Robust Next Release Problem: Handling Uncertainty During Optimization

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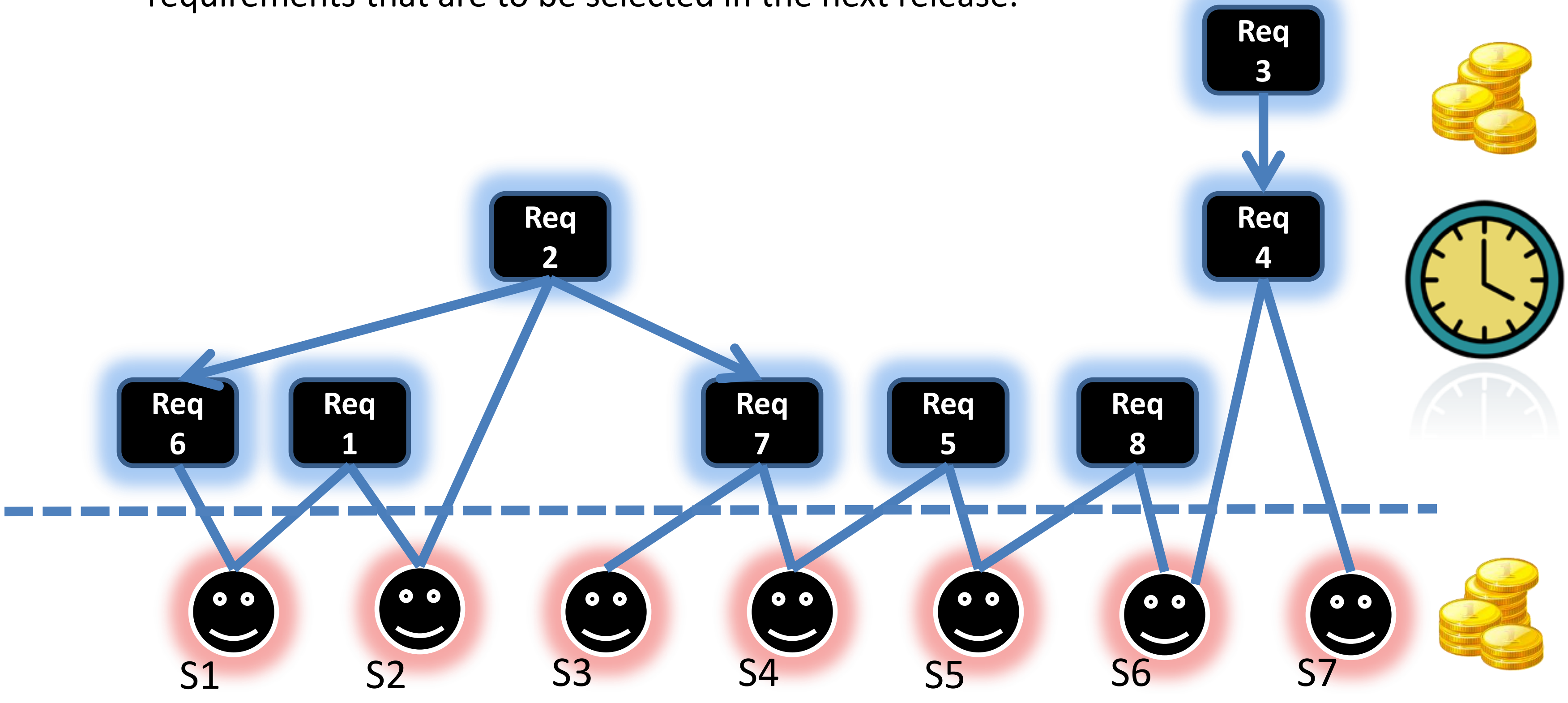
Overview

- Uncertainty is inevitable in real world requirement engineering. It has a significant impact on the feasibility of proposed solutions and thus brings risks to the software release plan.

