LocalSolver

The Etesian placement tool for Coriolis

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The Coriolis toolchain

Introduction to placement

Etesian: design choices

Results

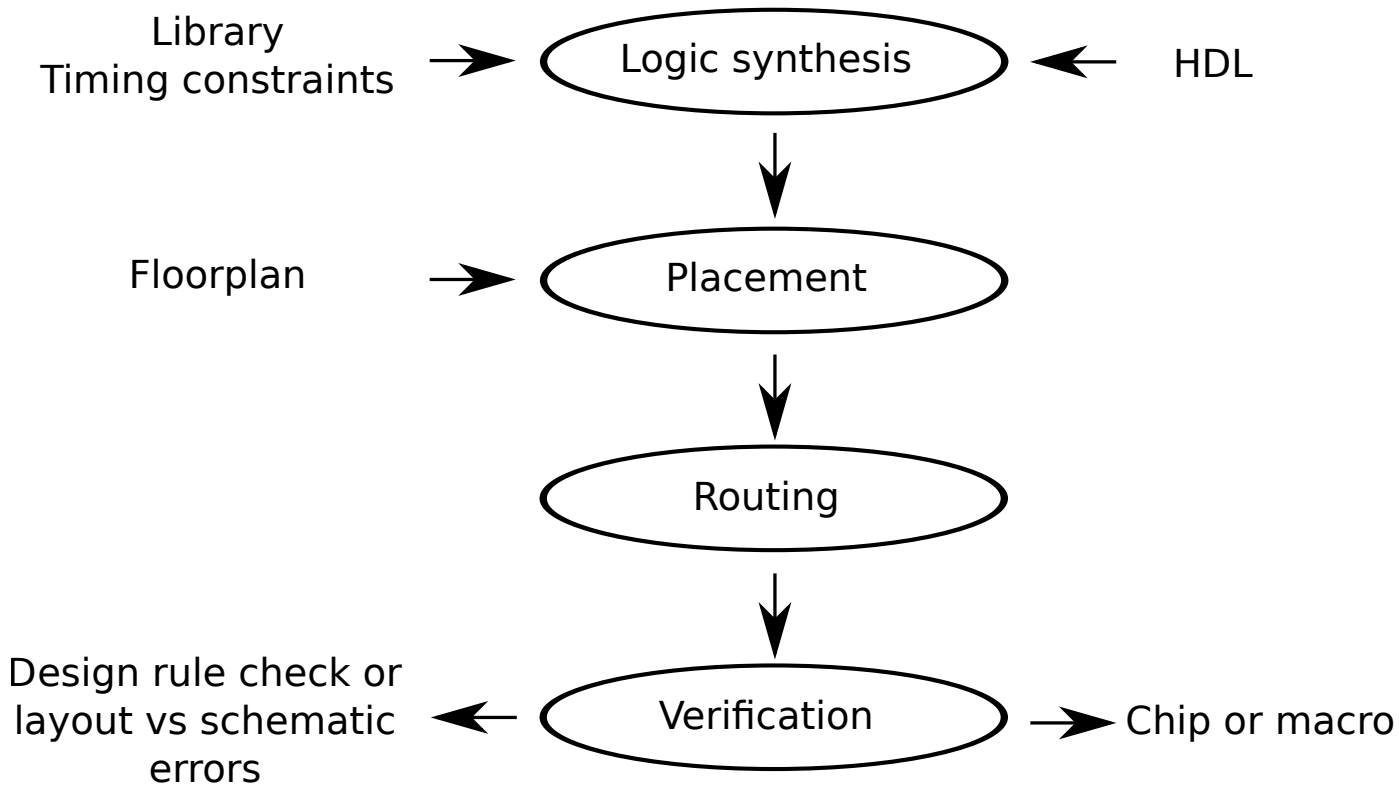
The Coriolis toolchain

Introduction to placement

Etesian: design choices

Results

The digital synthesis flow



The Alliance toolchain

A complete, open toolchain developped in the lab

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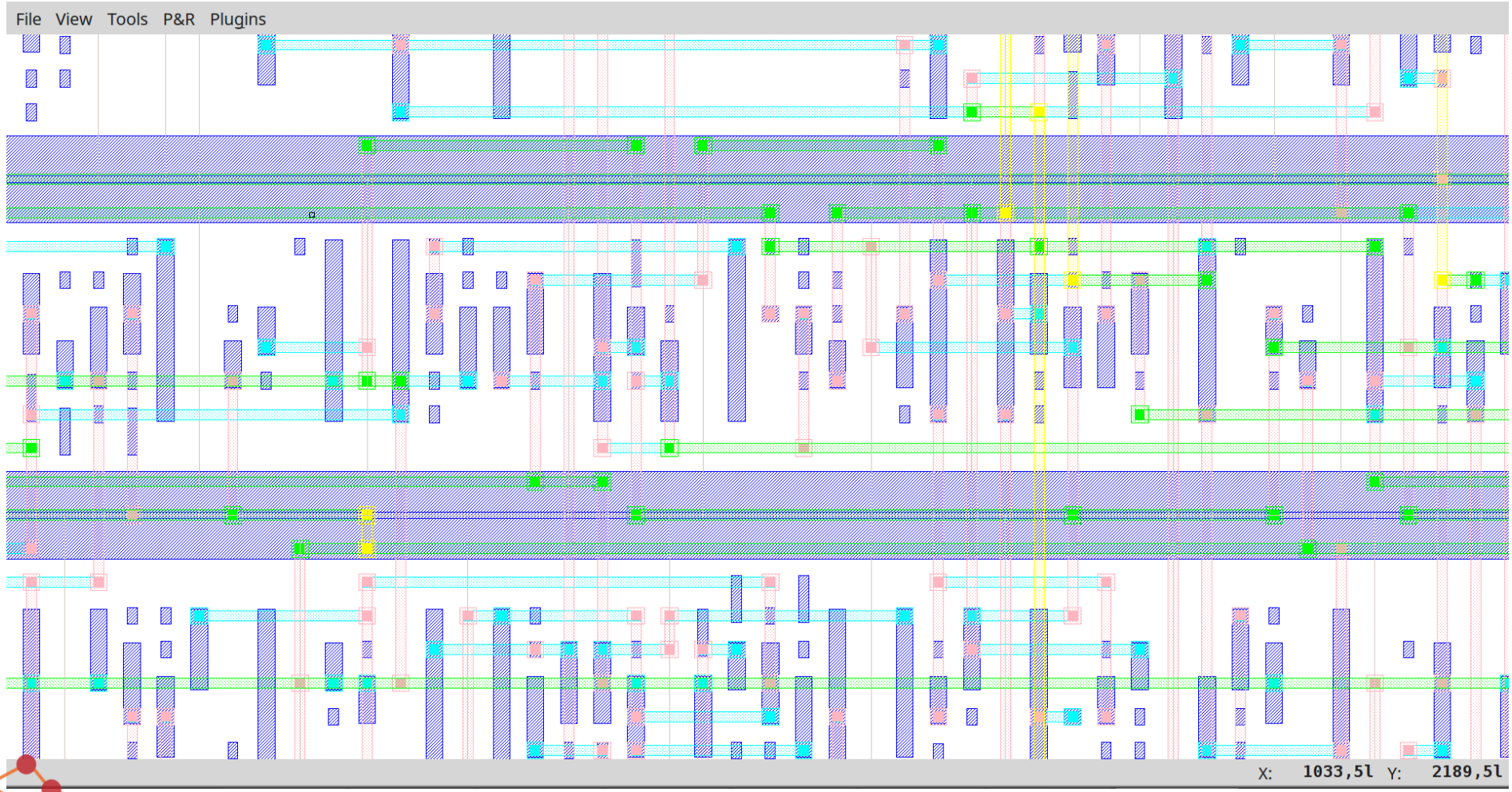
Coriolis: modern rewrite, physical design only

