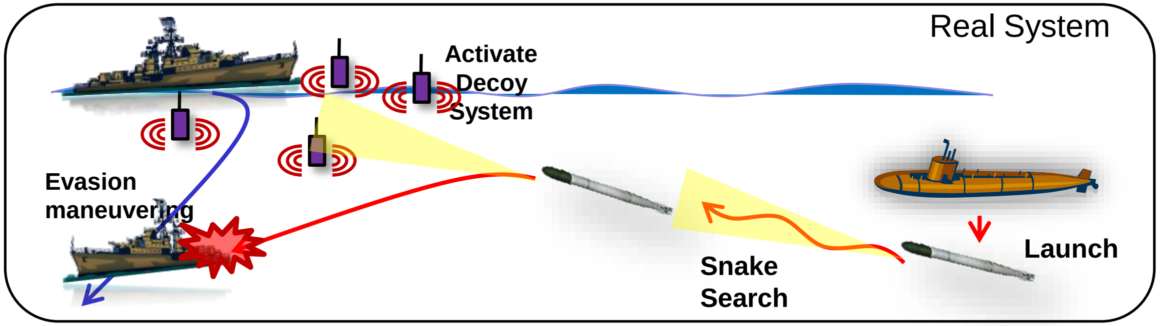
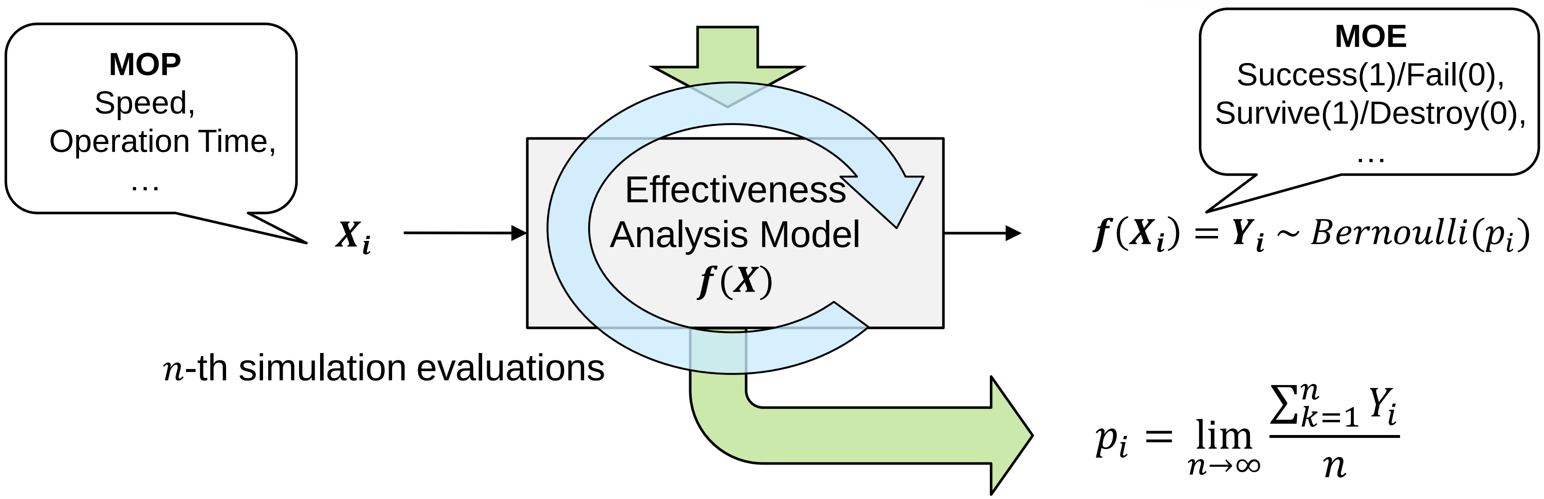
Effectiveness Analysis Model





