \left(- \sum_{i=1}^{n \text{ var}} \left(\frac{x - x_{ij}}{\sigma_i} \right)^2 \right)$$

$$\text{base}(x) = \max(\rho, |f_{rbf}(x)|)$$

$$f_{rbf}(x) = Rbf(x, f(x_i))$$

where α and ρ are constant coefficient by user defined.

Base function $base(x)$ (M. Arakawa, C70-697, 2004) should be an absolute value from simulation output. Maximum value of this function means the top or valley point in a response surface. In this approach, the maximum point is searched in exploration process. Tunnel function $tunnel(x)$ (M. Arakawa, C70-695, 2004) is a filter to avoid duplicated points using Gauss function $G(x)$ until the end of sampling. Explored points are added to a teacher data to update the model.

In this system, RBF (Radial Basis Function) model, which is one of Approximation models in Isight, is used. Because of it is strong for generating nonlinear response surface.

3. Simflow of new approach

Isight Simflow including new approach for creating Approximation model with good accuracy is generated as shown in figure 2.

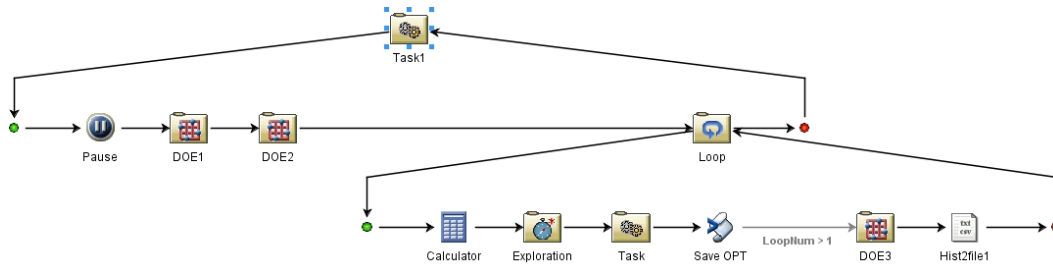


Figure 2. Simflow of Isight for new approach

Main task (“Task 1”) of this Simflow has three (3) sub-flows as shown in figure 2.

- First DOE (“DOE1”) executes initial sampling for Approximation model.
- Second DOE (“DOE2”) executes to verify the model accuracy.
- Exploration process (“Loop”) is to search new points for a teacher data and verify the model.

“Loop” component has three (3) sub-flows to update Approximation model.

- “Exploration” component searches and calculates new sampling points.
- A teacher data is updated by new sampling points in “Task” component.
- Maximum point of Base function is saved in “Save OPT” component after each loop.
- DOE (“DOE3”) is to verify accuracy of Approximation model.
- The sampling result is written into a text file.

Figure 3 is shown tree structure of sub-flows to describe.

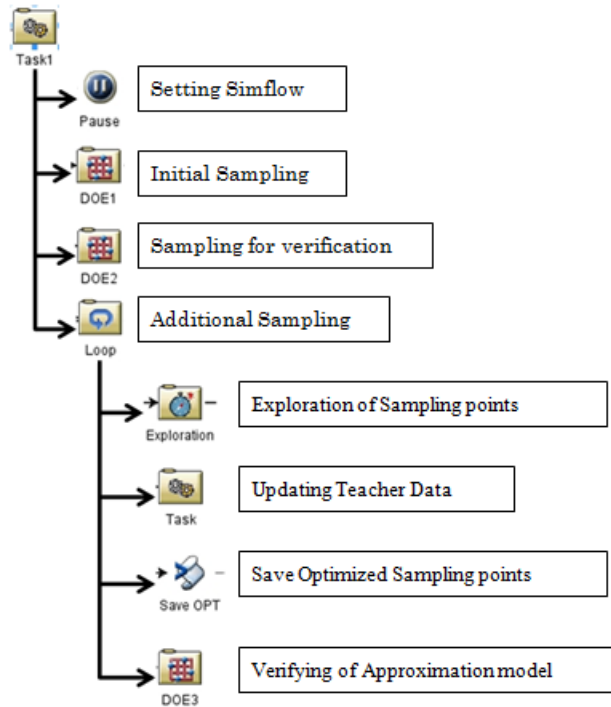


Figure 3. Description of sub-flows

There are three (3) DOE components in this Simflow.

