IRIS: Iterative and Intelligent Experiment Selection

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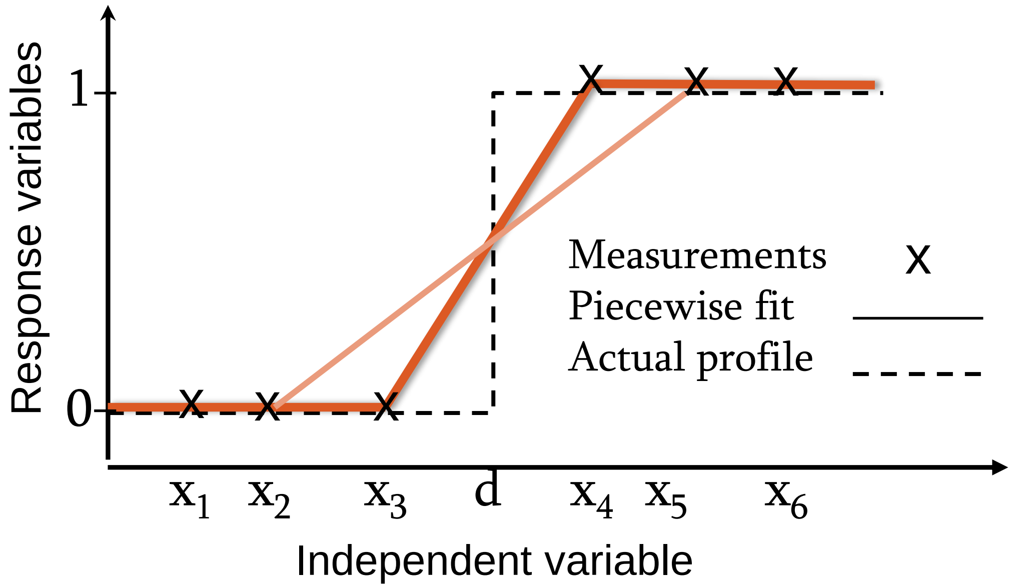
OUTLINE

- **Motivation**
- **Related work**
- **IRIS method**
- **Evaluation**
- **Tuning guideline**
- **Conclusions**

MOTIVATION

- Benchmarking is not always cheap: time, resource limits

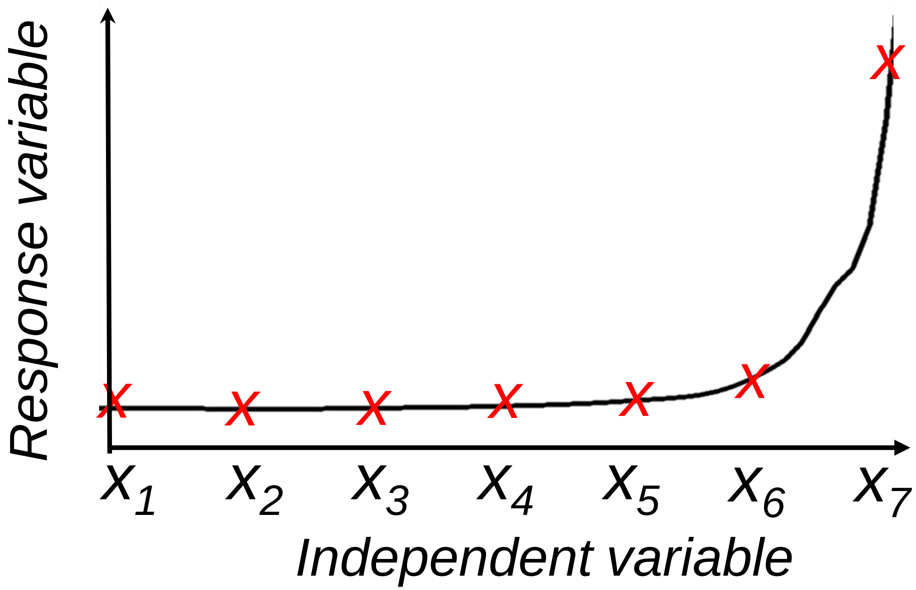
Simple Scenario: Step function



- Not all measurement points have the same value
- The position of points affect the accuracy of the fit
- Selecting points closer to step → more accurate fit with less budget

MOTIVATION

a more realistic case



- Experiment results from a real server
- Removing points X_2 to X_5 has little effect on prediction accuracy

RELATED WORK

- **Response Surface Methodology**
  - Select most effective parameters
  - Find optimum point of the system function
  - e.g. Box–Behnken, fractional factorial
- **Regression based, iterative function prediction techniques**
  - Build model in each iteration
    1. More costly due to model validation techniques
    2. Model error can propagate into future iterations

RELATED WORK

- **The problem scope**
  - Given the previously identified independent variables of interest, how to select the placement of experiment points?
- **Criteria**
  - Should consider both **independent** and **response** variables when deciding about the next experiment point
  - Scalability for scenarios with many independent variables