Find p_i(Measure of Effectiveness, MOE) from given X_i(Measure of Performance, MOP)

Simulation Based Optimization (1/2)

- For Effectiveness Analysis Model
  - Find input scenarios that maximizes(or minimizes) p_i

$$\boldsymbol{X}_o = \arg\max_{X\in\Theta} p_i = \arg\max_{X\in\Theta}\left[\lim_{n\to\infty}\sum_{k=1}^{n} f(X_i)/n\right]$$

$f(X)$: Effectiveness Analysis Model
p_i: Effectiveness of X_i decided by $f(X)$
$\boldsymbol{X}_o$: Optimal Solution Set
$X_i = [x_1, x_2, \ldots, x_n]$: Input Scenario
Θ: Range of input scenarios
n: # of simulation evaluations

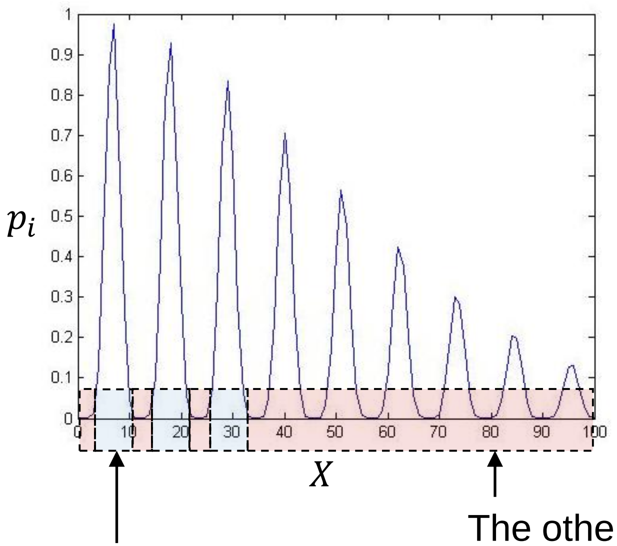
  - In real world, infinite evaluations is impossible.
    ➔ Get point estimate $\widehat{p_i}$ by limited n-th evaluation

$$\widehat{p_i} = p_i + N(0, p_i(1-p_i)/n) = p_i + \boldsymbol{noise}$$

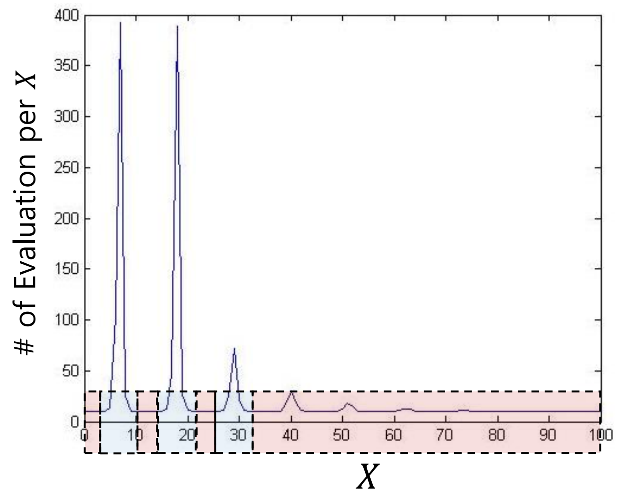
How can we find input scenarios that maximizes(or minimizes) $\boldsymbol{p_i}$ with reducing an effect of the $\boldsymbol{noise}$ in limited evaluations?