- “DOE1” is applied with original method of Optimized-Latin hyper cube.
- “DOE2” is Random sampling.
- “DOE3” is copied from “DOE2” component matrix.

4. Tests of the approach

Test study has been done to evaluate this approach. This document will report two (2) kinds of tests.

- Test by Mathematical function
- Test by FEM crash simulation

4.1 Mathematical function case

Simple test using mathematical function has been executed.

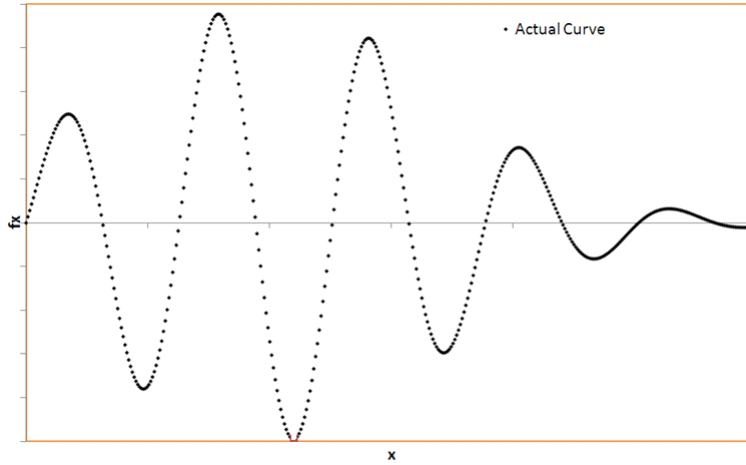


Figure 4. Curve of mathematical function for test

Function for this test is used nonlinear and different amplitude curve shown as figure 4. No initial sampling of Approximation model (See “initial sampling“ in figure 3) is done. Because the function is a simple model.

First explored point is shown in figure 5. Red point is found on a valley of the function. This means an effect of Basic function.

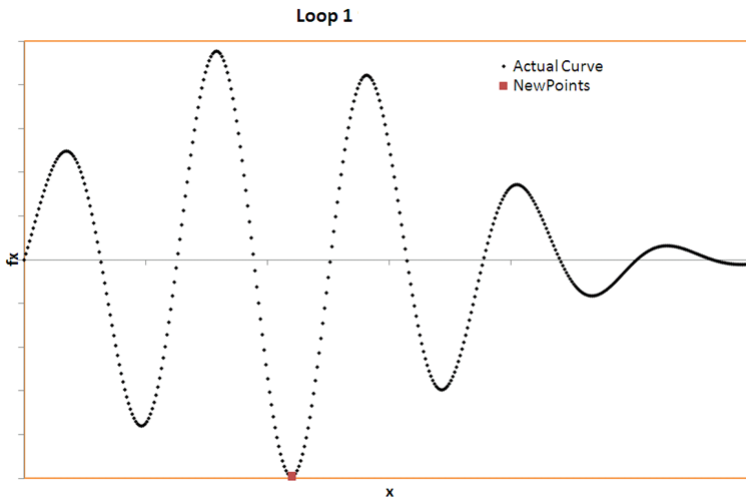


Figure 5. Sampling result at Loop=1

At third loop, three (3) explored points are shown in figure 6. These points are in the top or valley of the function. No duplicated point is found, so it means that Tunnel function activates.