IRIS
OVERVIEW

Two steps algorithm:

1) Initial Point Selection

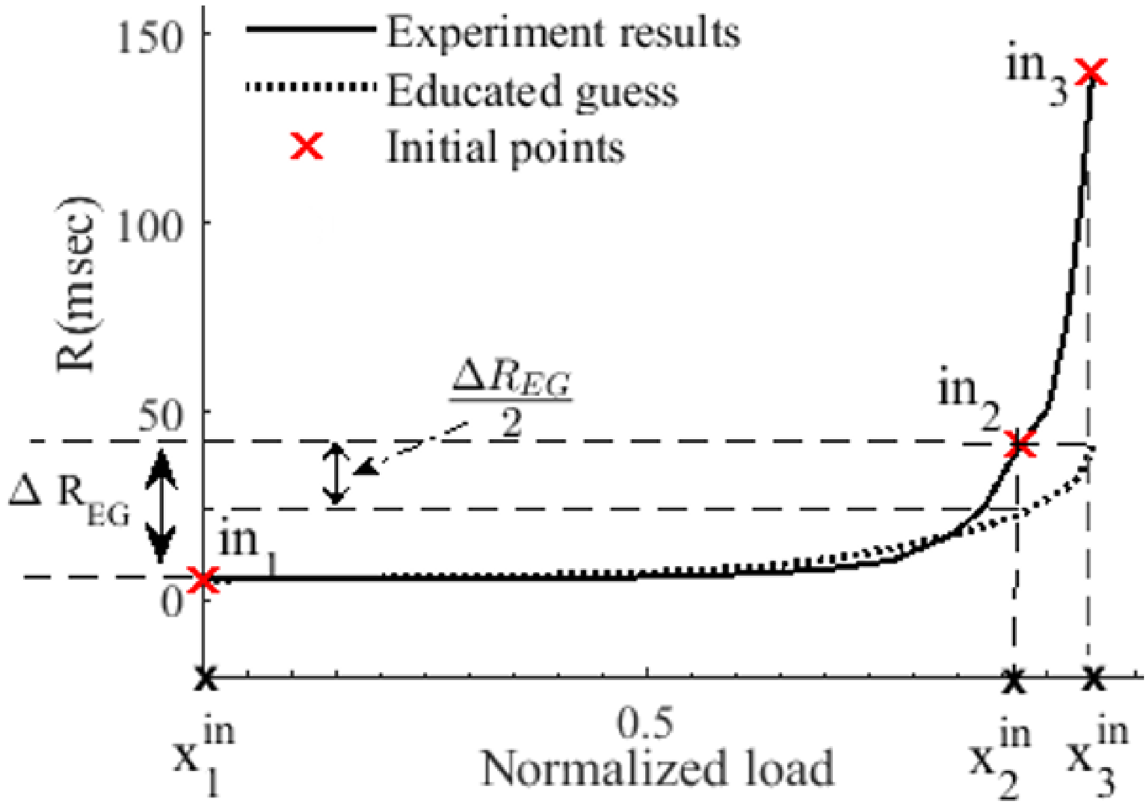
- Select a set of initial points to run the experiment based on:
  - An educated guess (e.g. a queueing model, …)
  - Or a linear assumption

2) Iterative Point Selection

- *Assumption:* The experiment budget is limited
  - IRIS iteratively selects the next point to run the experiment, until it runs out of budget
  - Each point is selected based on the results of all previous experiments

IRIS
INITIAL POINT SELECTION

A multi-core web server (load vs. response time)



- An educated guess: a layered queueing model (LQM) for the system with estimated resource demands

IRIS
ITERATIVE POINT SELECTION

Inputs

- a list of already measured $(\boldsymbol{x_i} \,;\, \boldsymbol{y_i})$ points where $1 \leq i \leq N_i$
- $\boldsymbol{N_t}$: total experiment budget
- $\boldsymbol{\alpha}$: gain trade-off factor

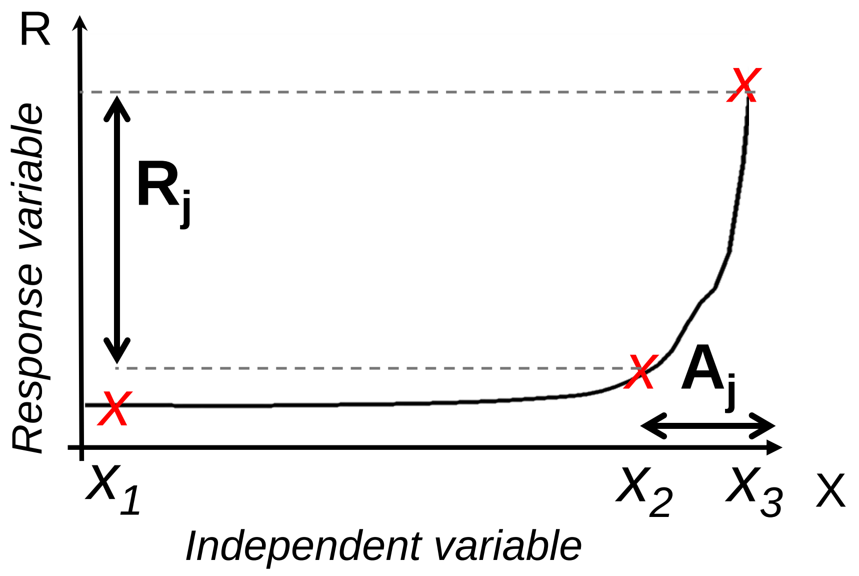
output

- List of all experimented points $(\, \boldsymbol{x_j} \,;\, \boldsymbol{y_j} \,)$ where $1 \leq j \leq N_t$

