

A Parameterized Compositional Multi-dimensional Multiple-choice Knapsack Heuristic for CMP Run-time Management

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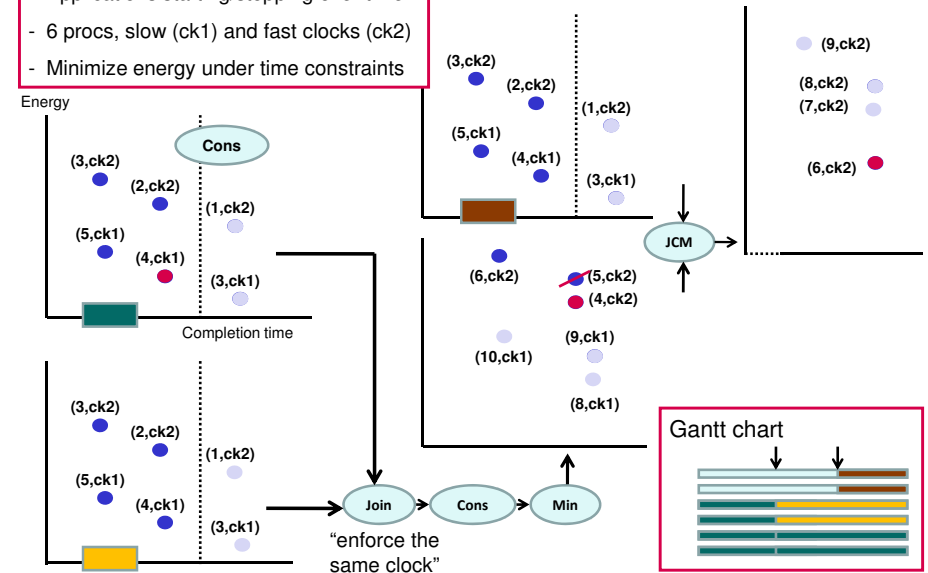
Joint work with

Twan Basten, Marc Geilen, AmirHossein Ghamarian, Rob Hoes, Sander Stuijk

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2 CMP Run-time Management

- Applications starting/stopping over time
- 6 procs, slow (ck1) and fast clocks (ck2)
- Minimize energy under time constraints



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3 Multi-dimensional Multiple-choice Knapsack Problem

MMKP

- One optimization objective (value)
 - Multiple resource dimensions with capacity constraints
 - Multiple independent applications
 - Multiple independent configurations per application
- Pick one configuration per application optimizing value within constraints

NP hard

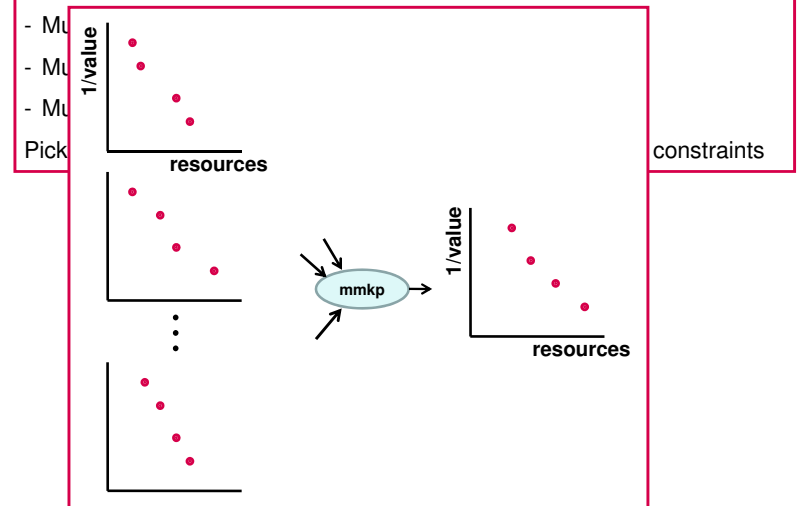
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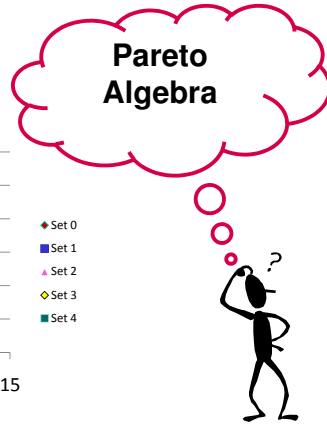
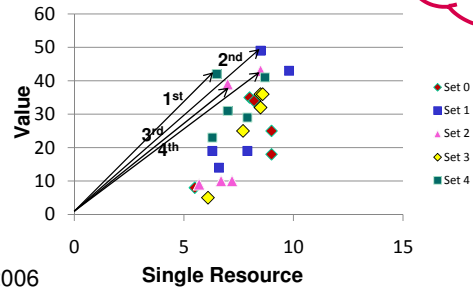
NP hard