- This paper proposes a multi-objective optimization technique, augmented with Monte-Carlo Simulation, that optimizes requirement choices for the three objectives of cost, revenue, and uncertainty.

What is NRP

- The Next Release Problem (NRP) has been proposed to model the decision for customer profits and requirements costs in requirements engineering. [Bagnall2001]
  - the solution is presented as a decision vector $\vec{x} = \{x_1, x_2, \ldots x_n\}$ to determine the requirements that are to be selected in the next release.



Uncertainty in RE

- Uncertainty is inevitable in real world requirement engineering
  - What is the actual implementation cost?
  - What is the actual revenue?
  - What is the actual release time?
  - What is the final implemented functionalities.
- We have to make decision without much knowledge

Previous Point-based estimation MONRP

Expected Cost	Expected Revenue
£500	£700

↓

Expected Net-Revenue
£700 - £500 = £200

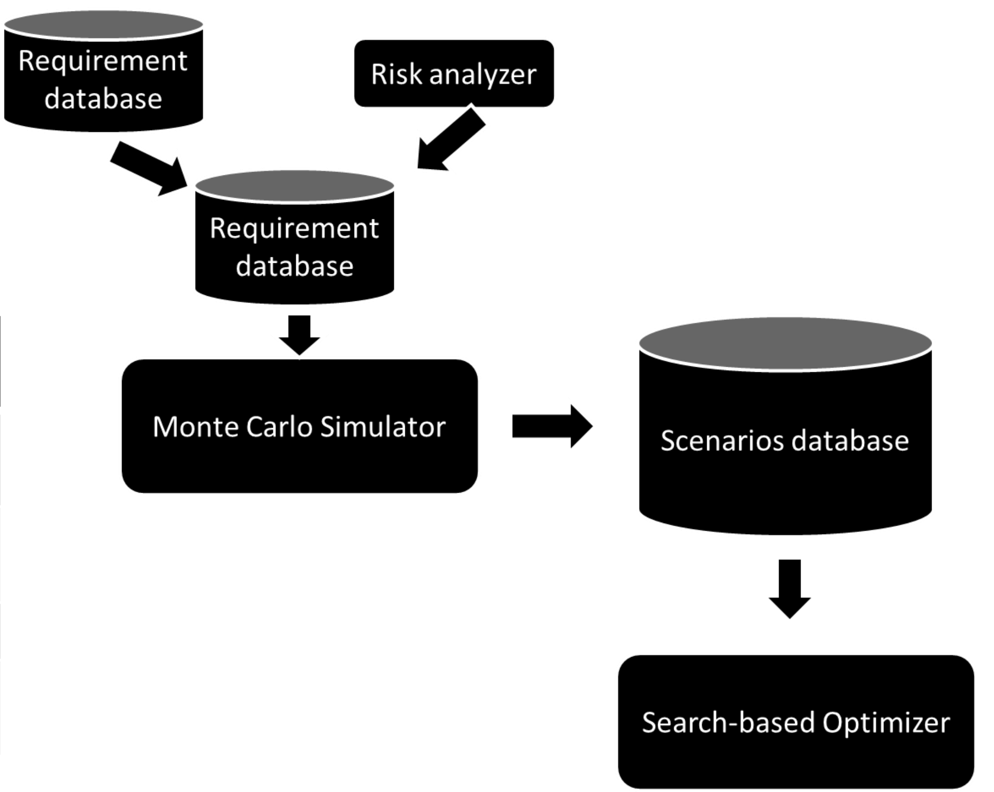
- There is a risk that the expected net revenue may be lower than a threshold assigned by decision makers due to uncertainty concerning the true revenue and cost.
- The development cost of the feature may exceed £500, and the revenue of the feature may lower than £700.