IRIS
GAIN FORMULA

- Gain for each interval

$$G_j = A_j^{\alpha} * R_j^{1-\propto}$$



  - $A_j = Size\ of\ interval$
  - $R_j = |R(x_{j+1}) - R(x_j)|$
  - Trade-off factor: α

IRIS – ITERATIVE PHASE

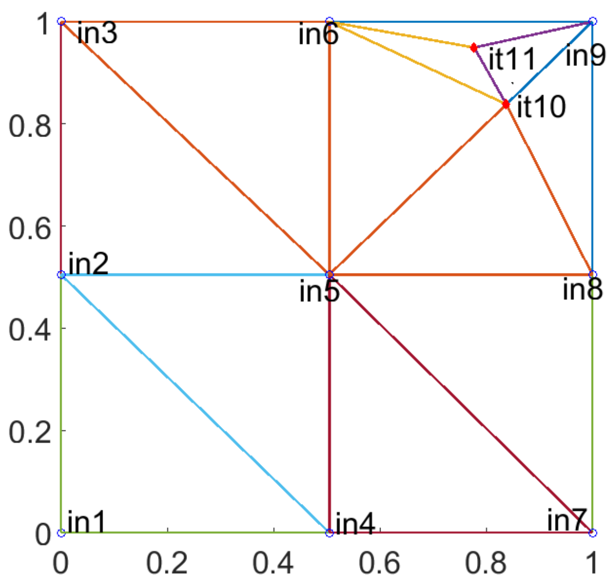
algorithm

1. $n=N_i$, $P = \{p_i \mid 1<i<N_i\}$
2. For each of thr n-1 intervals $[x_j : x_{j+1}]$ where $1 \leq j < n$, calculate Gj
3. Find the interval $[x_{k:} x_{k+1}]$, where G_k= max{Gj}
4. $p_n = \frac{(x_k + x_{k+1})}{2}$, $P = P \cap \{ P_n \}$, $n=n+1$
5. If ($n \leq N_t$) then *goto* 2, else END

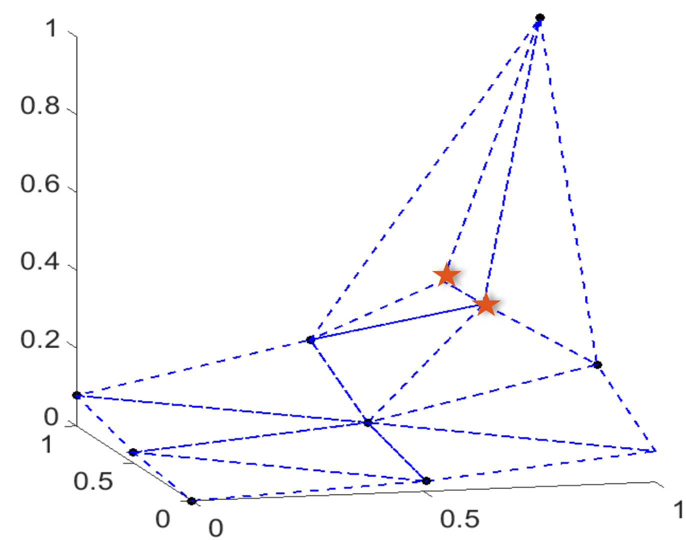
IRIS
MULTI-DIMENSIONAL SCENARIO

Delaunay triangulation to calculate *Aj*

- A unique planar triangulation of the independent variable space
- The resulting triangles consist of points with high proximity
- Easy to calculate
- Generalizes to multiple dimensions



A_j = Area of the triangles



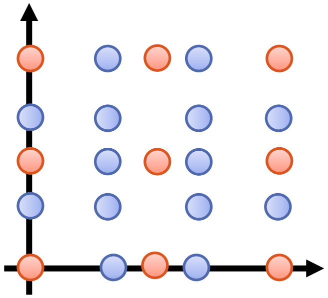
R_j = Maximum difference in response variables of the 3 nodes in each triangle

EVALUATION
BASE-LINE: EQUAL DISTANCE POINT SELECTION

- Equal Distance Point Selection (EQD)
  - Possible range of each independent variable is divided into N -1 equally sized intervals.