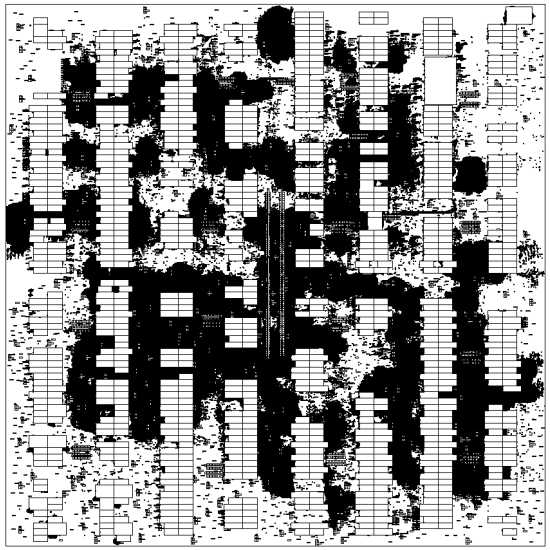
Database and visualization

- Hierarchical C++ database
- Several frontends and backends

Kite: an efficient router



The need for placement tools



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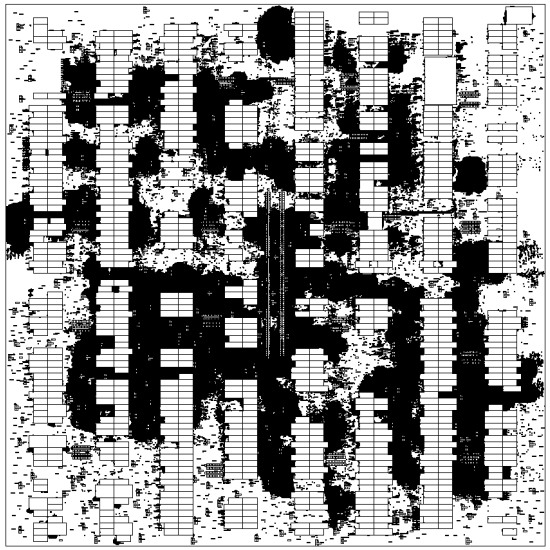

- Several thousands – millions – of cells
- Partly determines the circuit's quality

What is a good placer?

- We want everything:
  - Error-free routing
  - Fast placement
  - Fast and low-power circuit

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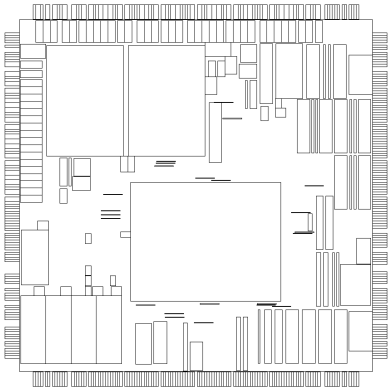
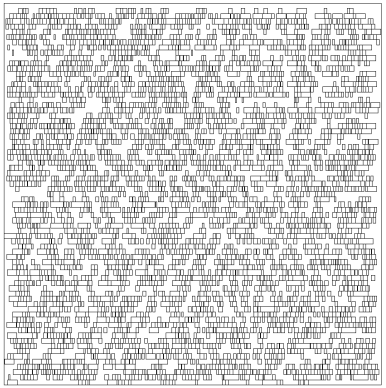
- We want everything:
  - Error-free routing
  - Fast placement
  - Fast and low-power circuit
- Lots of open benchmarks [3]
- Various optimization objectives
  - Wirelength
  - Routability
  - Timing