Motivation

- Previous work on requirements engineering undertook sensitivity analysis after optimizing the Next Release Problem (NRP)
- It is important to investigate uncertainty during the process of optimization rather than using post-analysis [Hans-Georg. Beyer2007]

Robust MONRP Optimization Framework

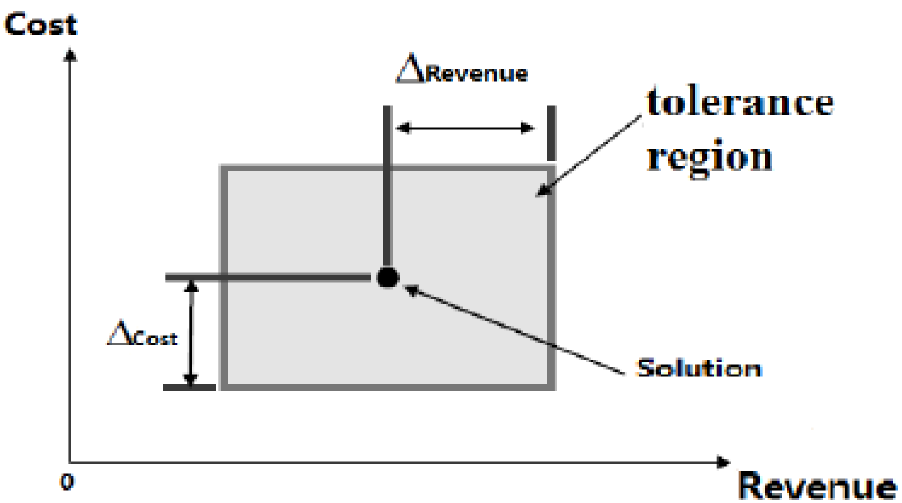
- We adopt a search-based optimization technique with Monte-Carlo Simulation (MCS) to address uncertainty and risk in the early stages of the software engineering development process.



	Scenarios 1	Scenarios 2	…	Scenarios n
Cost_Req 1	10	20	..	17
Cost_Req 2	6	6	…	6.5
…	…	…	…	…
Cost_Req n	15	4	…	25

- This paper considers two types of robustness in MONRP.
  - “reduction of the uncertainty size”, (MCNRP-US)
  - “reduction of the possibility that actual cost exceeds a threshold” (MCNRP-R)

- Uncertainty size
  - Uncertainty size is used to measure the tolerance region of the solutions of multi-objective optimization problem in d dimensions (d is the number of the objectives) [Li 2005]



The tolerance region of a MONRP solution

$$perimeter(\vec{x}) = \sum_{k=1}^{d} \frac{2 \cdot \Delta fitness_k(\vec{x})}{referent\_fitness_k}$$

$$volume(\vec{x}) = \prod_{k=1}^{d} \frac{2 \cdot \Delta fitness_k(\vec{x})}{referent\_fitness_k}$$

$$Size(\vec{x}) = \alpha \cdot volume(\vec{x}) + \beta \cdot perimeter(\vec{x})$$

- Failure risk
  - The probability that the actual cost exceeds a threshold determined by the decision maker.

$$Risk(\vec{x}) = Pro(actual\_cost(\vec{x}) > \theta \cdot Expected\_Cost(\vec{x}))$$

Experiments setup and results

MOTOROLA

- Four synthetic data sets (*S*1,*S*2,*S*3,*S*4) constructed from one real project data set from Motorola.
- There is no uncertainty information for the cost and revenue of requirements. we simulated these uncertainties according to the “triangle probability distribution”

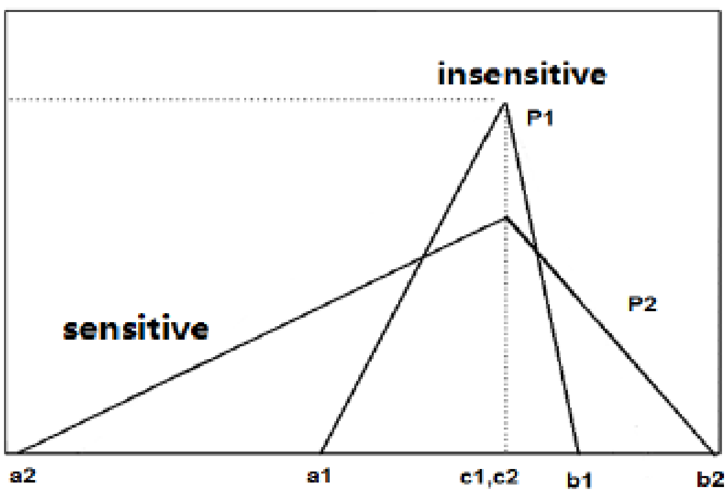


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Table 1: Illustrative fragment of *S1* data