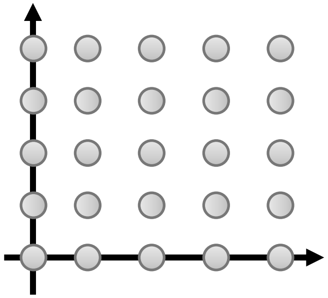
***Multi-stage* EQD**: available point budget is spent in multiple stages of EQD

N= 9 → N= 23



***Single-stage* EQD**: all the budget is spent in a single round (penalty free)

N= 9 → N= 16 → N= 25



EVALUATION
COMPARISON METRICS

- **Average Absolute Error**

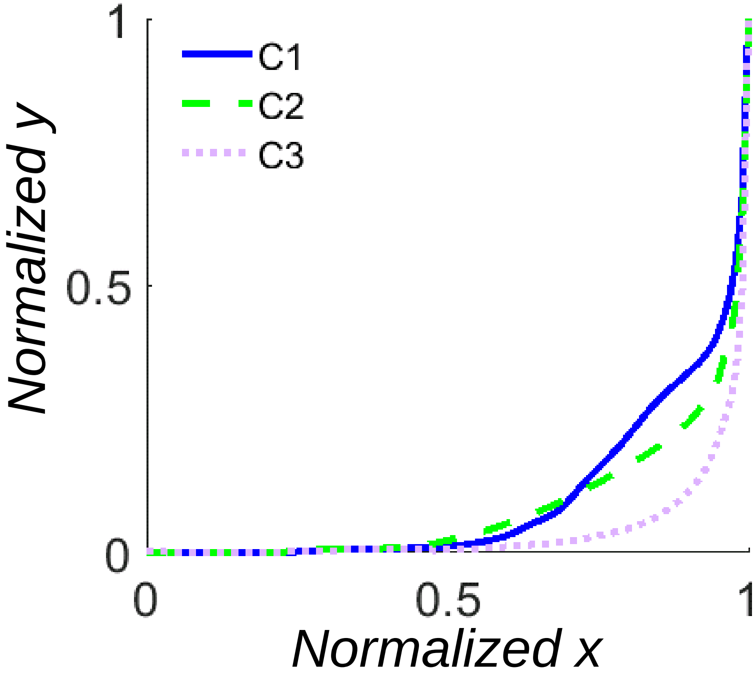
$$AAE = \frac{\sum_{j=1}^{n} | R_{PRD}(X_j) - R(X_j)|}{\sum_{j=1}^{n} R(X_j)}$$

- **Error Reduction Ratio**

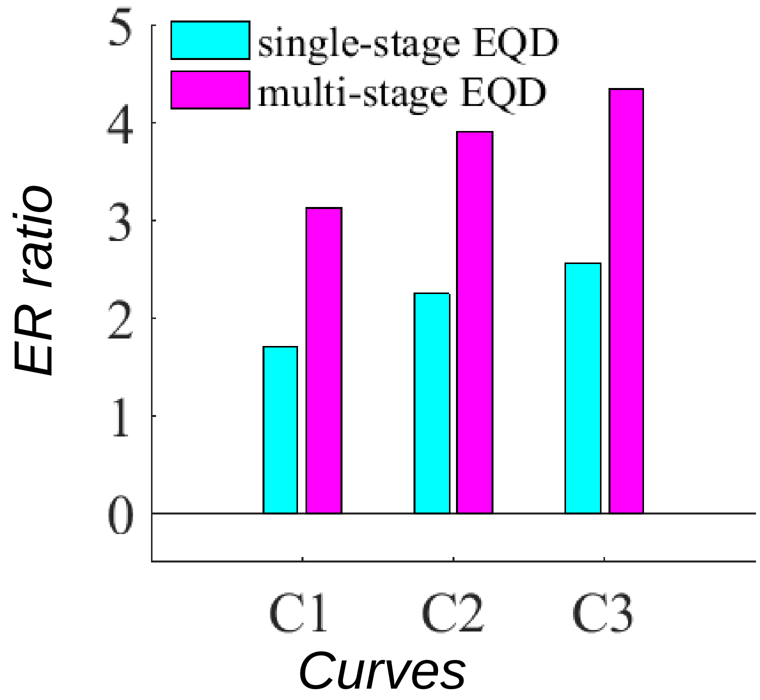
$$ER = \frac{(\overline{AAE}_{baseline} - \overline{AAE}_{IRIS})}{\overline{AAE}_{IRIS}}$$