Simulation Based Optimization (2/2)

- To minimize an effect of the $noise$
  - Increase n (# of evaluations)
    - Increasing n for all input scenarios is inefficient
  - Increase n for input scenarios which has a probability to be the optimal solution and decrease n for the others



Allocate n

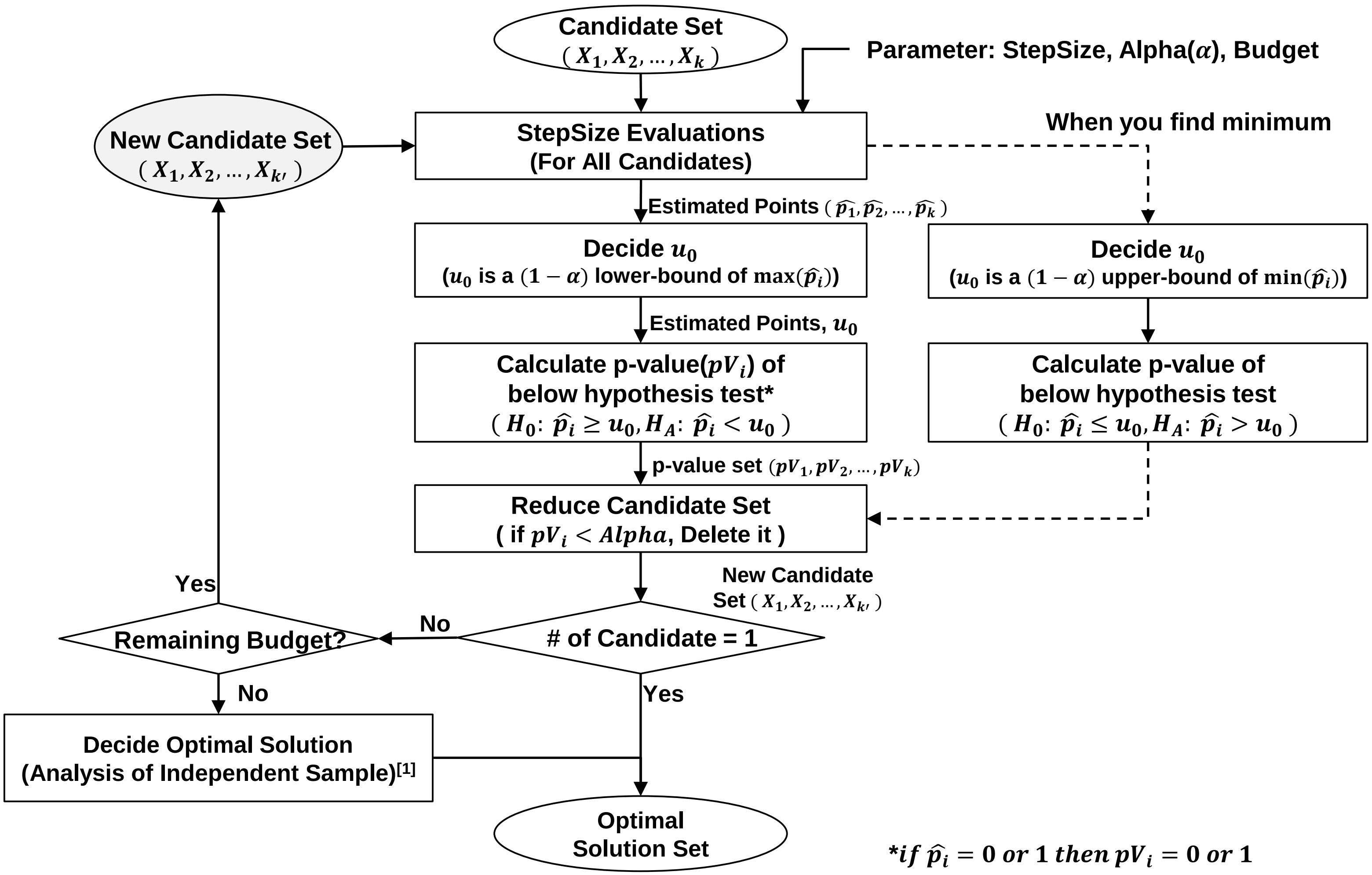


The others ➔ Decrease n

More likely to be the optimal solution ➔ Increase n

Proposed Algorithm

Proposed Algorithm (1/2)