Two types of placement problems





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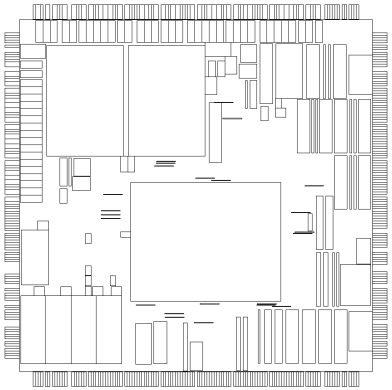
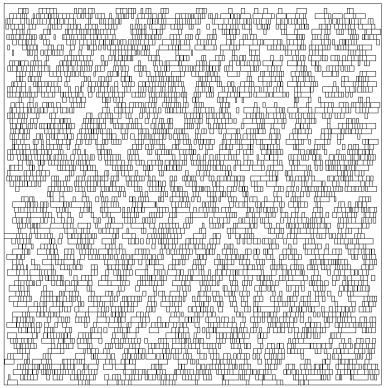
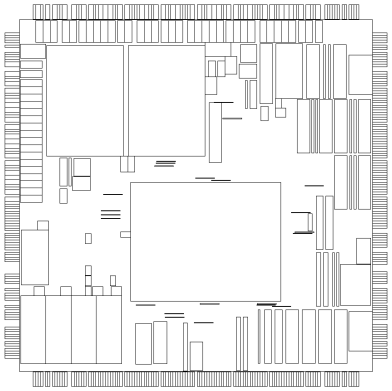
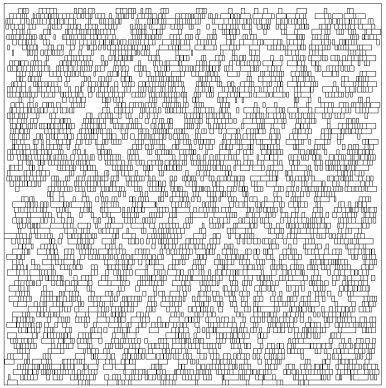




- Big modules $\rightarrow$ Floorplanning
  - Irregular rectangles
  - Few modules

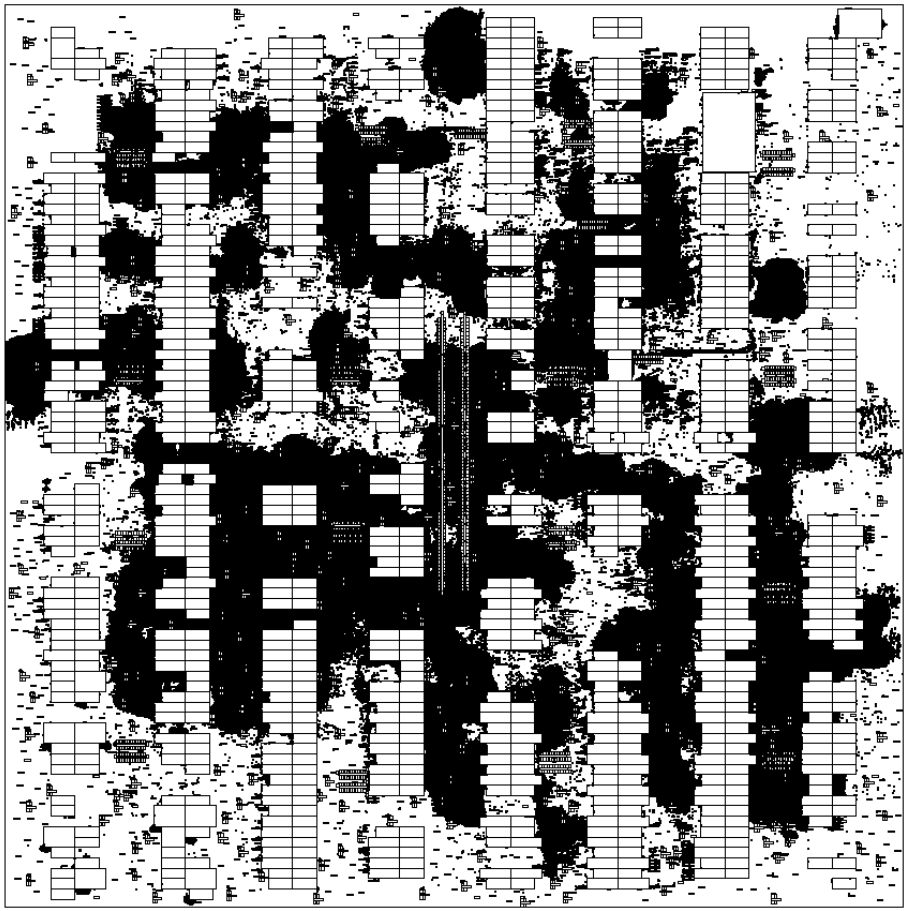
Two types of placement problems





- Big modules $\rightarrow$ Floorplanning
  - Irregular rectangles
  - Few modules
- Standard cell placement
  - Uniform height $\Rightarrow$ placed in rows
  - 10^6 cells or more

The real world: mixed-size placement



In practice, circuits have both macros and standard cells

Before the technical stuff...

Obviously....

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Obviously.... It is NP-hard.

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Obviously.... It is NP-hard.

- Bin-packing
- Multiple-machine scheduling
- Graph partitioning
- Steiner trees

Simulated annealing and metaheuristics

Simulated annealing

- Accepts bad moves depending on a temperature
- Theoretically converges

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Made it quite far thanks to Graywolf [6]

Three-step placement

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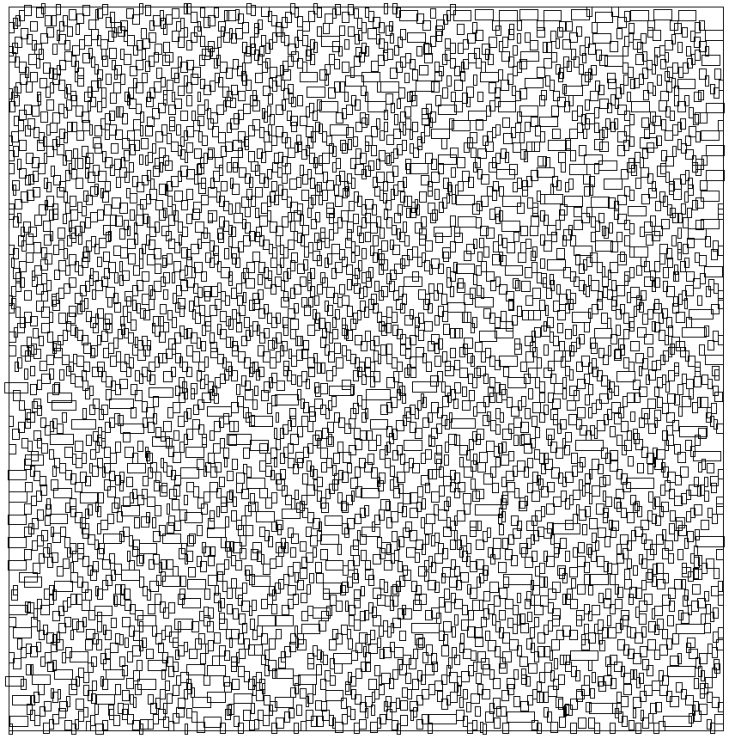
Three-step placement