EVALUATION
SINGLE INDEPENDENT VARIABLE

System functions



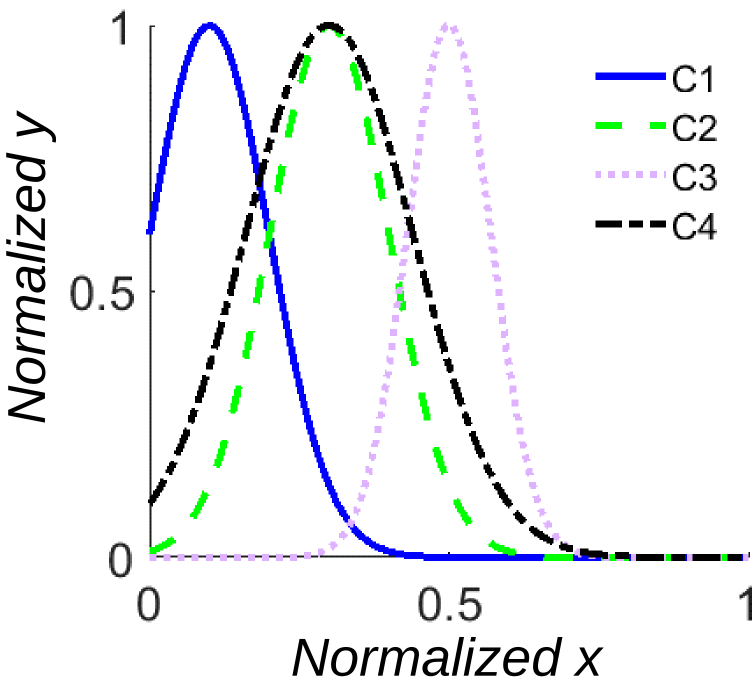
Error Reduction Ratio



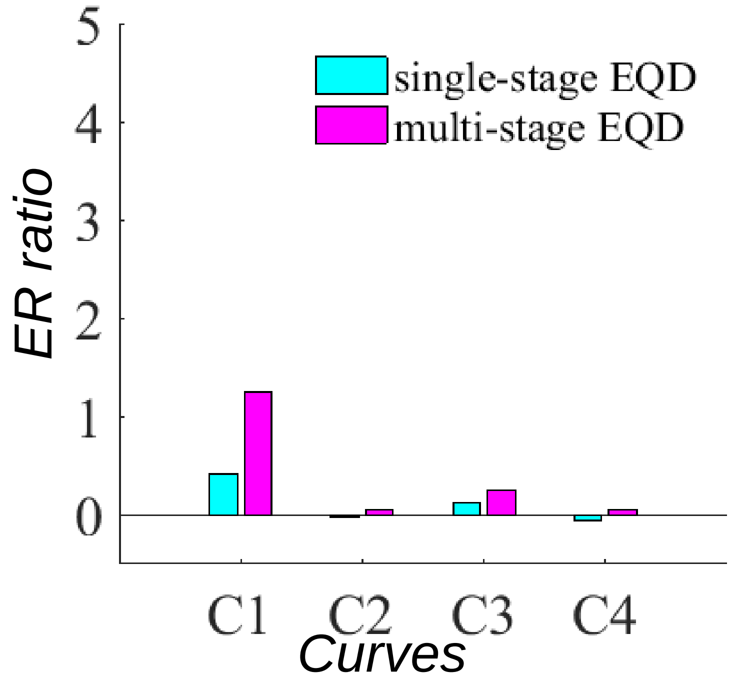
- An experimental system with web workload on a multi-core server
- **Result:** Higher ER ratio in the graph with larger flat region