	Cost			Revenue			
NAME	Mode	Min	Max	Mode	Min	Max	Sensitivity
REQ 1	100.00	79.42	127.91	3.00	0.65	3.32	insensitive
REQ 2	50.00	15.08	53.51	3.00	1.30	3.95	insensitive
REQ 3	300.00	270.74	1154.15	3.00	0.32	4.76	sensitive
REQ 4	80.00	52.73	105.30	3.00	1.31	5.50	insensitive
REQ 5	70.00	42.00	78.77	3.00	1.66	4.62	insensitive
REQ 6	100.00	87.34	133.04	3.00	1.01	4.19	insensitive
REQ 7	1000.00	620.75	3671.35	3.00	0.77	5.68	sensitive

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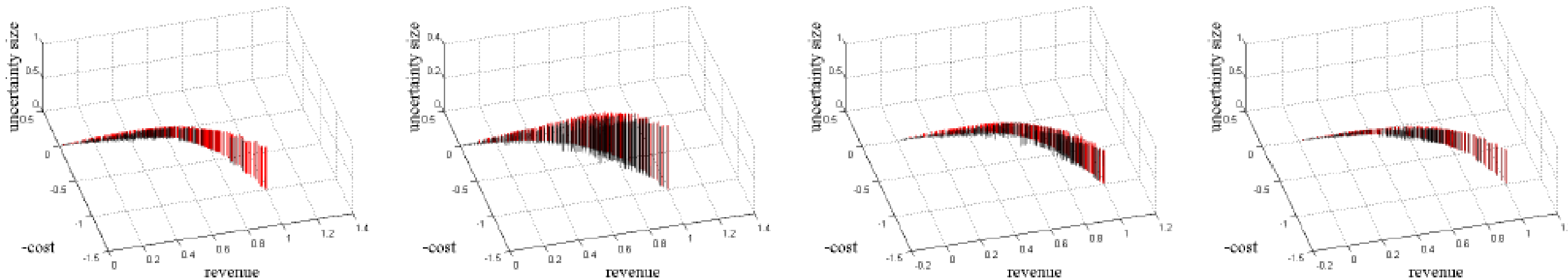
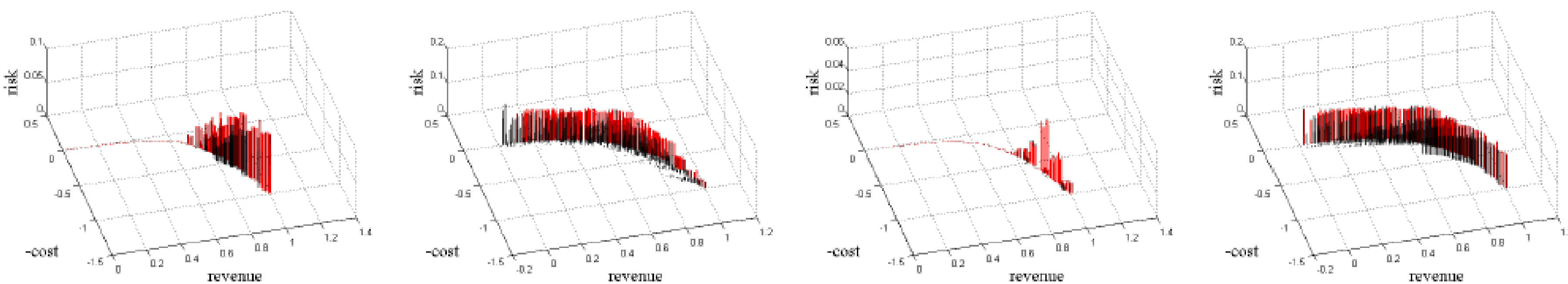


