Anytime Algorithms for Robust Multi-Objective Next Release Problem

UNIVERSIDAD DE MÁLAGA

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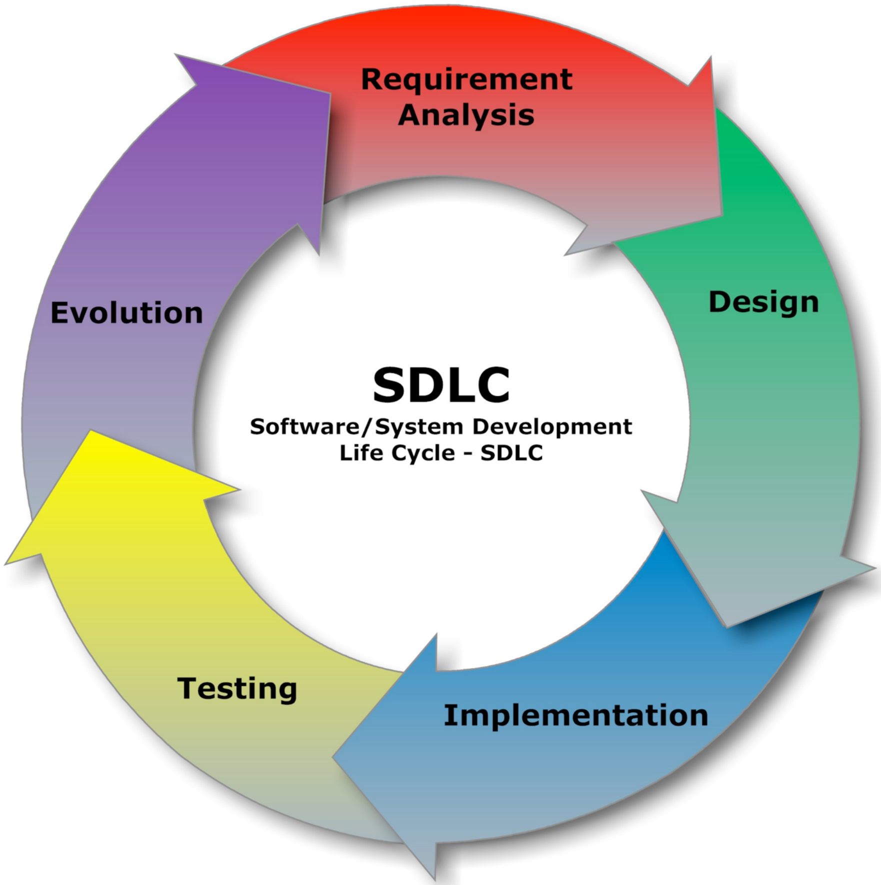
Next Release Problem (NRP)



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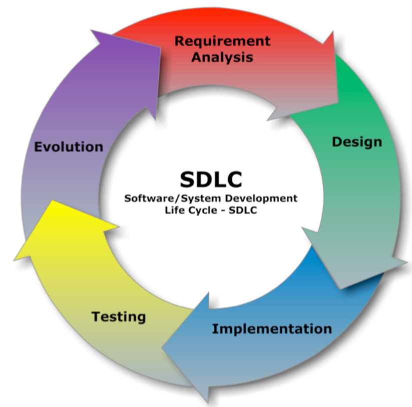


Given:

- **A set of requirements** $R = \{r_1, r_2, ..., r_n\}$
- **Each one with a cost** c_j **and a value** w_j
- **A set of functional relationships among them**
  - **Implication (**r_i **prerequisite of** r_j**):** $r_i \Rightarrow r_j$
  - **Combination (**r_i **at the same time as** r_j**):** $r_i \odot r_j$
  - **Exclusion (not together):** $r_i \oplus r_j$

Find a set of requirements $X \subseteq R$ **that fulfil the interactions and minimize the cost and maximize the value:**

min $$cost(\hat{R}) = \sum_{j, r_j \in \hat{R}}^{n} c_j,$$

max $$value(\hat{R}) = \sum_{i=1}^{m} w_i \prod_{j, r_j \in \hat{R}} v_{ij}$$

Xuan et al.

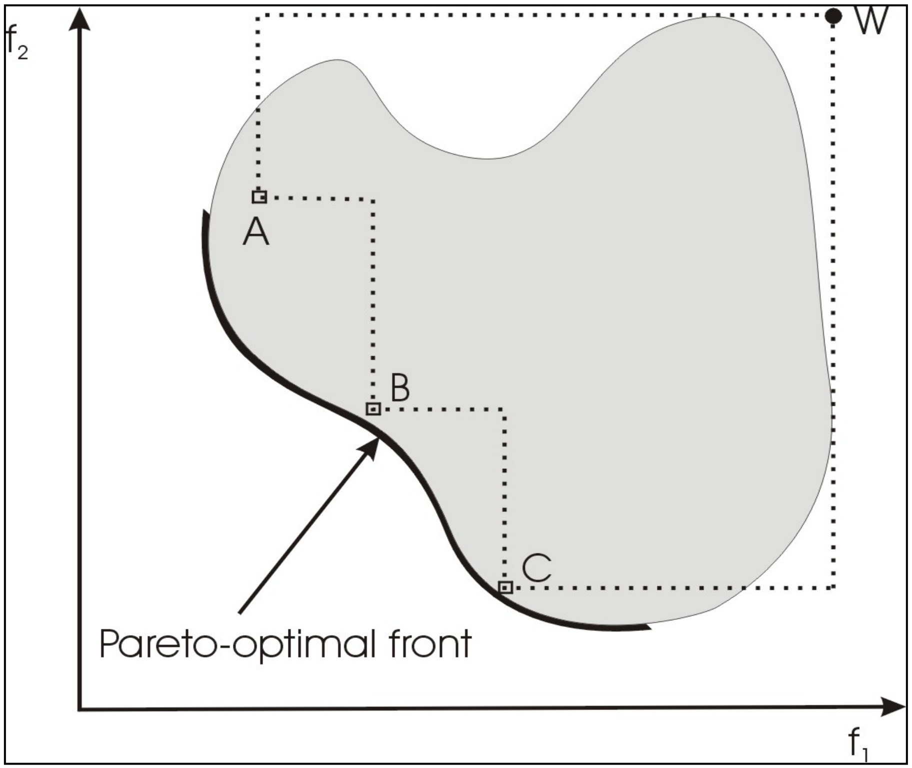
$$value(\hat{R}) = \sum_{j, r_j \in \hat{R}}^{n} s_j,$$