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5 The Fastest Heuristic to Date(IMEC)

- Pareto filtering preprocessing
 - Resource projection
 - Pareto point sorting
 - Greedy selection
-
- Not compositional
 - How about feasibility?

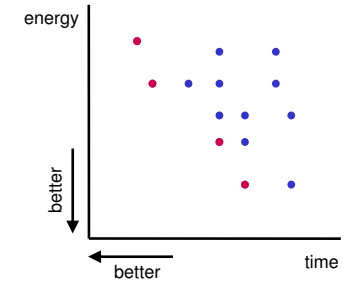


IMEC,SOC2006

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6 Pareto Algebra

- The elements: sets of configurations
- (Relevant) operators:
 - **Minimization**
Gives the Pareto points (optimal trade-offs)
 - **Product**
Cartesian product of configurations
e.g. application and platform configurations
 - **Constraint**
Selects solutions according to constraints
e.g. all application configurations with some minimal quality
 - **Abstraction**
Discards information about solutions
e.g. bandwidth usage in bandwidth × energy × quality configurations
 - **Derived metric**
Derive a new metric from other metrics
e.g. total power from power of components



prerequisite
monotonicity

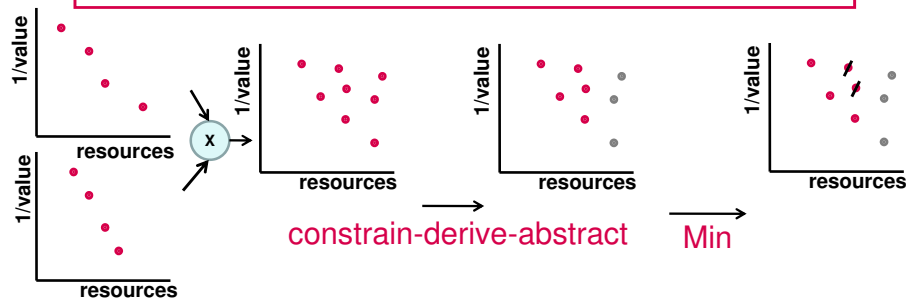
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7 Multi-dimensional Multiple-choice Knapsack Problem

MMKP

- One optimization objective (**value**)
 - Multiple resource dimensions with capacity **constraints**
 - Multiple independent applications
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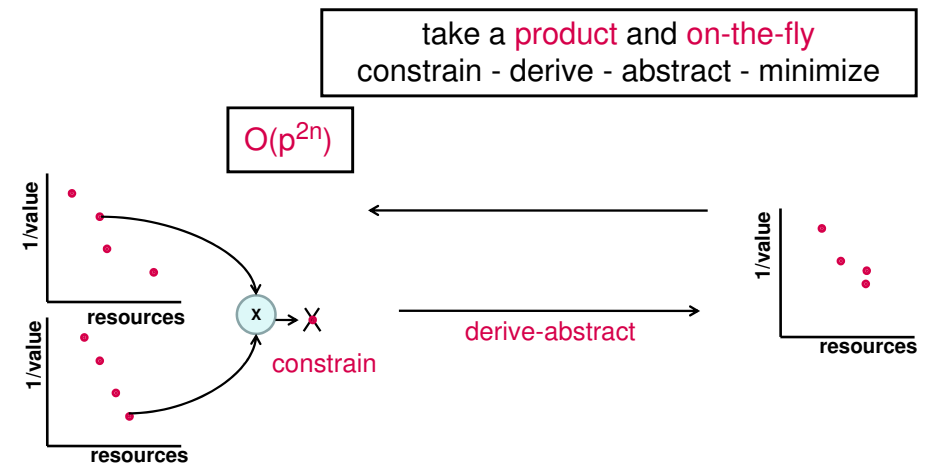
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8 Complexity

n components with p Pareto points each



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9 A Parameterized Compositional Heuristic