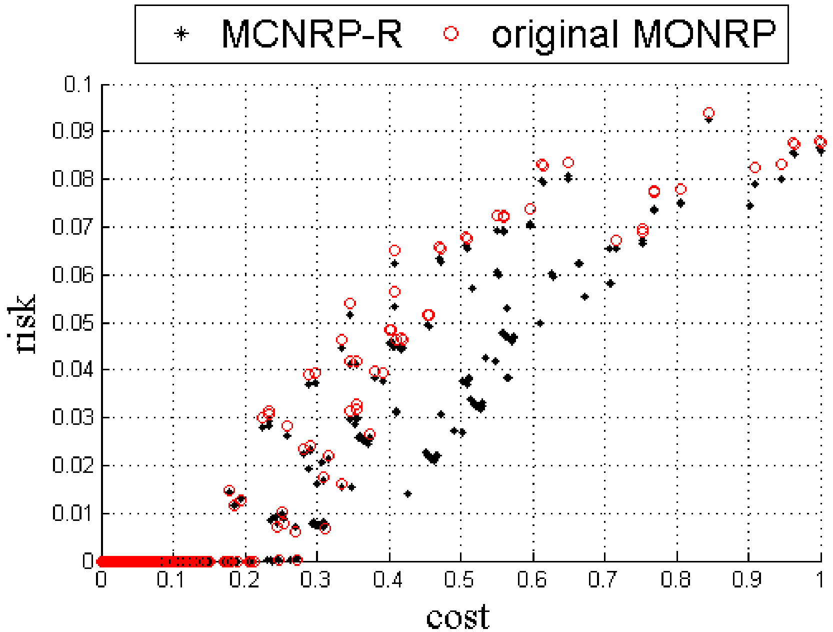
(a) The results of *E1* in *S1* (b) The results of *E1* in *S2* (c) The results of *E1* in *S3* (d) The results of *E1* in *S4*

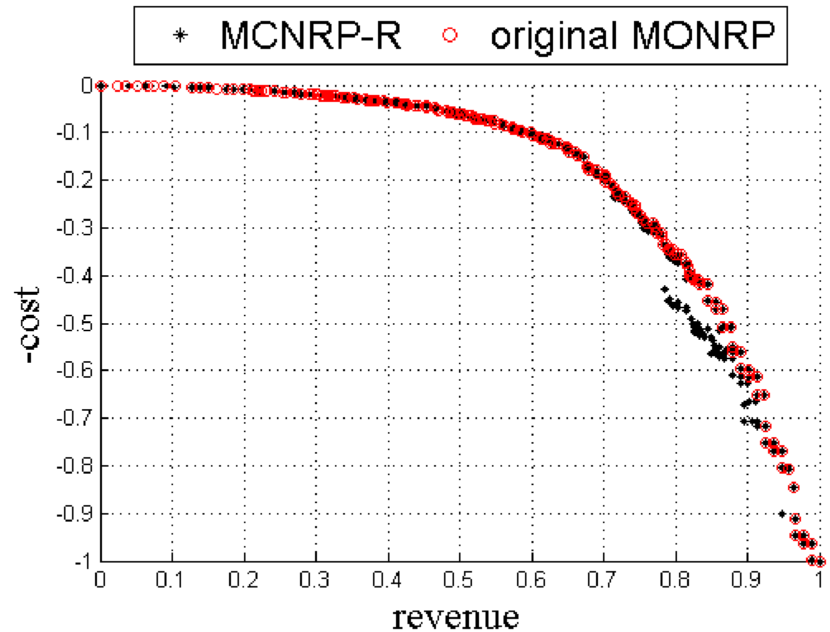
Figure 3: The Pareto-front of *MCNRP-US* and Original Approach