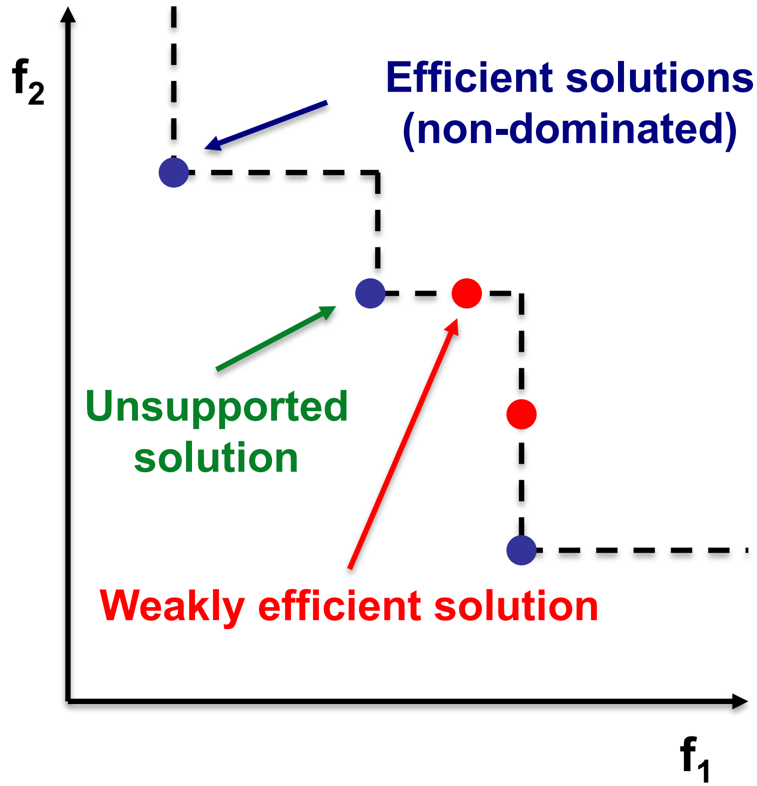
$$s_j = \sum_{i=1}^{m} w_i * v_{ij}$$

Del Sagrado et al.

Multi-objective problems

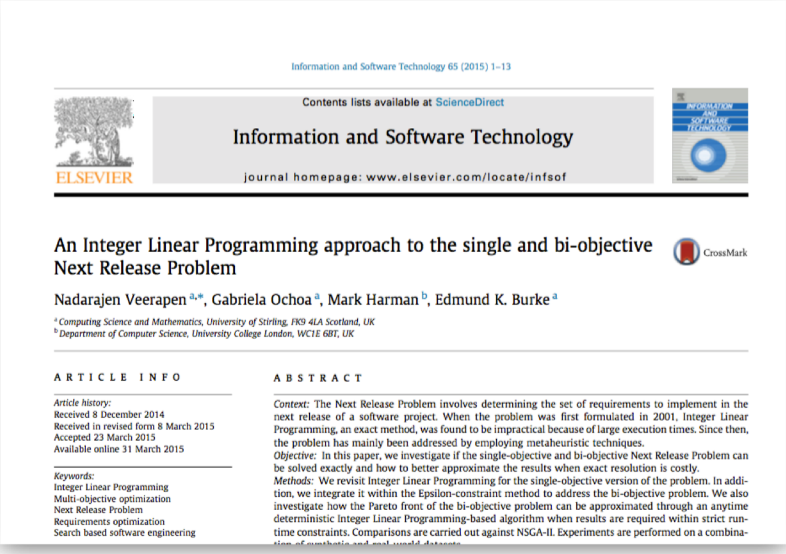
- Several objective functions to optimize (we will asume mimization here)





Previous Work on NRP

- **Initially solved using ILP in a single-objective version**
- **Later, metaheuristics (NSGA-II, GRASP, ACS)**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An Integer Linear Programming approach to the single and bi-objective Next Release Problem

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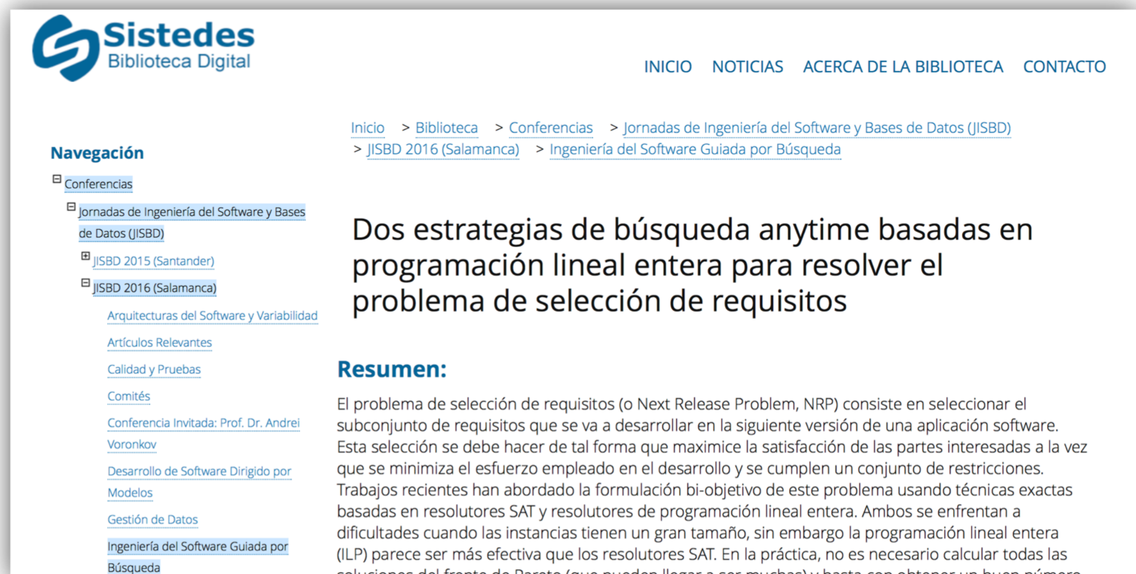
ABSTRACT