EVALUATION
SINGLE INDEPENDENT VARIABLE

System functions



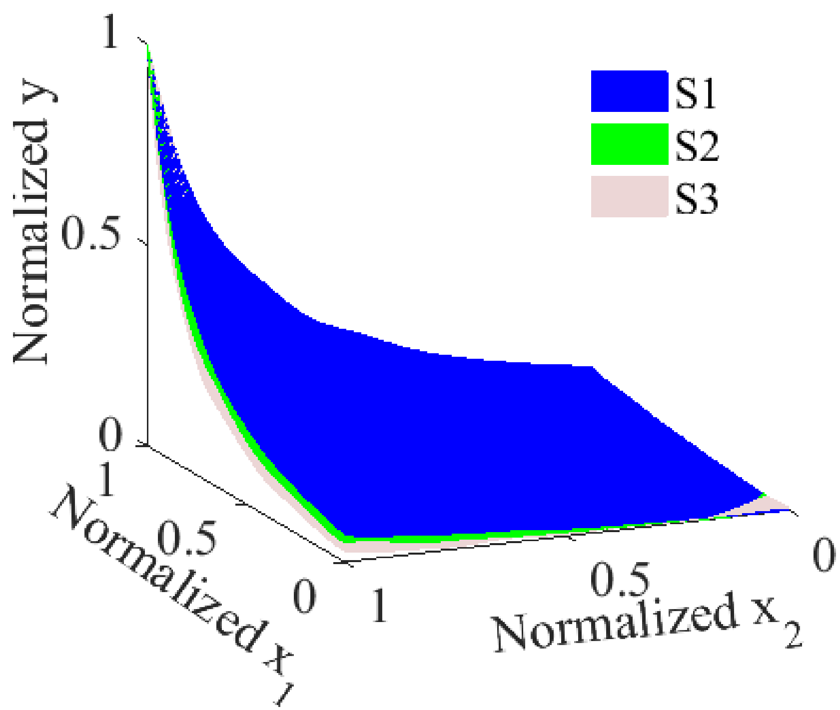
Error Reduction Ratio



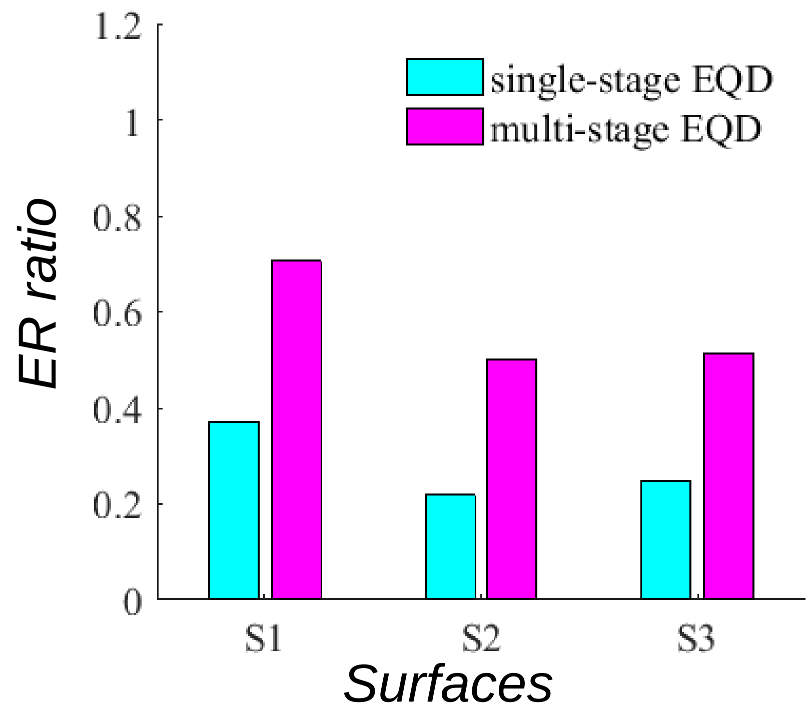
- A group of bell-shaped synthetic functions representing normal distributions
- **Result:** IRIS more effective for non-symmetric curves