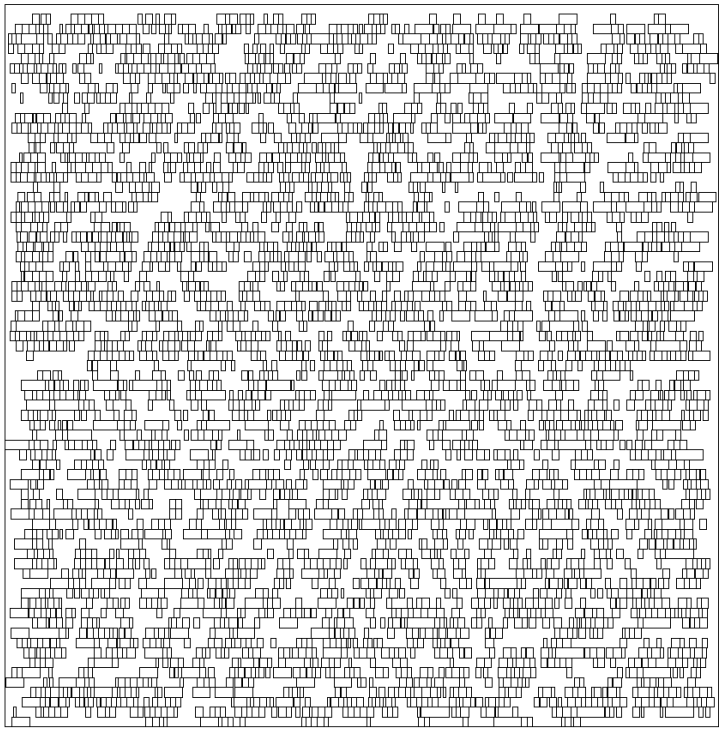
Use multiple steps to obtain a good placement

- A global placement step
  - Approximate positions
  - Overlaps are possible
  - Only density constraints
- A legalization step
  - Obtain an overlap-free placement
- A detailed placement step
  - Remove local suboptimalities

Visually



Global placement result



Final placement

Global placement ≫ detailed placement

Global placement is the most performance-critical part

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Legalization

- Needs to succeed, but not critical

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Detailed placement

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Global placement is the most performance-critical part

Legalization

- Needs to succeed, but not critical

Detailed placement

- Just simple moves to polish the result

Global placement algorithms

Two approaches:

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- Discrete view: the circuit is a graph
  $\Rightarrow$ Partitioning

Global placement algorithms

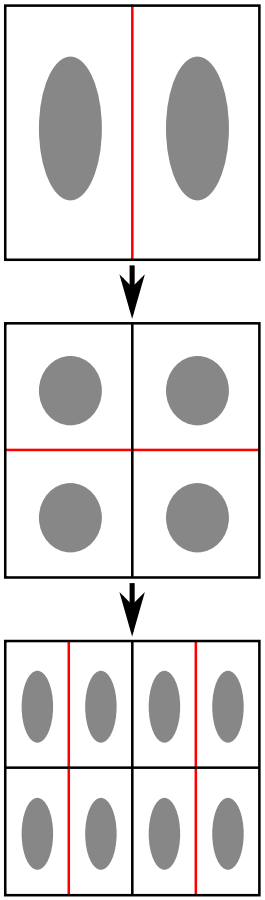
Two approaches:

- Discrete view: the circuit is a graph
  $\Rightarrow$ Partitioning
- Continuous view: it is a vector of positions
  $\Rightarrow$ Analytical placement

Partitioning placers

Basic idea

- Partition the circuit
- Cut as few wires as possible
- Allocate the parts to placement regions



Some nice achievements with Capo [5]

Analytical placers

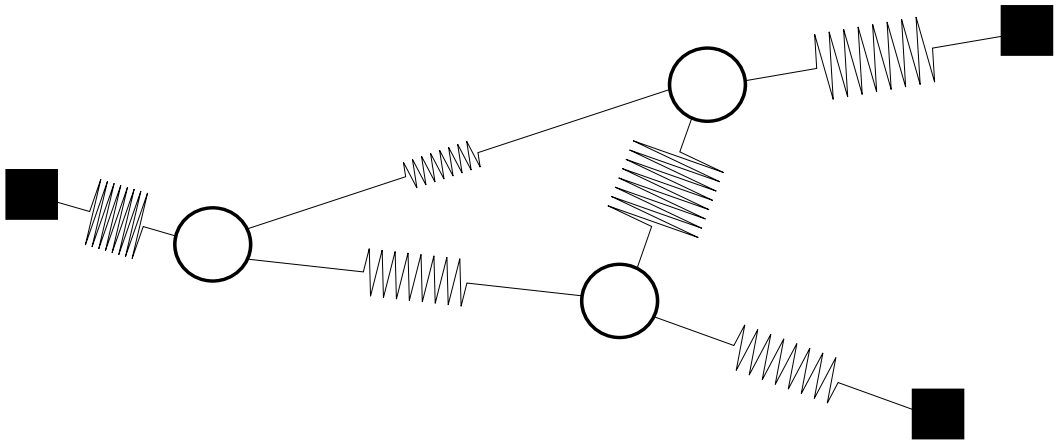
Basic idea

- A convex cost function
- A huge vector of positions
- Optimize

Most current placers [3]

Analytical quadratic placers

Model wires as springs [1]