Context: The Next Release Problem involves determining the set of requirements to implement in the next release of a software project. When the problem was first formulated in 2001, Integer Linear Programming, an exact method, was found to be impractical because of large execution times. Since then, the problem has mainly been addressed by employing metaheuristic techniques.
Objective: In this paper, we investigate if the single-objective and bi-objective Next Release Problem can be solved exactly and how to better approximate the results when exact resolution is costly.
Methods: We revisit Integer Linear Programming for the single-objective version of the problem. In addition, we integrate it within the Epsilon-constraint method to address the bi-objective problem. We also investigate how the Pareto front of the bi-objective problem can be approximated through an anytime deterministic Integer Linear Programming-based algorithm when results are required within strict runtime constraints. Comparisons are carried out against NSGA-II. Experiments are performed on a combina-

- **ε-constraint with ILP finds the whole Pareto front in less tan 8 hours**
- **They propose dichotomic search and NSGA-II to reduce time**

Previous Work on NRP



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Inicio > Biblioteca > Conferencias > Jornadas de Ingeniería del Software y Bases de Datos (JISBD) > JISBD 2016 (Salamanca) > Ingeniería del Software Guiada por Búsqueda

Navegación
- Conferencias
  - Jornadas de Ingeniería del Software y Bases de Datos (JISBD)
    - JISBD 2015 (Santander)
    - JISBD 2016 (Salamanca)
      - Arquitecturas del Software y Variabilidad
      - Artículos Relevantes
      - Calidad y Pruebas
      - Comités
      - Conferencia Invitada: Prof. Dr. Andrei Voronkov
      - Desarrollo de Software Dirigido por Modelos
      - Gestión de Datos
      - Ingeniería del Software Guiada por Búsqueda

Dos estrategias de búsqueda anytime basadas en programación lineal entera para resolver el problema de selección de requisitos

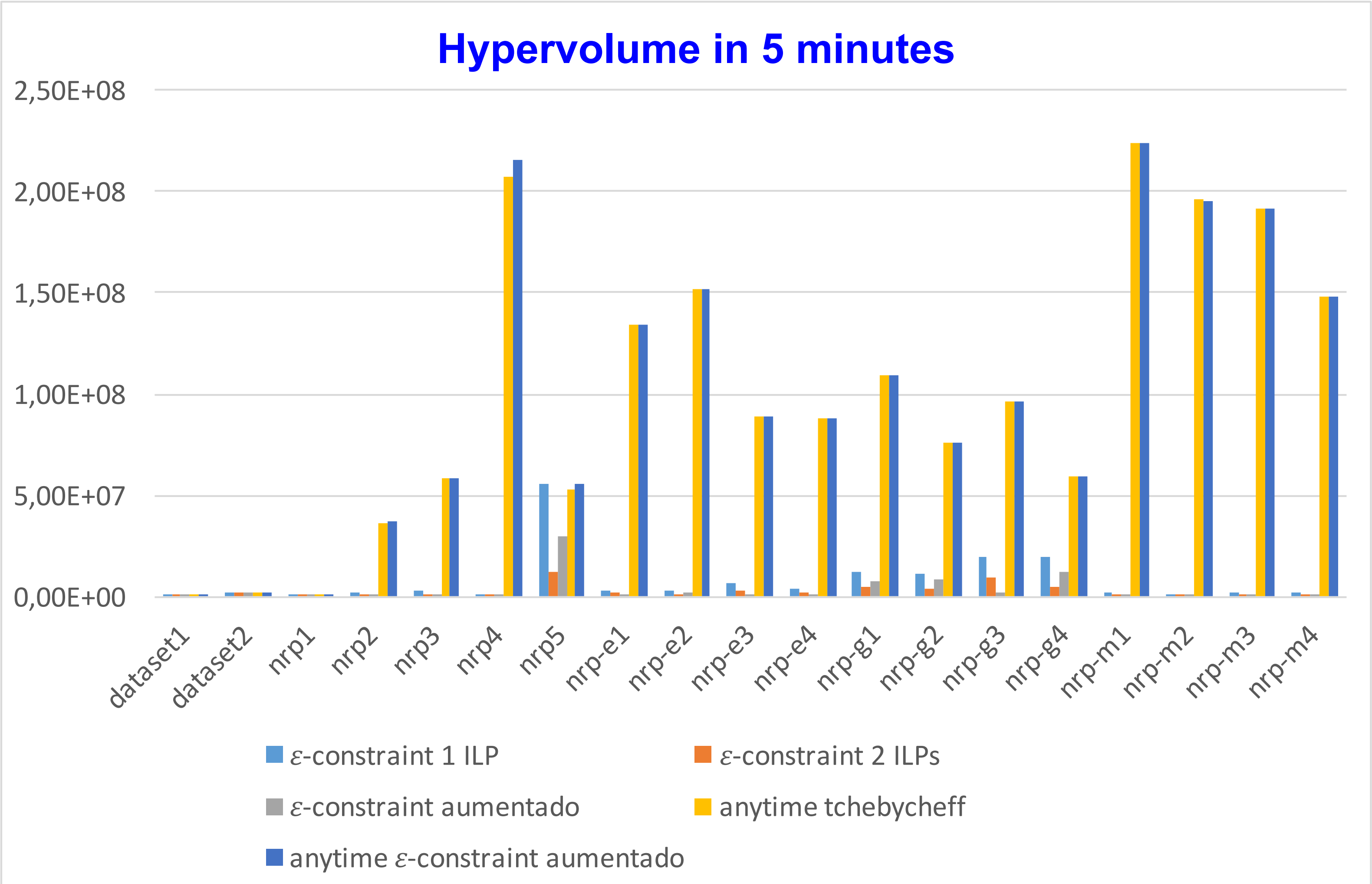
Resumen:

El problema de selección de requisitos (o Next Release Problem, NRP) consiste en seleccionar el subconjunto de requisitos que se va a desarrollar en la siguiente versión de una aplicación software. Esta selección se debe hacer de tal forma que maximice la satisfacción de las partes interesadas a la vez que se minimiza el esfuerzo empleado en el desarrollo y se cumplen un conjunto de restricciones. Trabajos recientes han abordado la formulación bi-objetivo de este problema usando técnicas exactas basadas en resolutores SAT y resolutores de programación lineal entera. Ambos se enfrentan a dificultades cuando las instancias tienen un gran tamaño, sin embargo la programación lineal entera (ILP) parece ser más efectiva que los resolutores SAT. En la práctica, no es necesario calcular todas las soluciones del frente de Pareto (que pueden llegar a ser muchas) y basta con obtener un buen número