EVALUATION
MULTIPLE INDEPENDENT VARIABLES

System functions



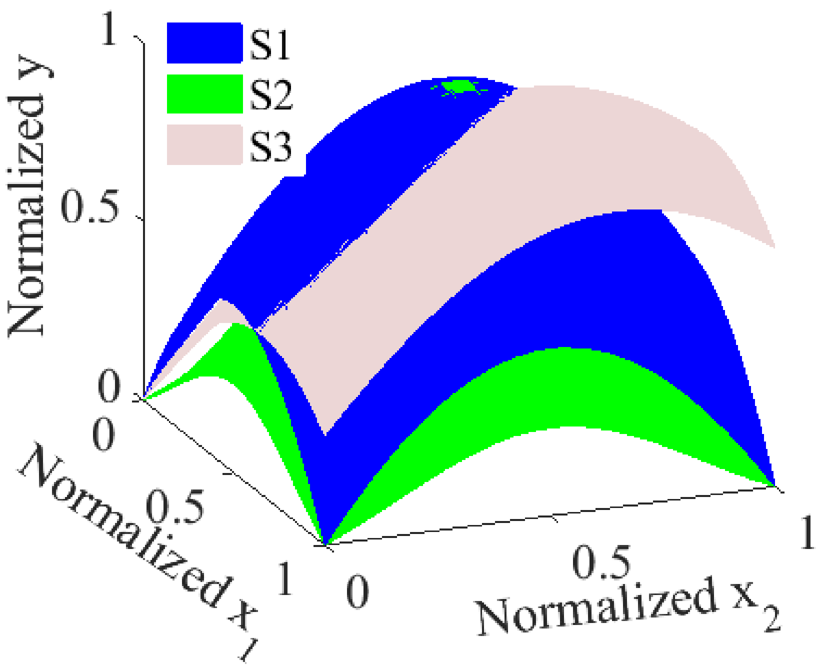
Error Reduction Ratio



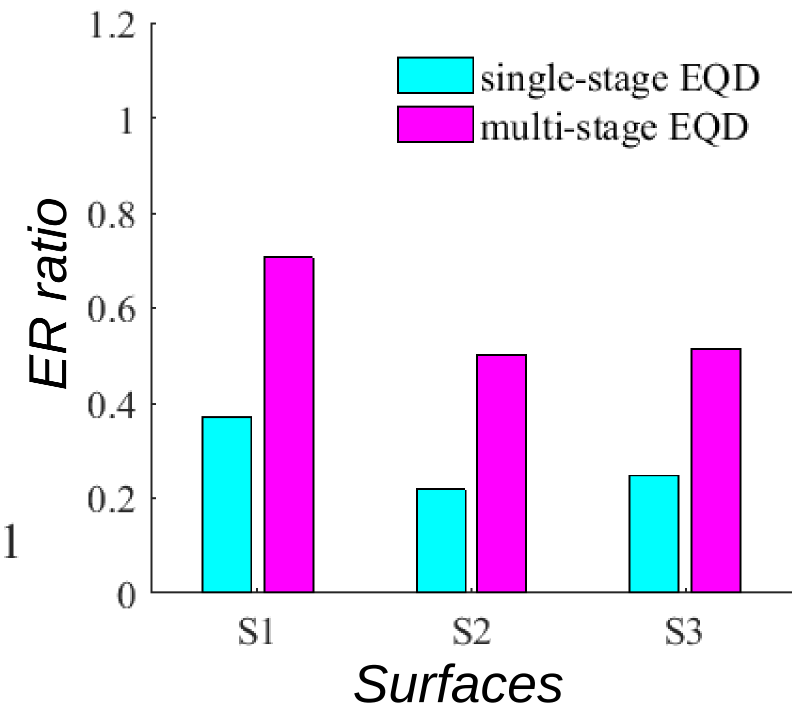
- Load-response time dataset with two load parameters as independent variables
- **Result:** Lower ER due to large flat surface

EVALUATION
MULTIPLE INDEPENDENT VARIABLES

System functions



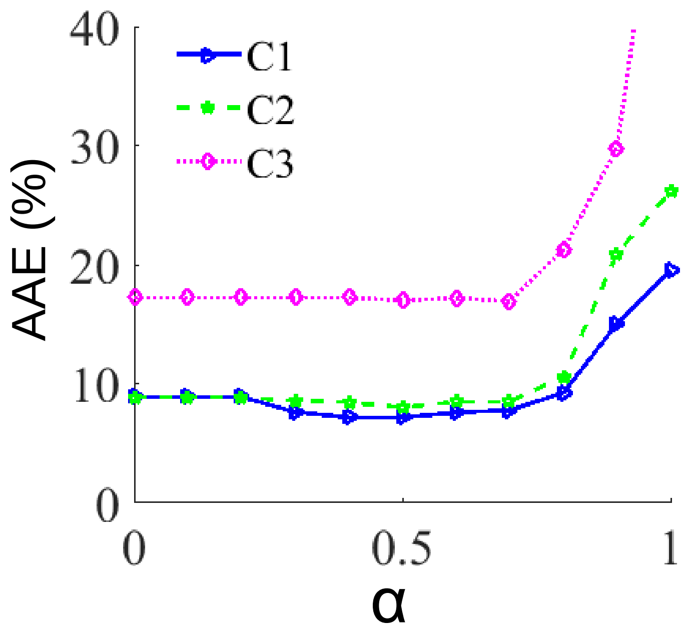
Error Reduction Ratio



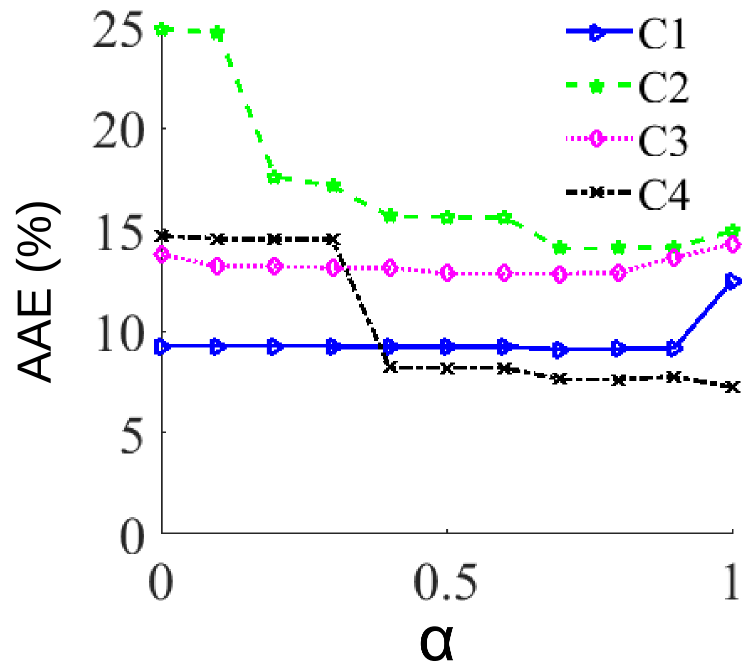
- A group of three synthetic Gaussian surfaces with different means and standard deviations
- **Result:** higher ER in surfaces with larger slope