Analytical quadratic placers

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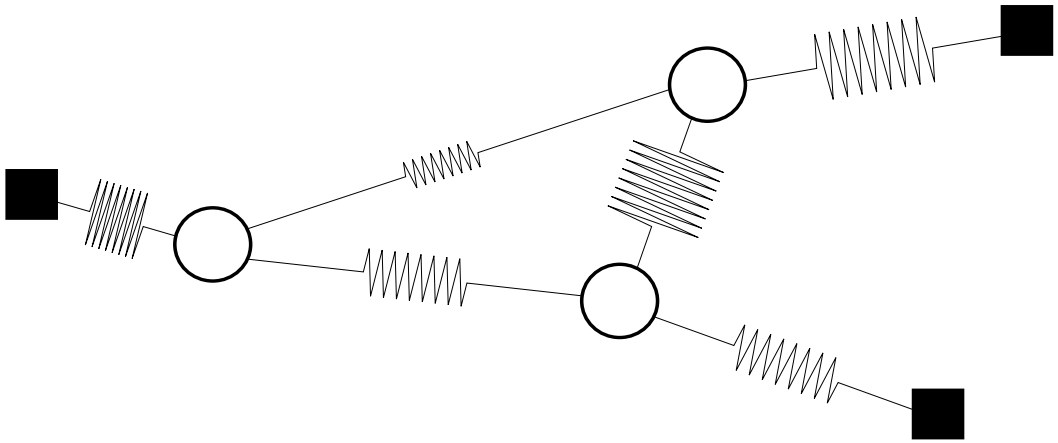
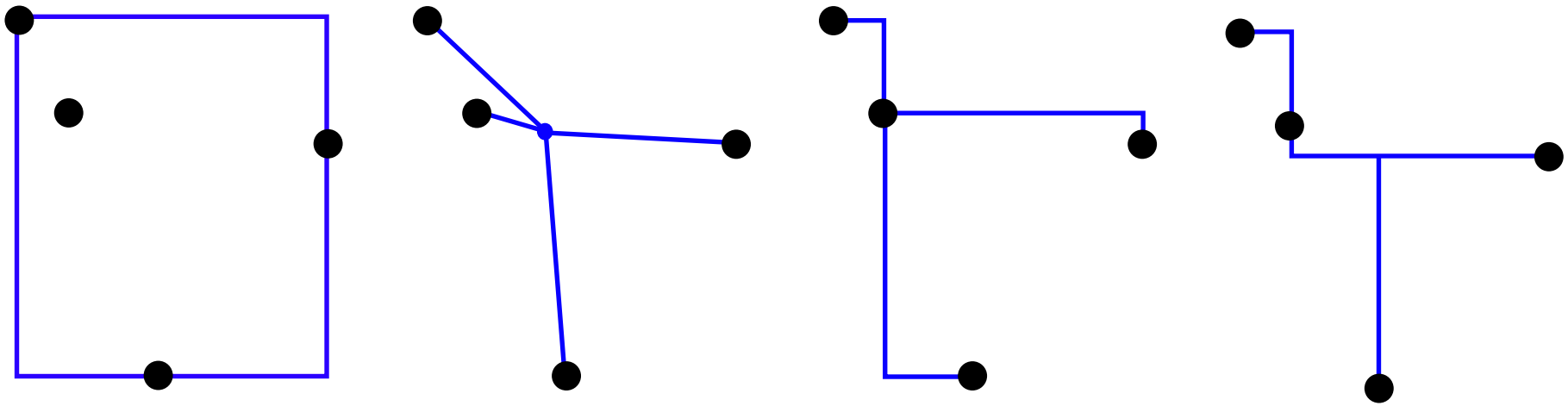


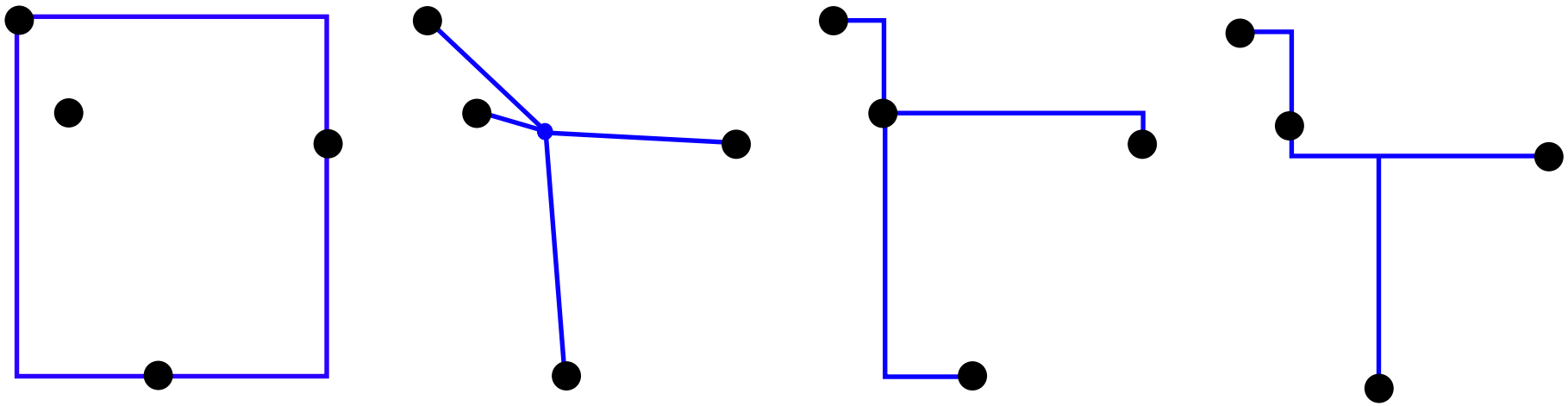
Easy to solve: sparse symmetric linear system