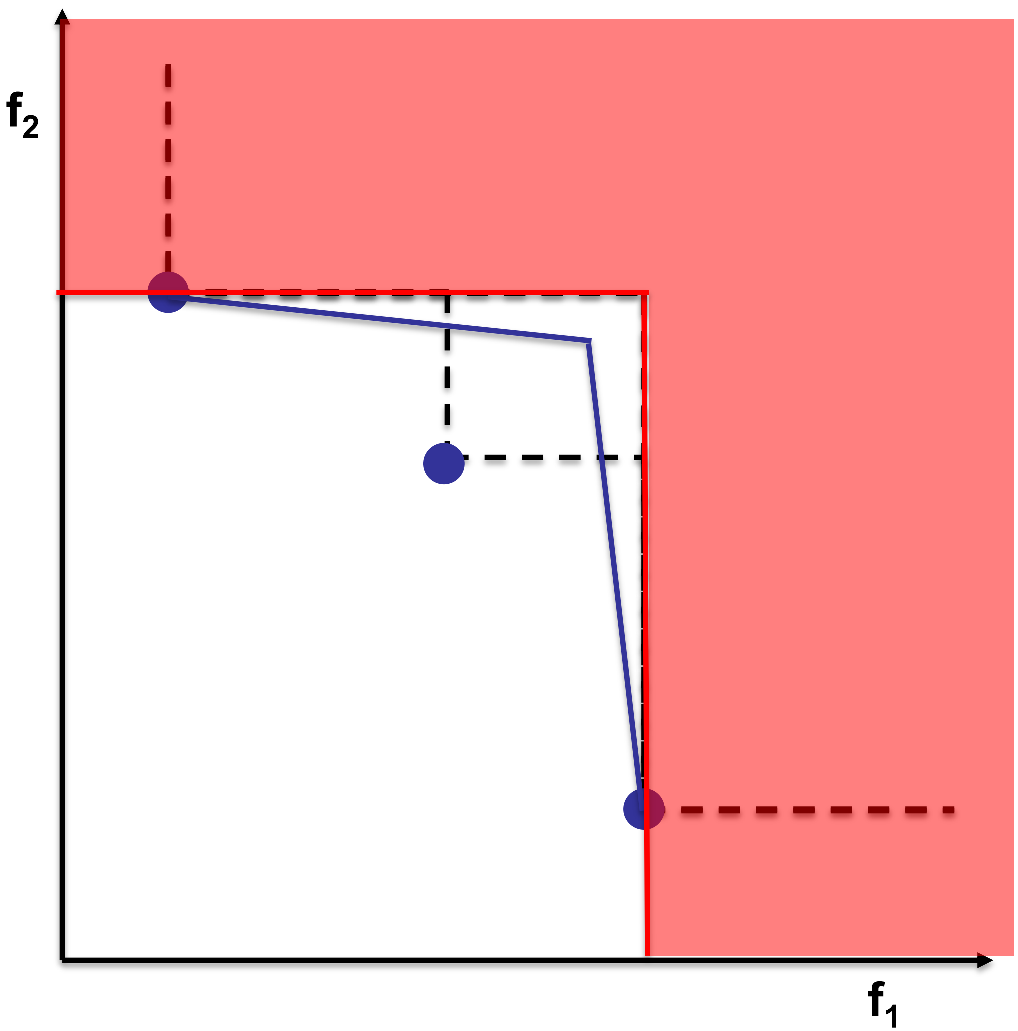
JISBD 2016

- **We developed anytime strategies to find a spread set of solutions of the Pareto front at anytime**
- **More appropriate for Software Engineers**