(a) The results of *E2* in *S1* (b) The results of *E2* in *S2* (c) The results of *E2* in *S3* (d) The results of *E2* in *S4*

Figure 4: The Pareto-front of *MCNRP-R* and Original Approach


MCNRP-R
original MONRP
risk
cost
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


MCNRP-R
original MONRP
-cost
revenue
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

RQ1&2 the efficiency and effectiveness

Table 2: The Robustness & Comparison of the *MCNRP-US* Approach and the Traditional Approach

	S1	*S2*	*S3*	*S4*
MCNRP-US	0.1531	0.1558	0.1850	0.1290
Original Approach	0.1983	0.1599	0.1993	0.1511
Price of Robustness	0.0110	0.0201	0.0154	0.0102
Robustness Improvement	22.78%	2.54%	7.19%	14.65%

Table 3: The Robustness & Comparison of the *MCNRP-R* Approach and the Traditional Approach

	S1	*S2*	*S3*	*S4*
MCNRP-R	0.0396	0.0404	0.0109	0.0591
Original Approach	0.0500	0.0755	0.0132	0.0888
Price of Robustness	0.0036	0.0253	0.0003	0.0285
Robustness Improvement	20.82%	46.49%	17.70%	33.37%

RQ3&4 The similarity of the results and the drive of the MONRP optimization

- Statistical analysis

Table 4: The Correlation of Rankings of Requirements

		MONRP&R	MONRP&US	US&R
S1	τ	0.9361	0.7345	0.7311
	p-value	< 0.000	< 0.000	< 0.000
S2	τ	0.8646	0.7872	0.8756
	p-value	< 0.000	< 0.000	< 0.000
S3	τ	0.9655	0.7233	0.7311
	p-value	< 0.000	< 0.000	< 0.000
S4	τ	0.8646	0.8713	0.8387
	p-value	< 0.000	< 0.000	< 0.000

In this table, R means MONRP-R, and US means MONRP-US.

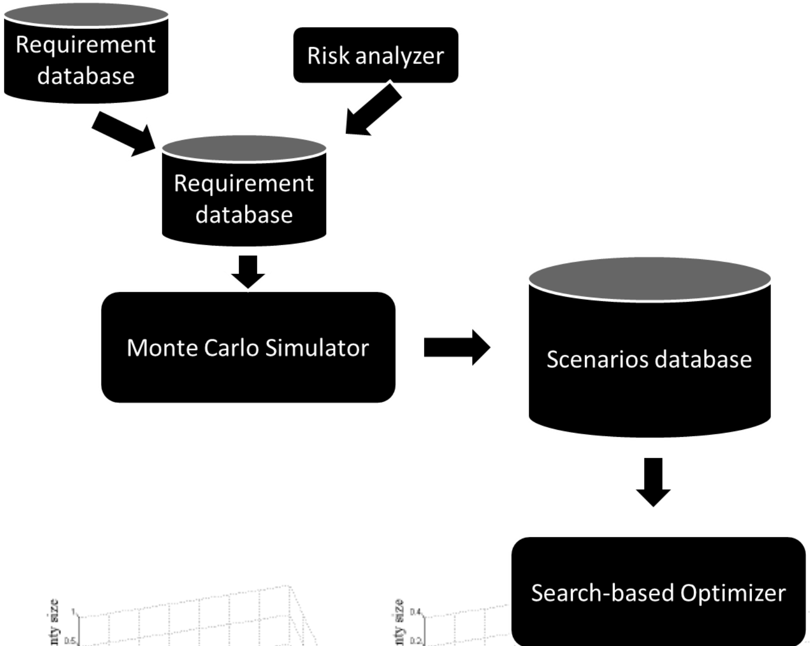
Table 5: The Correlation between the Attributes of Requirement and its Ranking