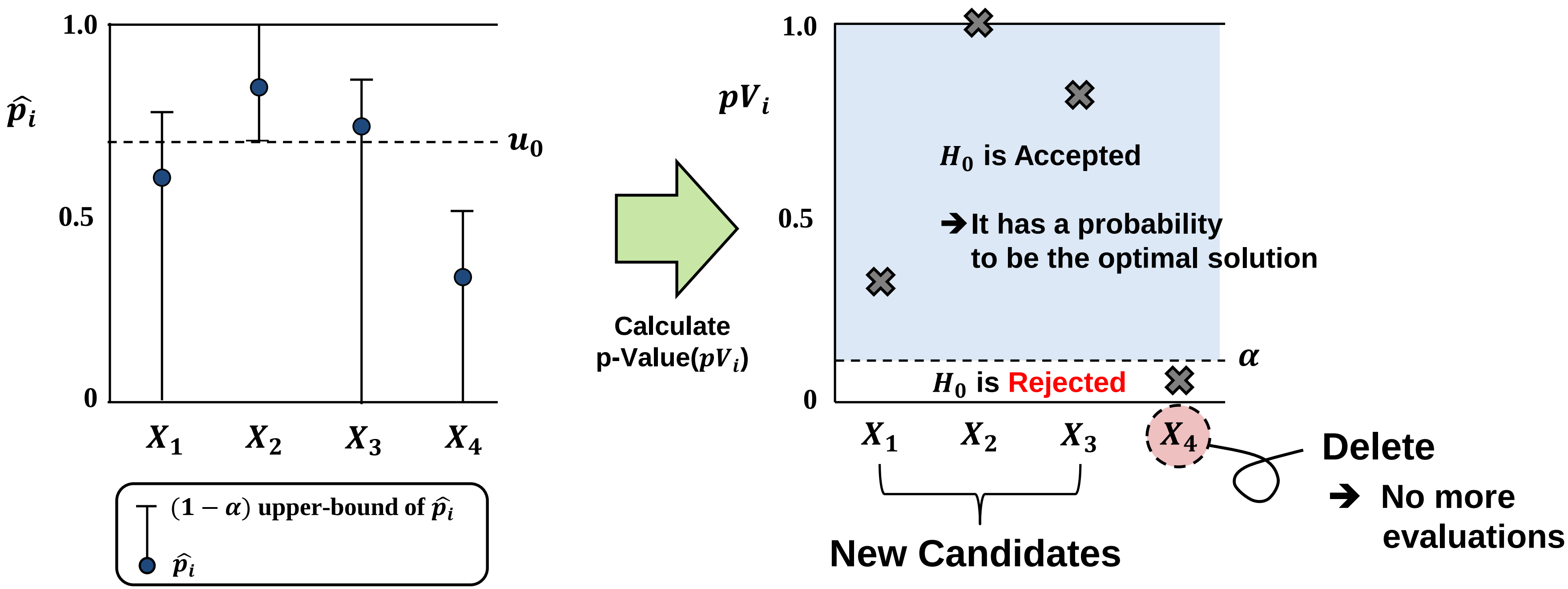


$*if\ \widehat{p}_i = 0\ or\ 1\ then\ pV_i = 0\ or\ 1$

[1] Walpole, Ronald E., et al. *Probability and statistics for engineers and scientists*. Vol. 5. New York: Macmillan, 1993.

Proposed Algorithm (2/2)