Previous Work on NRP



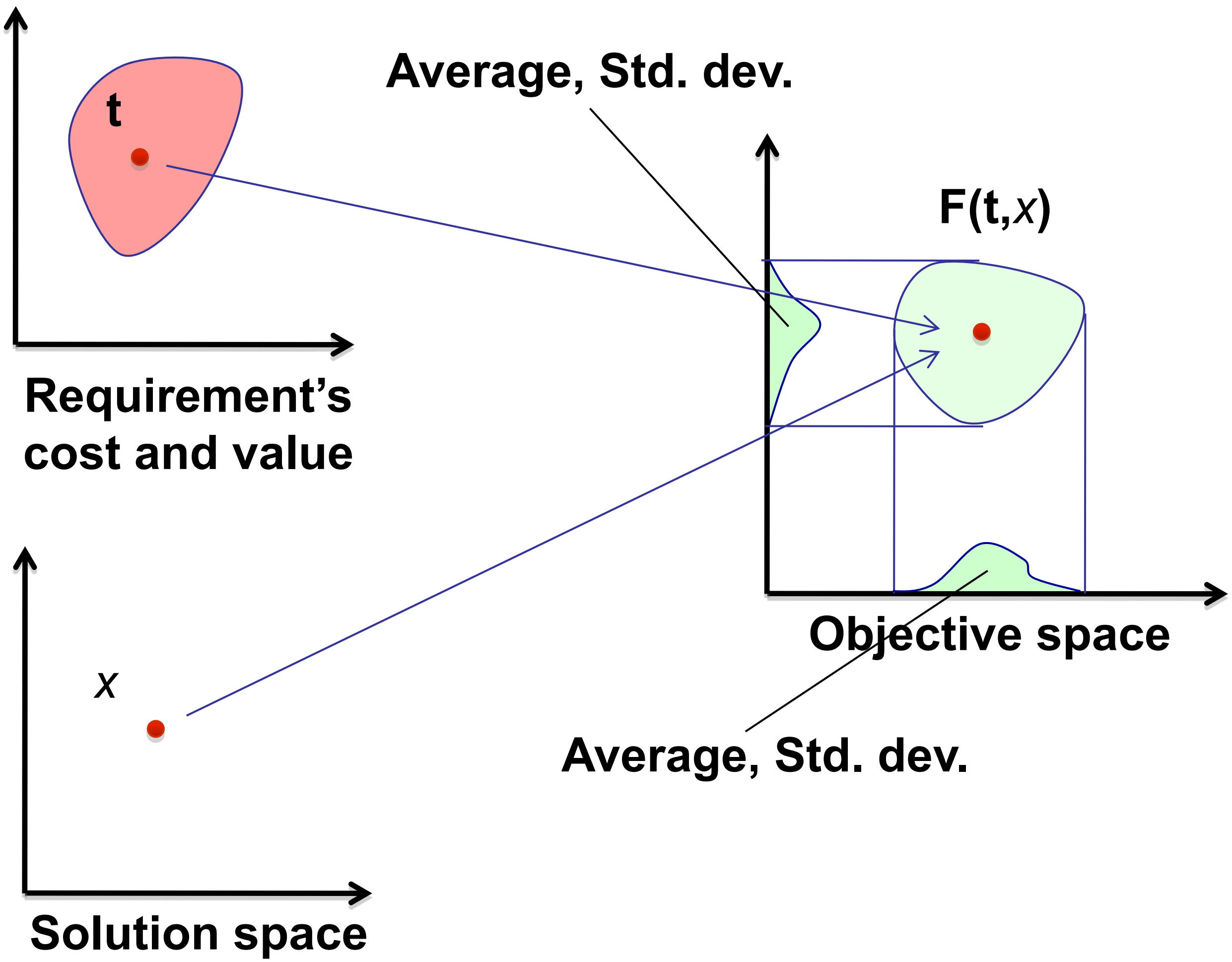
Anytime Augmented Weighted Tchebycheff



Algoritmo 4 *Anytime augmented weighted* Tchebycheff

$z^{(1)} \leftarrow$ calcular óptimo lexicográfico para el orden (f_1, f_2)
$z^{(2)} \leftarrow$ calcular óptimo lexicográfico para el orden (f_2, f_1)
FP $\leftarrow \{z^{(1)}, z^{(2)}\}$ // Frente de Pareto
Cola $\leftarrow \{(z^{(1)}, z^{(2)})\}$
while Cola $\neq \emptyset$ **do**
    $(z^{(1)}, z^{(2)}) \leftarrow$ extraerParDeMayorArea(Cola)
    $z \leftarrow$ resolverTchebycheff$((z^{(1)}, z^{(2)}))$
    if z no dominado en $(z^{(1)}, z^{(2)})$ **then**
        FP = FP $\cup \{z\}$
        Cola $\leftarrow$ Cola $\cup \{(z^{(1)}, z), (z, z^{(2)})\}$
    end if
end while

Robustness


t
Requirement's cost and value
Average, Std. dev.
F(t,x)
Objective space
x
Average, Std. dev.
Solution space

Previous Work on Robust NRP

Robust next release problem: handling uncertainty during optimization

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2014 Article

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Emmanuel Letier
Yuanyuan Zhang

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· Proceeding
GECCO '14 Proc
Computation
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The Value of Exact Analysis in Requirements Selection

Lingbo Li, Mark Harman, Fan Wu, and Yuanyuan Zhang

Abstract—Uncertainty is characterised by incomplete understanding. It is inevitable in the early phase of requirements engineering, and can lead to unsound requirement decisions. Inappropriate requirement choices may result in products that fail to satisfy stakeholders' needs, and might cause loss of revenue. To overcome uncertainty, requirements engineering decision support needs uncertainty management. In this research, we develop a decision support framework *METRO* for the Next Release Problem (NRP) to manage algorithmic uncertainty and requirements uncertainty. An exact NRP solver (*NSGDP*) lies at the heart of *METRO*. *NSGDP*'s exactness eliminates interference caused by approximate existing NRP solvers. We apply *NSGDP* to three NRP instances, derived from a real world NRP instance, RALIC, and compare with NSGA-II, a widely-used approximate (inexact) technique. We find the randomness of NSGA-II results in decision makers missing up to 99.95 percent of the optimal solutions and obtaining up to 36.48 percent inexact requirement selection decisions. The chance of getting an inexact decision using existing approximate approaches is negatively correlated with the implementation cost of a requirement (Spearman ρ up to -0.72). Compared to the inexact existing approach, *NSGDP* saves 15.21 percent lost revenue, on average, for the RALIC dataset.

Index Terms—Software engineering, exact multi-objective optimisation, simulation optimisation, next release problem