Usual cost functions



Wirelength models

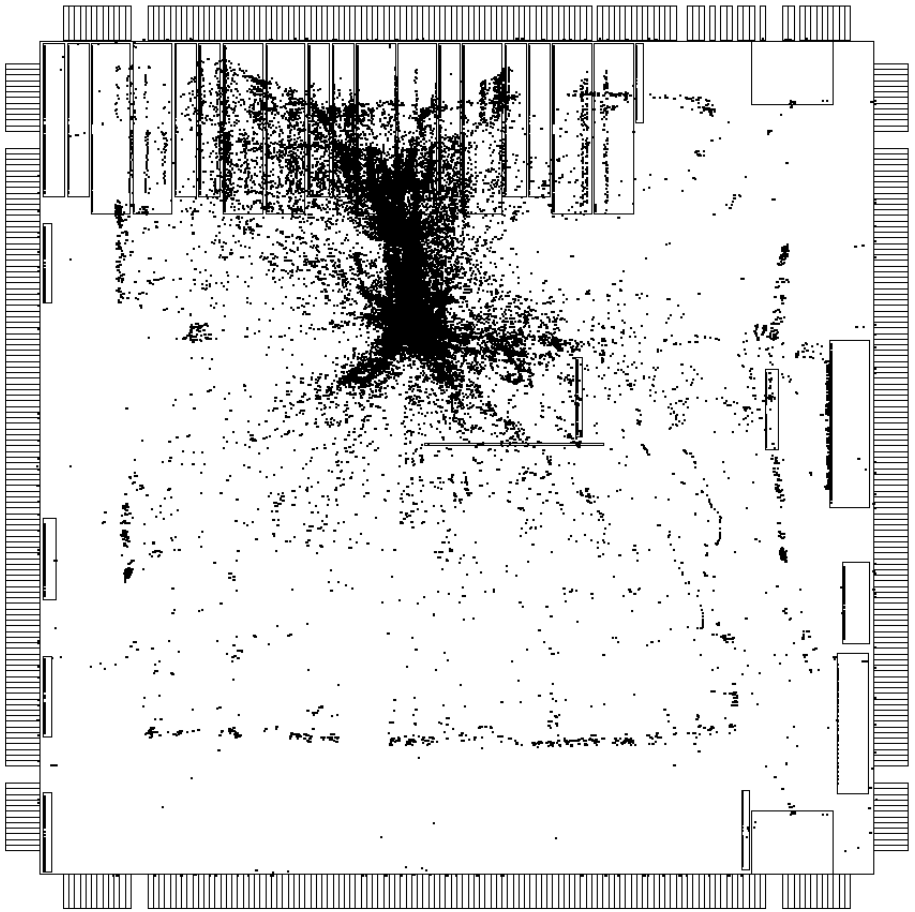
Usual cost functions



Wirelength models

$$\text{HPWL} = \sum_{c \in \{x,y\}} \sum_{n \in \text{nets}} \left(\max_{\text{pin} \in n} c_{\text{pin}} - \min_{\text{pin} \in n} c_{\text{pin}} \right)$$

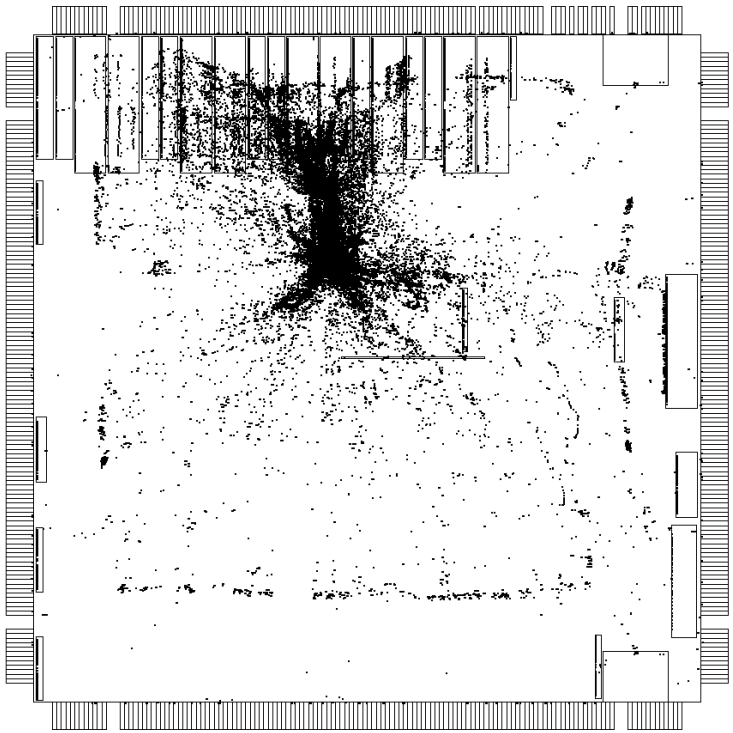
Optimization result



Lots of overlaps

Lookahead legalization

Remove density overflow, minimize the displacement



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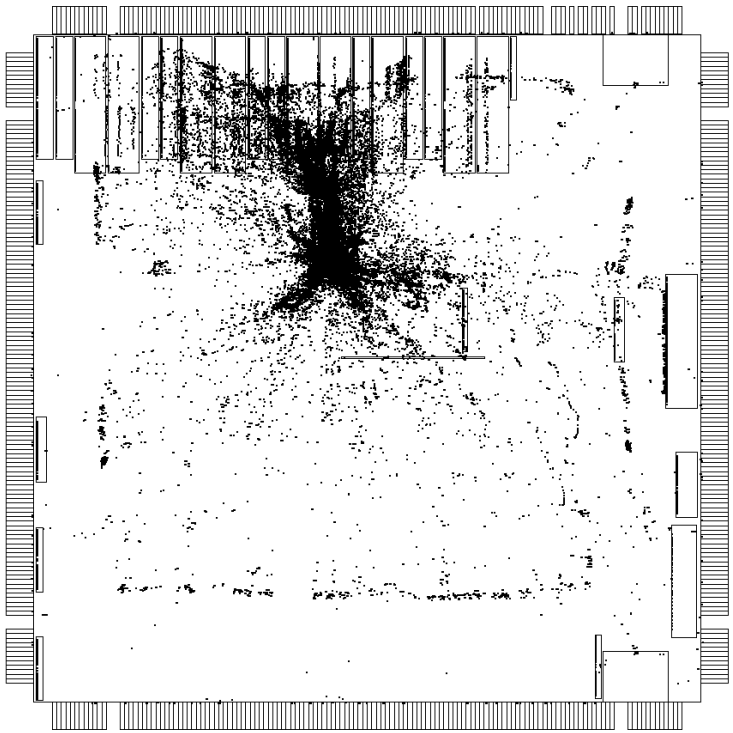