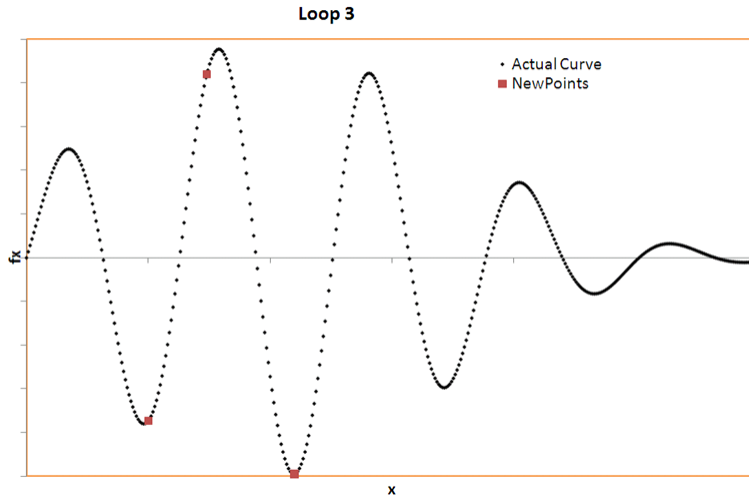


Figure 6. Sampling result at Loop=3

Five (5) explored points are shown in figure 7. These points are in a top or valley of the function. Any duplicated point is not found as same as last case.

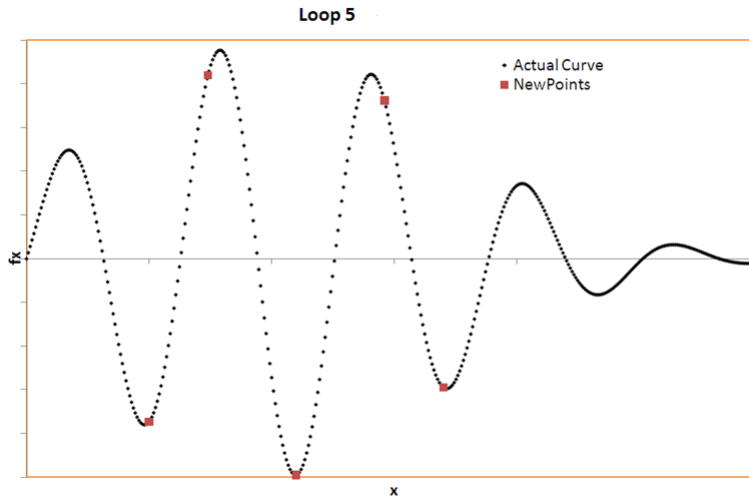


Figure 7. Sampling result at Loop=5

In all cases, the sampling points are placed on top and valley points of a response surface. This method can help to create accurate Approximation model by less calculations.

4.2 FEM Crash simulation case

FEM simulation study was conducted to validate this approach as second test. Generally, crash simulation is nonlinear and complicated among the FEM simulation, so it is thought that this simulation is best to verify the new approach.

Figure 8 shows a model of crash simulation. This model is to simulate a behavior of frontal offset vehicle crash. A vehicle model collides with a flat wall barrier with 40.2 km/h speed. Wall barrier and ground model have been made by rigid body.

Crash simulation tests have been computed by Abaqus/Explicit and HPC machine.