Lingbo Li work on robustness for NRP is based on Monte Carlo Simulation

Formulation

$$\min E\left[cost(r)\right] = E\left[\sum_{j=1}^{n} c_j r_j\right]$$

$$E\left[cost(r)\right] = \sum_{j=1}^{n} E[c_j] r_j$$

$$\min Var\left[cost(r)\right] = Var\left[\sum_{j=1}^{n} c_j r_j\right]$$

$$\min -E\left[value(t)\right] = -E\left[\sum_{i=1}^{m} w_i t_i\right]$$

$$-E\left[value(t)\right] = -\sum_{i=1}^{m} E[w_i] t_i$$

$$\min Var\left[value(t)\right] = Var\left[\sum_{i=1}^{m} w_i t_i\right]$$

Formulation

$$Var\left[cost(r)\right] = Var\left[\sum_{j=1}^{n} c_j r_j\right]$$

$$= \sum_{i,j=1}^{n} Cov[c_i, c_j] r_j r_i = \sum_{i=i}^{n} Var[c_i] r_i$$

$$Var\left[value(t)\right] = Var\left[\sum_{i=1}^{m} w_i t_i\right]$$

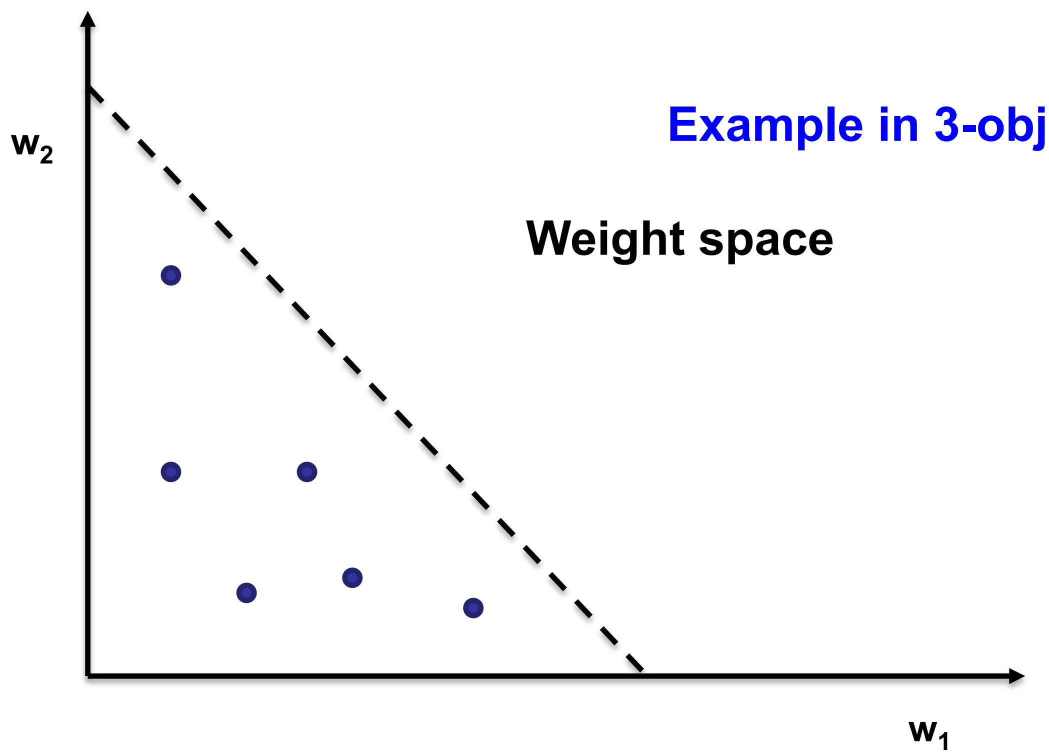
$$= \sum_{i,j=1}^{n} Cov[w_i, w_j] t_j t_i = \sum_{i=i}^{n} Var[w_i] t_i$$

If costs and values are uncorrelated the expression is simplified

Algorithm

- We implemented an algorithm exploring only supported solutions
- It picks random weights until time is over

Example in 3-objective problem



Results: Instances

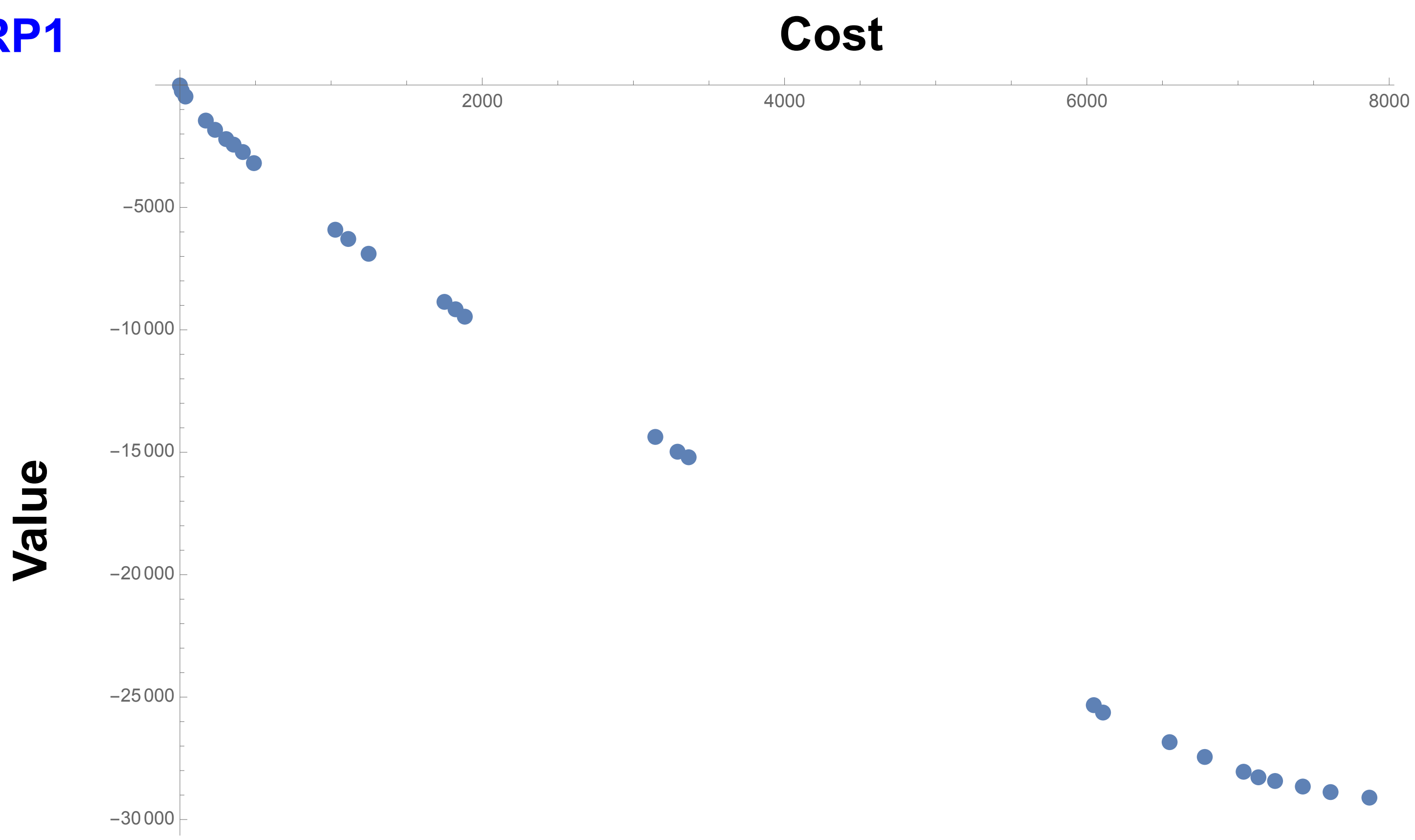
- **17 instances by Xuan et al.**
- **Only implication relation**