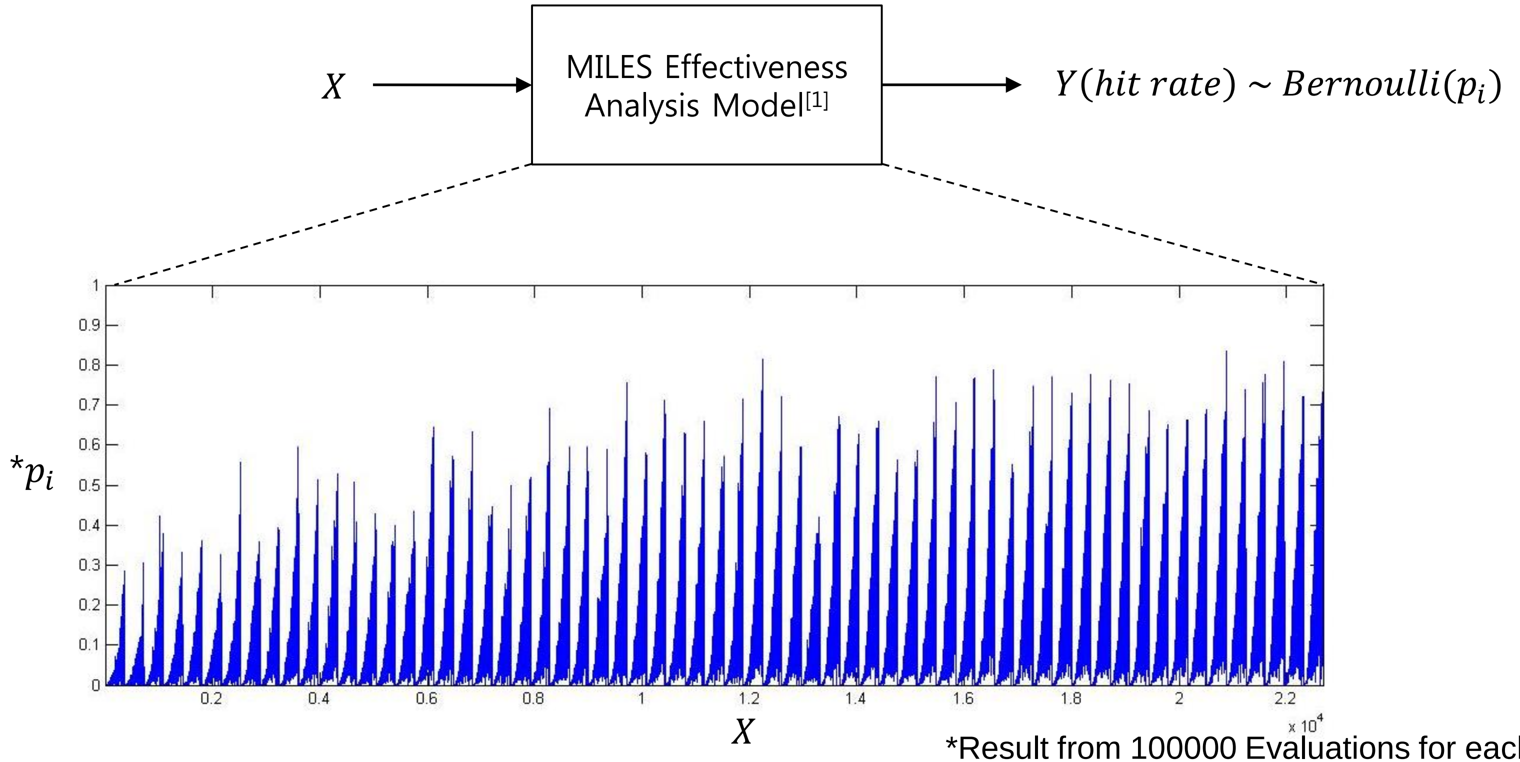
- Hypothesis Test[1]
  - H_0: $\hat{p}_i \geq u_0, H_A$: $\hat{p}_i < u_0$
  - $u_0 = \max(\hat{p}_i) - t_{\alpha,n-1} \times \sqrt{\max(\hat{p}_i)(1-\max(\hat{p}_i))/n}$



[1] Walpole, Ronald E., et al. *Probability and statistics for engineers and scientists*. Vol. 5. New York: Macmillan, 1993.