- Project all resource dimensions into one dimension
- Approximate Pareto set in 2-dimensional space

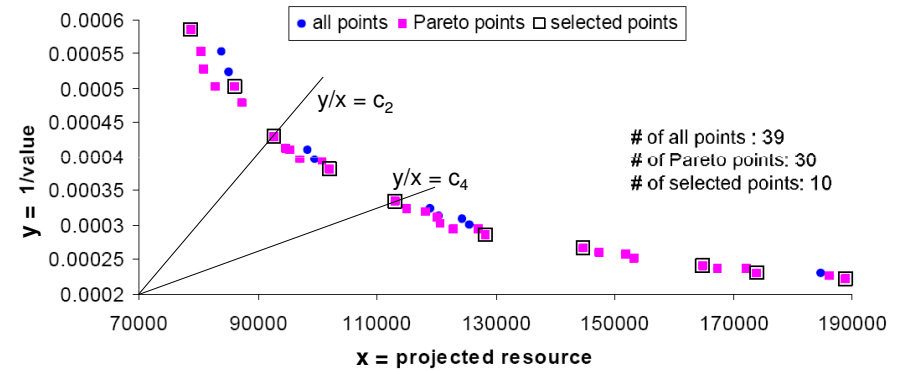
product	Compute product while on-the-fly
constrain	• Applying resource constraints
derive	• Computing values, projecting all resource dimensions into one (taking simply the sum)
abstract	
minimize	• Minimizing the configuration set in 2-dimensional space

product-constrain-derive-abstract-minimize

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10 A Parameterized Compositional Heuristic

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product-constrain-derive-abstract-minimize

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11 A Parameterized Compositional Heuristic

- Project all resource dimensions into one dimension
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parameter p : maintain (at most) p Pareto points

Allows to **budget** analysis time

$$\text{analysis time} \leq c \cdot n \cdot p^2$$

(n number of applications; c platform constant)

product-constrain-derive-abstract-minimize

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12 MMKP Benchmark

(www.laria.u-picardie.fr/hifi/OR-Benchmark/MMKP)

Test case	# of applications	# of configurations	# of resources
I1	5	5	5
I2	10	10	5
I3	15	10	10
I4	20	10	10
I5	25	10	10
I6	30	10	10
I7	100	10	10
I8	150	10	10
I9	200	10	10
I10	250	10	10
I11	300	10	10
I12	350	10	10
I13	400	10	10