We included variance information to the instances

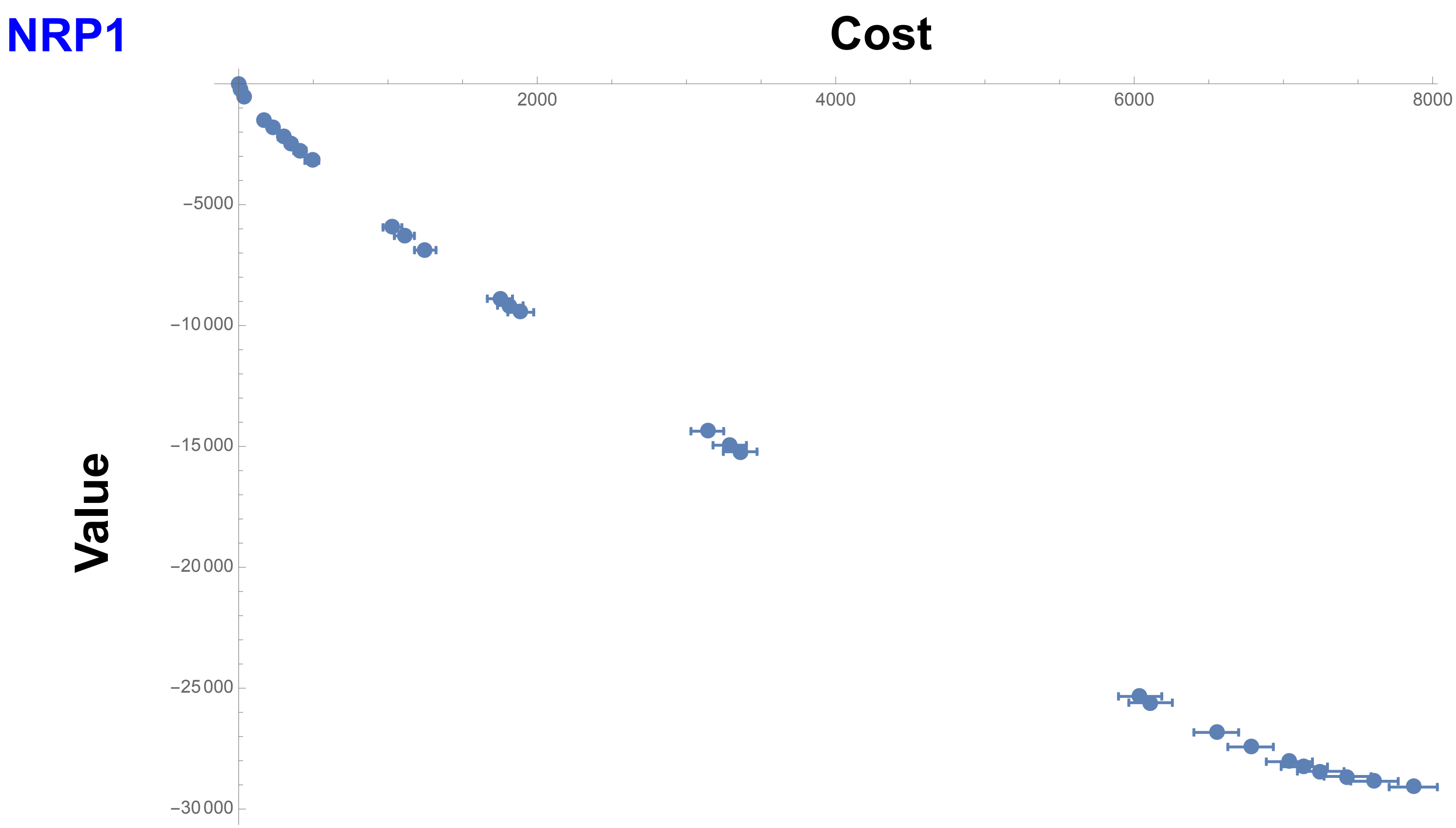
Instance	Requirements	Stakeholders
nrp1	140	100
nrp2	620	500
nrp3	1500	500
nrp4	3250	750
nrp5	1500	1000
nrp-e1	3502	536
nrp-e2	4254	491
nrp-e3	2844	456
nrp-e4	3186	399
nrp-g1	2690	445
nrp-g2	2650	315
nrp-g3	2512	423
nrp-g4	2246	294
nrp-m1	4060	768
nrp-m2	4368	617
nrp-m3	3566	765
nrp-m4	3643	568