	Cost		Revenue		R/C	
MONRP	τ	$p-$Value	τ	$p-$Value	τ	$p-$Value
S1	-0.7748	< 0.000	0.0723	0.55358	0.9597	< 0.000
S2	-0.7569	< 0.000	0.1413	0.23846	0.9521	< 0.000
S3	-0.7771	< 0.000	0.074	0.54138	0.9521	< 0.000
S4	-0.7704	< 0.000	0.1346	0.26185	0.9554	< 0.000
MONRP-US	τ	$p-$Value	τ	$p-$Value	τ	$p-$Value
S1	-0.5899	< 0.000	0.0824	0.49827	0.721	< 0.000
S2	-0.6034	< 0.000	0.2336	0.049495	0.7714	< 0.000
S3	-0.5832	< 0.000	0.0924	0.44599	0.7008	< 0.000
S4	-0.6807	< 0.000	0.1765	0.14052	0.8521	< 0.000
MONRP-R	τ	$p-$Value	τ	$p-$Value	τ	$p-$Value
S1	-0.7244	< 0.000	0.1092	0.3661	0.8958	< 0.000
S2	-0.6807	< 0.000	0.1966	0.09972	0.8555	< 0.000
S3	-0.758	< 0.000	0.0924	0.44599	0.9294	< 0.000
S4	-0.674	< 0.000	0.1899	0.11213	0.8521	< 0.000

In this table, Cost is the Expected Cost, Revenue is the Expected Revenue, and R/C is the Expected *Revenue-to-Cost* Ratio.

Conclusion

- An MCS based robust search-based optimization approach was introduced for requirement analysis and optimization
- Two notions of uncertainty measurements defined for NRP
- our approach reduces risk/uncertainty with very little change to the traditional 2D MONRP Pareto-front



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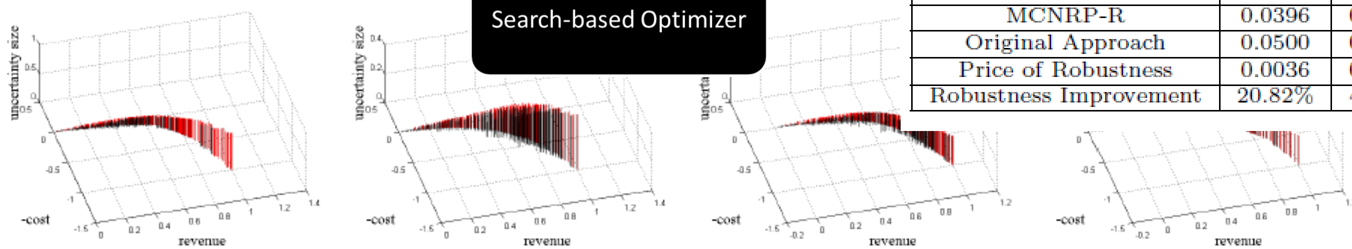

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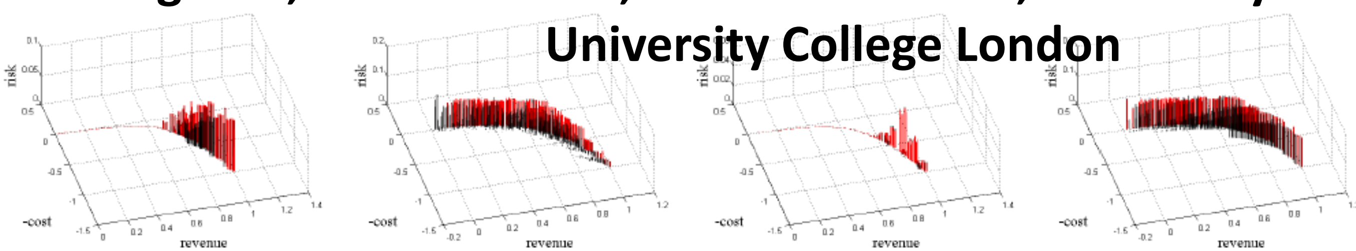

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Figure 4: The Pareto-front of *MCNRP-R* and Original Approach