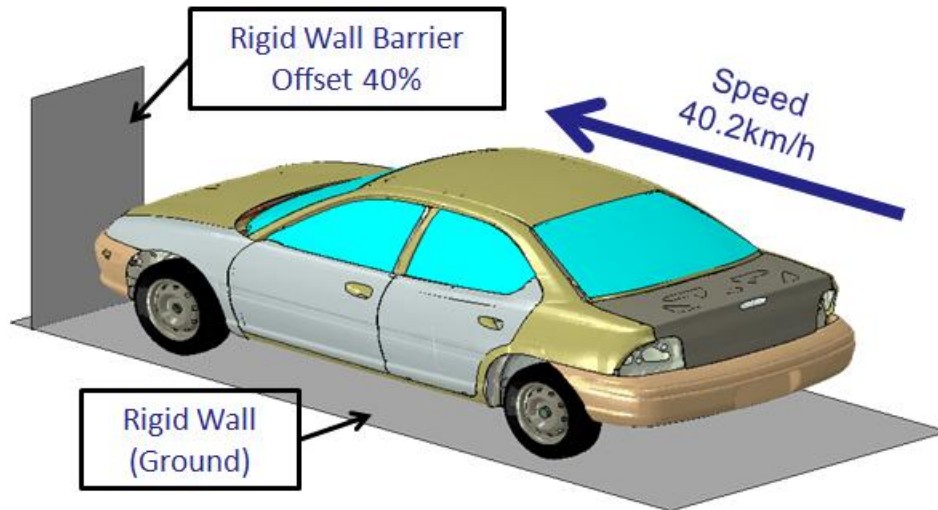


Figure 8. Crash Simulation Model

Thickness values of 37 parts (figure 9) are taken as Design parameter for sampling.

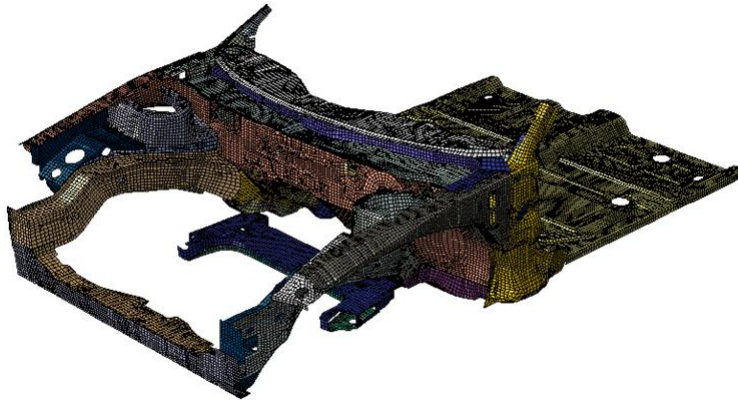


Figure 9. Vehicle parts of design parameters

Output parameters are defined as shown in figure 10.

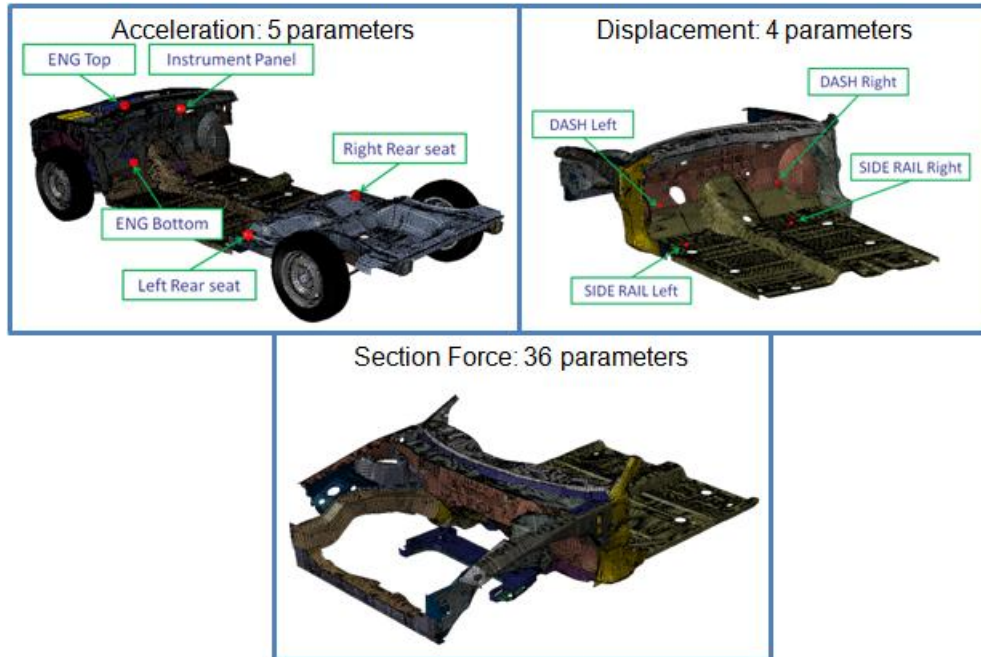


Figure 10. Output parameters

Calculation method to create Approximation model is as below.