Original 2-obj. Supported Non-Dominated Set

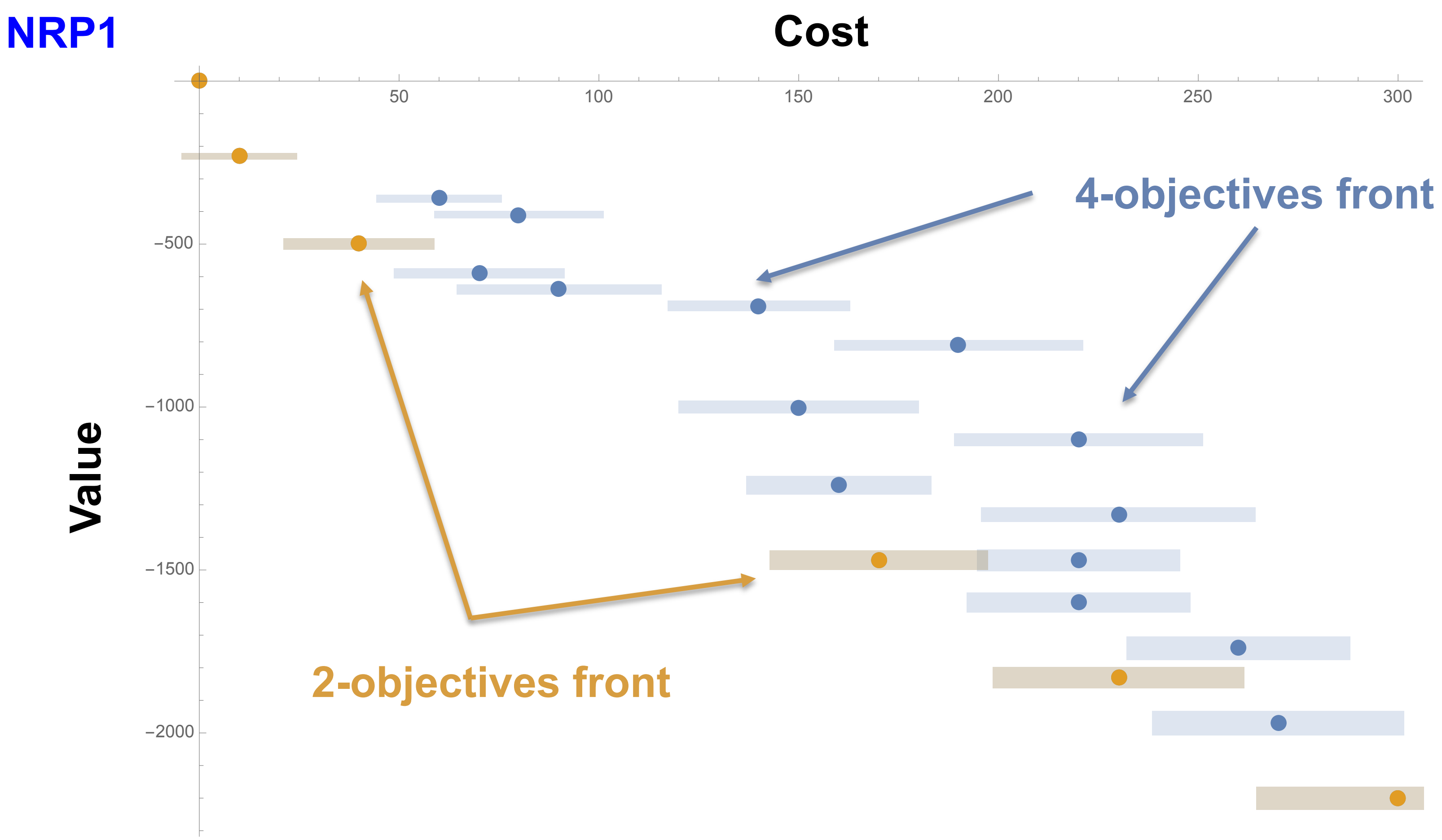
NRP1



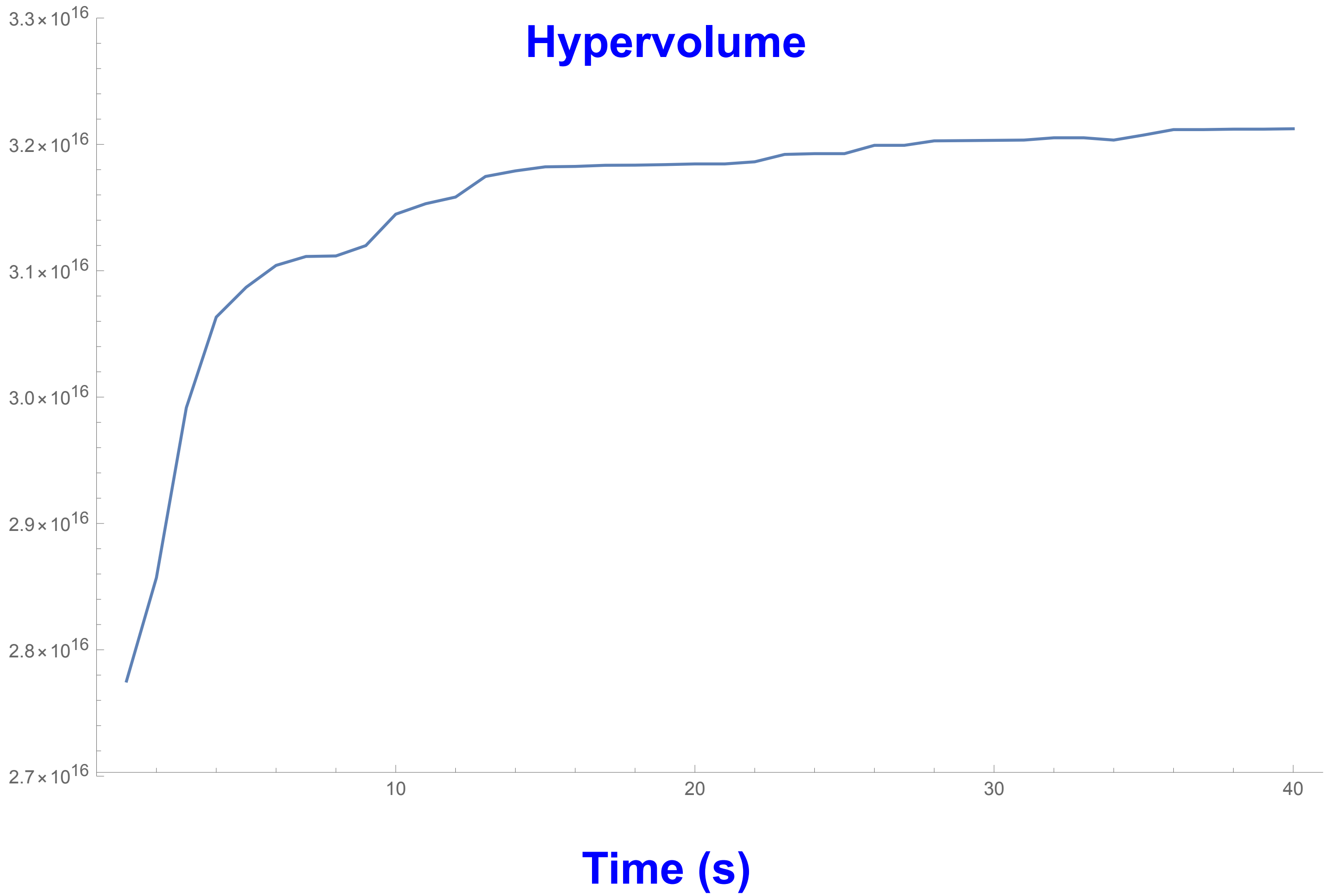
Original 2-obj. Supported Non-Dominated Set



4-obj. Supported Non-Dominated Set



Evolution of Hypervolume



Conclusions & Future Work

Conclusions

- A robust version of NRP has been modeled using ILP
- Anytime algorithms offer a well-spread set of non-dominated solutions

Future Work

- Apply other algorithms:
  - Przybylski, Gandibleux, Ehrgott (2010)
  - Dächert and Klamroth (2014)

Thanks for your Attention !!!

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