TUNING GUIDELINE
GAIN TRADE-OFF FACTOR

Load- response time



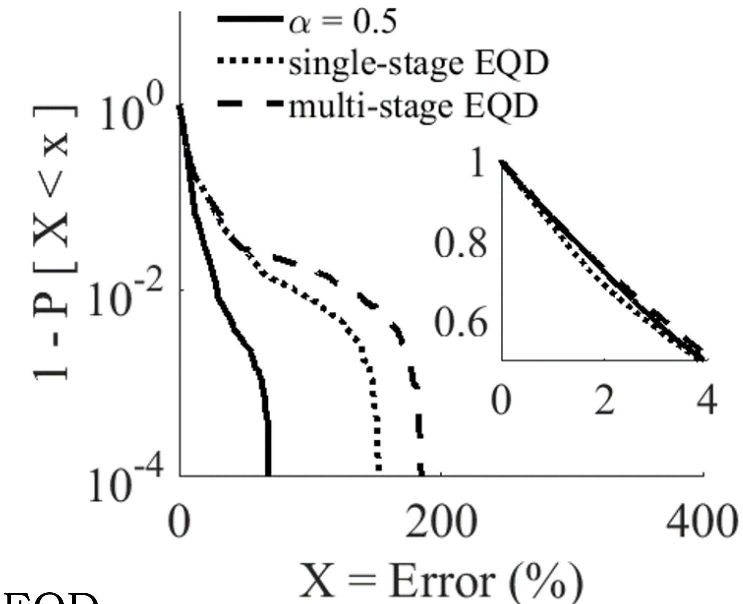
Bell-Shaped

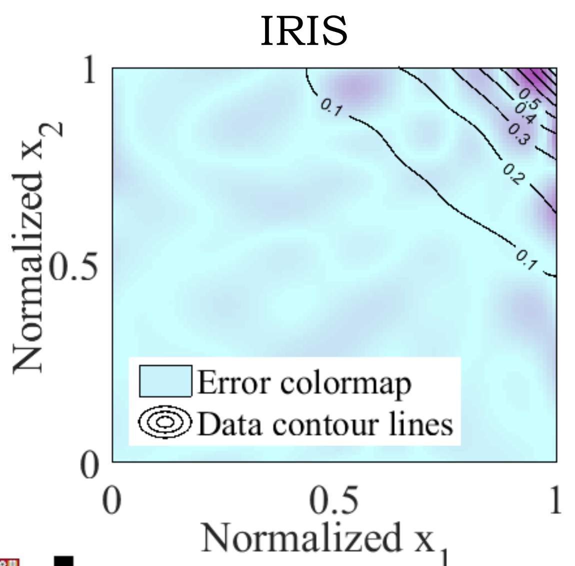


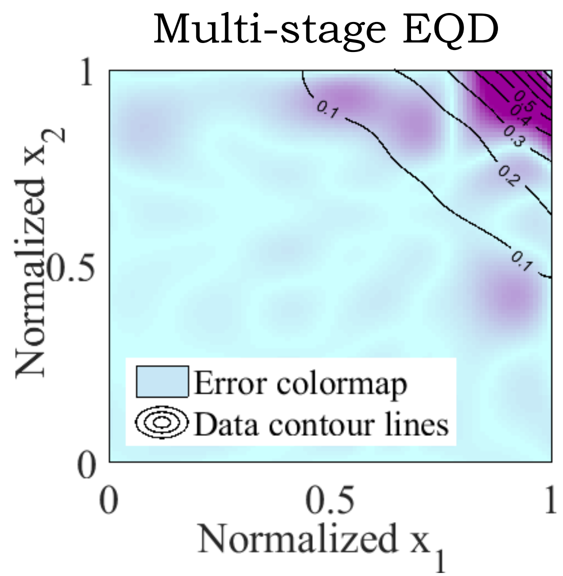
- *A convex sharp knee in the system function → Smaller α values*
- *A concave and symmetric maximum point → Larger α values*

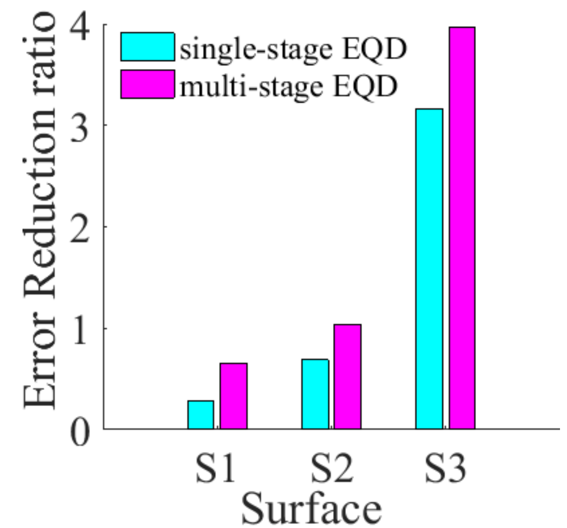
TUNING GUIDELINE
ERROR DISTRIBUTION

- IRIS can improve prediction in the ***Region of Interest*** in the parameter space
- **Trade-off*:*** Slightly lower prediction accuracy for the rest of the parameter space









CONCLUSIONS

- IRIS outperforms equal distance for the majority of the evaluated systems
- Trade-off factor is tuned through initial system knowledge
- More reduction in Region of Interest
- In future, we are going to examine systems with higher dimensionality

Thank you!

Questions?

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