Case Study: MILES Model (1/2)

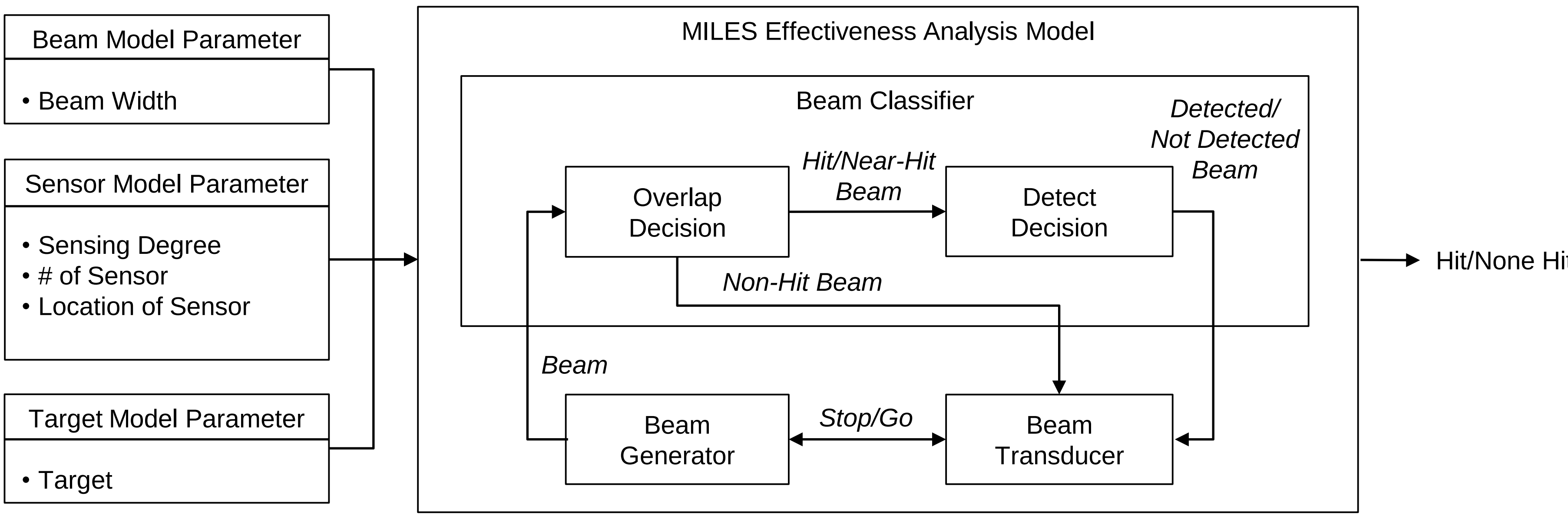
- Multiple Integrated Laser Engagement System (MILES)
  - Find input scenarios to maximize effectiveness(hit rate)
  - Input scenario = [Beam Width, Sensing Degree, # of Sensor, Location of Sensor, Target]



*Result from 100000 Evaluations for each X

[1] 김탁곤, 최선한, 이순주, 최창범, 박판준, 최태영, 김수범. "KCTC 마일즈 장비의 명중 감지율 계산을 위한 광 공학 모델 개발 및 활용 방안," 제 5회 육군 M&S 학술 대회, 2012년 11월

Case Study: MILES Model (2/2)



Parameter	Range
Beam Width (cm)	{ 5, 10, ..., 100 } (20)
Sensing Degree (°)	{ 5, 10, ..., 90} (18)
# and location of Sensor	{ P_1, P_2, ..., P_{63} } (63)
Target	{ T_1 } (1)