- Initial sampling ---- Optimized Hyper Latin Cube method, 37 sampling points
- Exploration sampling ---- 20 sampling x 13 Loops = 260 points
- Approximation model type ---- RBF (Radial Basis Function) model
 - Sampling points for a teacher data ---- Totally 297 (37 + 260) points
- Verification points ---- Random sampling, 11 sampling points

To compare with current approach, below calculation has also been executed.

- Sampling ---- Optimized Hyper Latin Cube method, 300 sampling points
- Approximation model type ---- RBF (Radial Basis Function) model
 - Sampling points for a teacher data ---- 300 points
- Verification points ---- Same as above

Symbolic results are shown below.

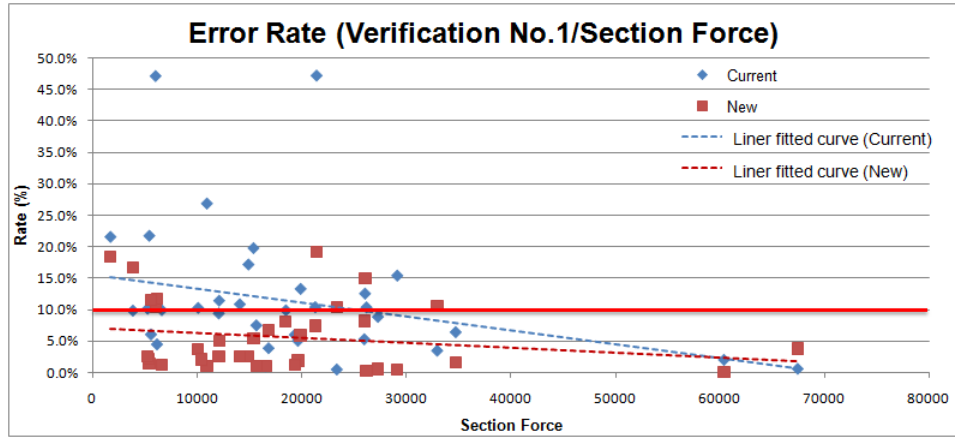


Figure 11. Result 1 – Error rate graph of Section force

Figure 11 showed that:

- Current approach has a large variation in error rates and more than 10% error.
- In the current, error rates tend to increase with decreasing cross-sectional force.
- Error rates of new approach are small variations, in many ways within 10%.

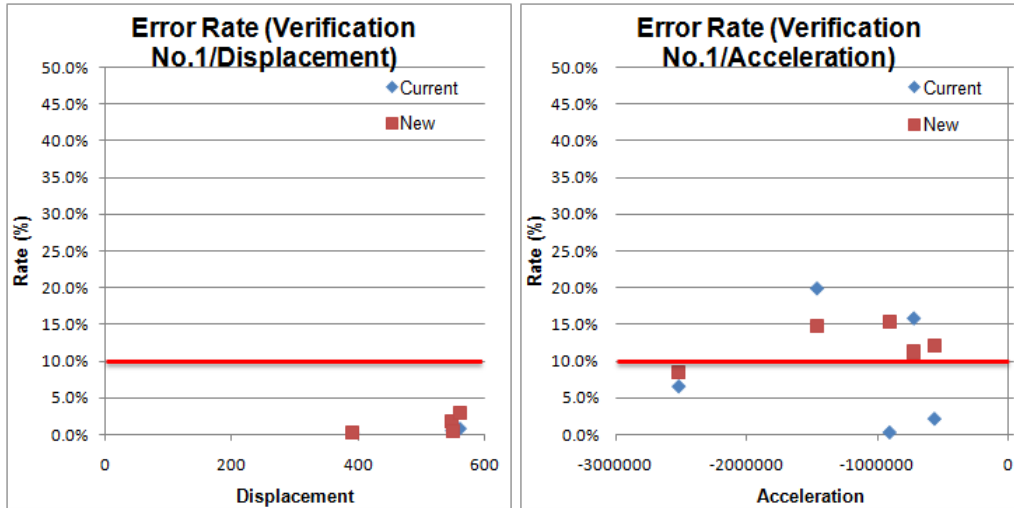


Figure 12. Result 2 – Error rate graph of Displacement and Acceleration

Figure 12 showed that:

- The error rate of displacement is low overall, so the difference of both approaches is not found.
- Sporadic acceleration trend (No trend).

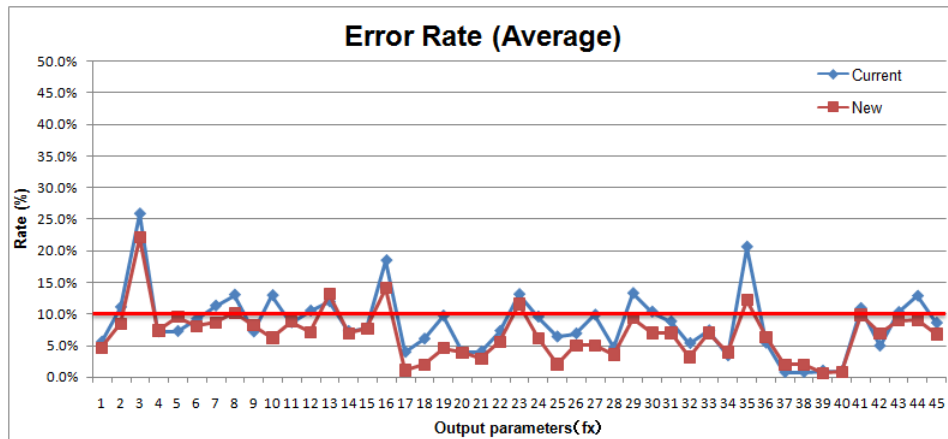


Figure 13. Summary Result – Average error rate

Figure 13 showed that:

- Most of large error points of current approach are improved by new approach.
- Error rate of new approach is generally tended to be equal or lower than current one.

5. Study of new approach

Using Isight, two (2) kinds of tests, mathematical function and FEM simulation, were conducted to validate new approach to create Approximation model.

Below things are gained from each test.

5.1 Mathematical function case

This test confirms that new approach using exploration sampling method can find top and valley points of a response surface and catch a feature of the surface effectively.

5.2 FEM Crash simulation case

New approach for Approximation modeling can improve large error rate points and reduce rate value than current one.

This result shows:

- Screening of Fitness function suppressed worse of the error rate because it searched the top and valley points of a response.
- New approach has an ability to improve a complicated response surface complex that is difficult to approximate by current approach.
- Optimized Hyper Latin Cube method of DOE for initial sampling can help to accurate Approximation model.

6. Conclusion

Strong point of new approach is to have Screening of Fitness function that is able to search the top and valley points of a response surface easily and stop to create duplicated sampling points. It can lead to create Approximation model with good accuracy. Two (2) examples of the approach are verified that small error rate can be gained and large error can be reduced. Also, OHLC method of DOE is best match with this new approach.

7. Reference

1. M. Arakawa, H. Nakayama, and H. Ishikawa, "Approximate Optimization Using RBF Network and Genetic Range Genetic Algorithms," The Japan Society of Mechanical Engineers, C70-697, 2004.
2. M. Arakawa, T. Miyashita, and H. Ishikawa, "Development of Genetic Range Genetic Algorithms," The Japan Society of Mechanical Engineers, C70-695, 2004.

8. Acknowledgment

The new approach for generating approximation model that we propose has been proven using two example cases. This approach more accurately captured the top and valley points on complex response surfaces to assist model creation in the accurate approximation less computational cost. Moreover, Isight can be used to create this kind of approach far more easily than the legacy one, iSIGHT.