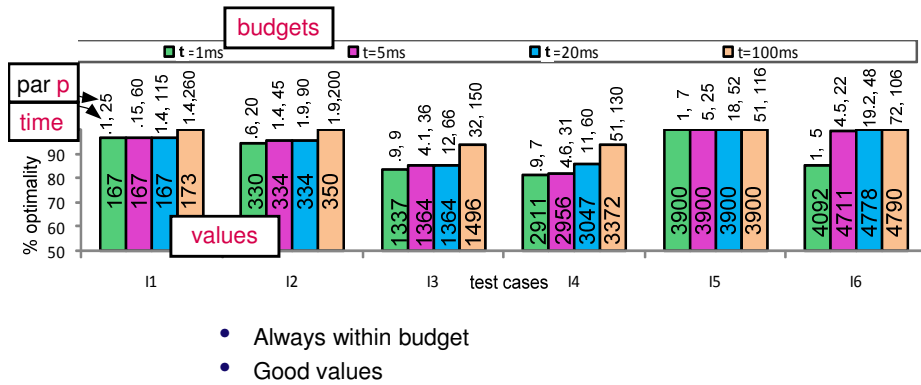
CMP cases

Tested on the
Simlt-ARM simulator
206 Mhz StrongARM

large cases

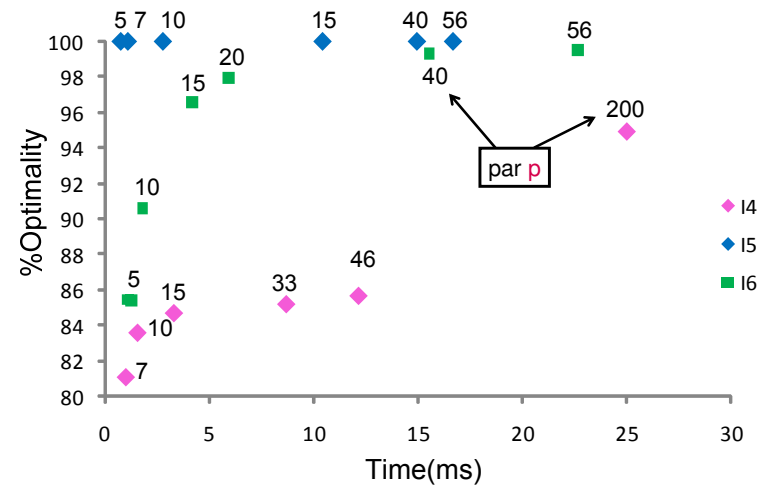
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13 Controlling Time Budgets



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14 Trading off Time vs. Quality

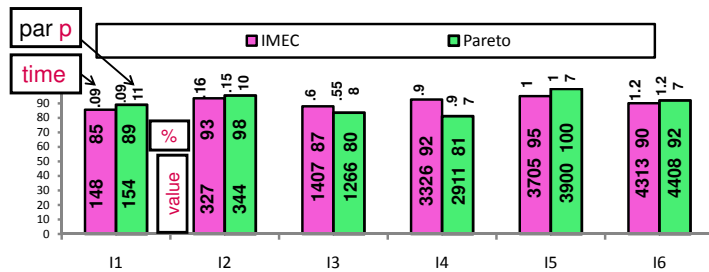


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15 Comparison with State of the Art

(IMEC, SOC 2006, non-compositional heuristic)

- All applications start simultaneously (worst-case for Pareto Algebra approach)
- Derive **p** from time needed by IMEC heuristic

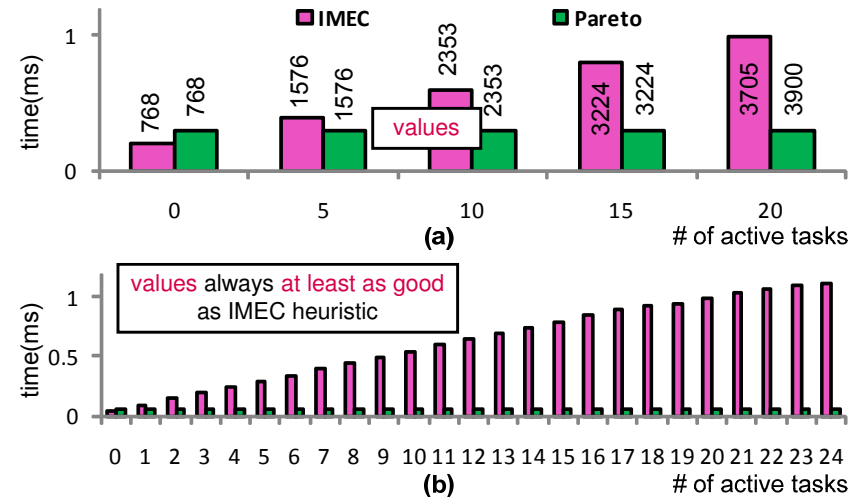


- Similar results

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16 Compositionality

- Applications start at various times
- 5 at a time (a), 1 at a time (b)



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17 Conclusions

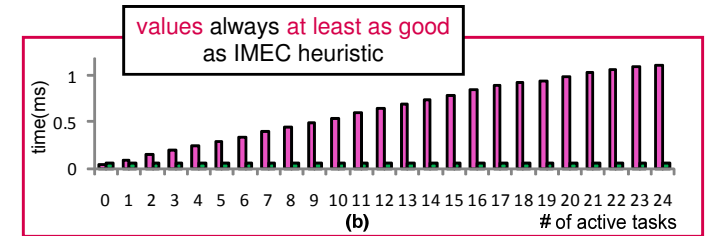
- Run-time adaptation:
product - constrain - derive - abstract - minimize
... select and configure
- Parameterized compositional method
 - Allows to trade off quality with analysis time
 - Allows to bound analysis time
- In comparison to best heuristic so far:
 - Similar results in the worst case
 - Much better results when applications start and stop over time

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Thank you !

Questions ?

More info:www.es.ele.tue.nl/pareto/



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