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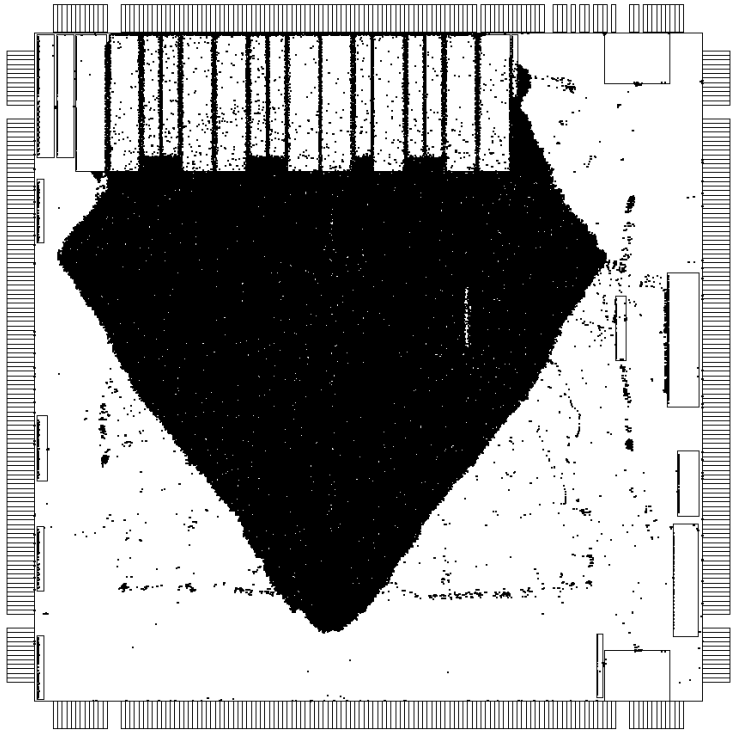
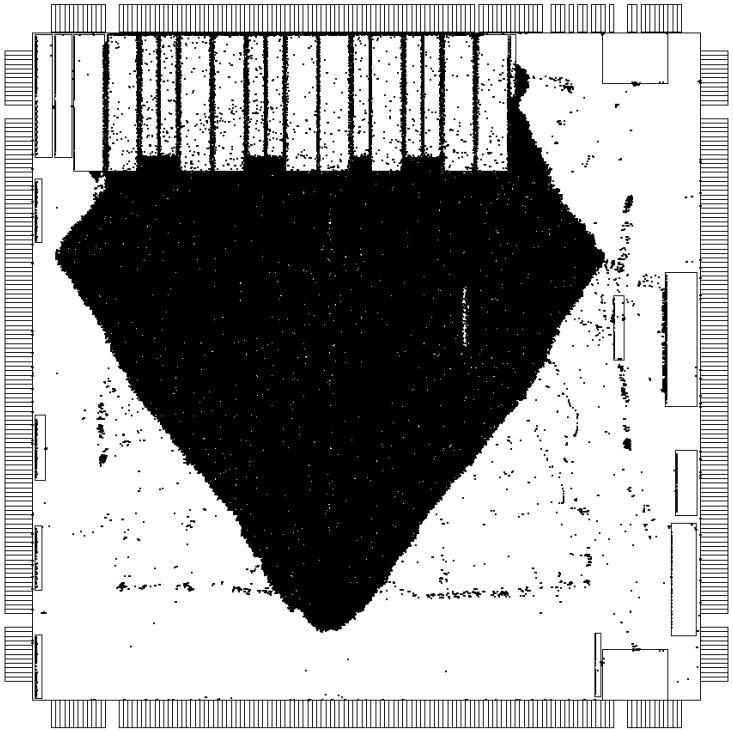
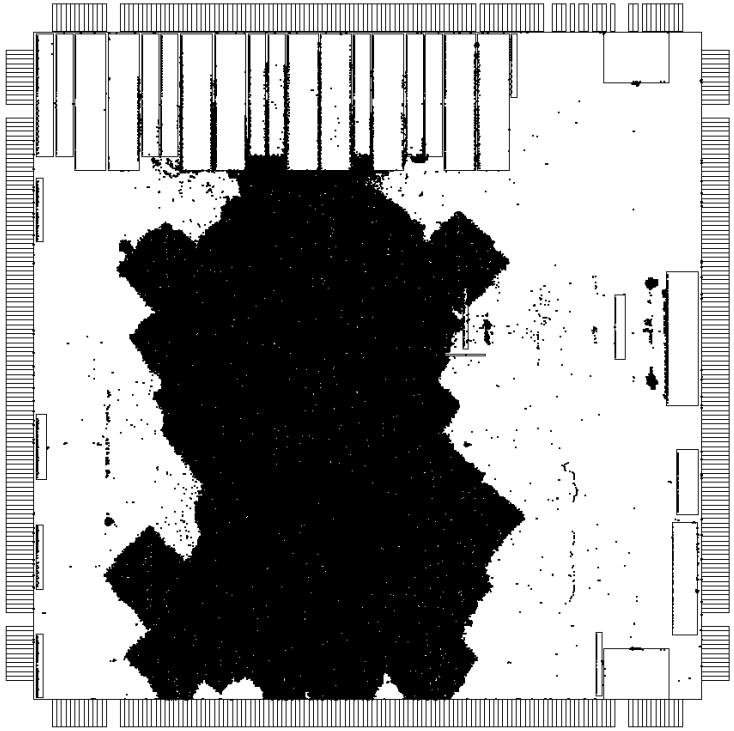


Projection

And over time...





Lots of variations and improvements

- Cost function
- Legalization algorithm
- Penalty function
- Local refinements

Benchmark winners

Placer	Optimization	Density handling	Refinement
ePlace	Nonlinear	FD (potential)	No
Maple	Quadratic	FD (legalizing)	Yes
Polar	Quadratic	FD (legalizing)	Yes
BonnPlace	Quadratic	Partitioning	No?