# of Input
20×18×63×1 = 22680

×

Time for 1 Evaluation
0.000524 sec

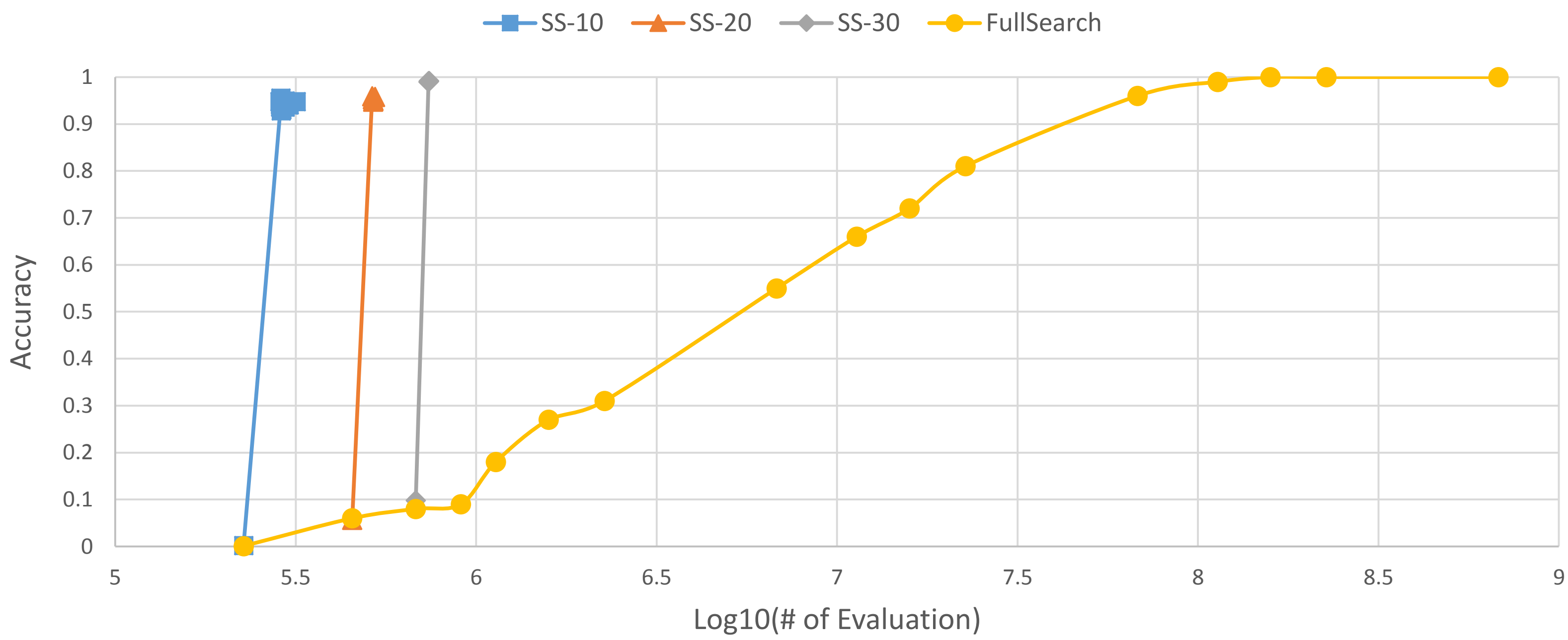
×

Ex) Full Search
(10000 Evaluation)

=

About 33 hours

Case Study: MILES Model - Result



Proposed algorithm is much faster than FS
SS-10 (393 times), SS-20 (220 times), SS-30 (153 times)

Parameter Setting: Alpha 0.01, 1000 replications, StepSize(SS) 10 ~ 30

Conclusion & Future Works

- Conclusion
  - Propose simulation based optimization algorithm for effectiveness analysis model
  - Using the hypothesis test, classify input scenarios
  - Increase n for input scenarios which has a probability to be the optimal solution and decrease n for the others
    ➔ That makes the algorithm use a limited budget efficiently.
  - Show enormous improvement of performance (Speed and Accuracy)

- Future Works
  - Apply the proposed algorithm to general stochastic model (noise model)
  - Expand the algorithm to reverse simulation framework

This work was supported by Defense Acquisition Program Administration and Agency for Defense Development under the contract UD140022PD, Korea.