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- Rather force-directed

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- Rather force-directed
- + various algorithms

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- Rather force-directed
- + various algorithms
- + **lots of trial-and-error**

Choice of a force-directed quadratic placer

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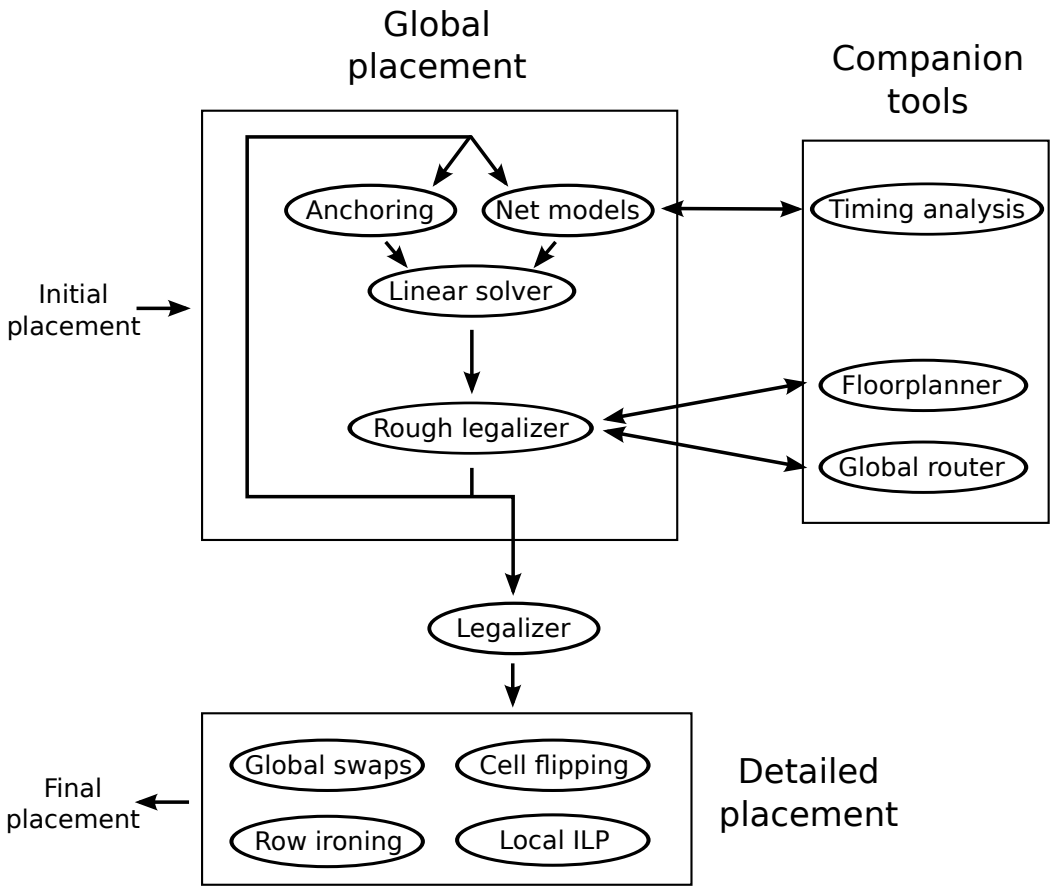
- Quadratic $\Rightarrow$ Simple yet efficient
- Lookahead legalization $\Rightarrow$ Local density control

Etesian's structure



What's special in Etesian?

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- Focus on good legalization

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- Algorithms for detailed placement

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- Focus on good legalization
- Algorithms for detailed placement
- Net models

The need for extensive benchmarking

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Small change $\Rightarrow$ random quality variations

The need for extensive benchmarking

Small change $\Rightarrow$ random quality variations

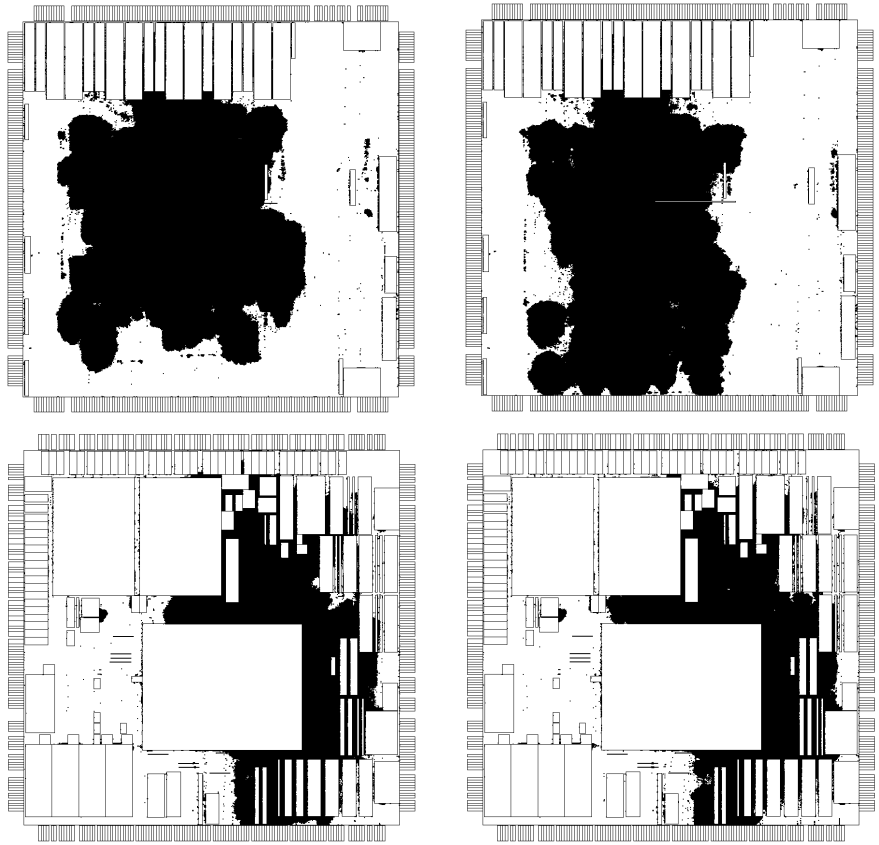
Experienced with:

- Penalty type
- Penalty weight

The need for extensive benchmarking

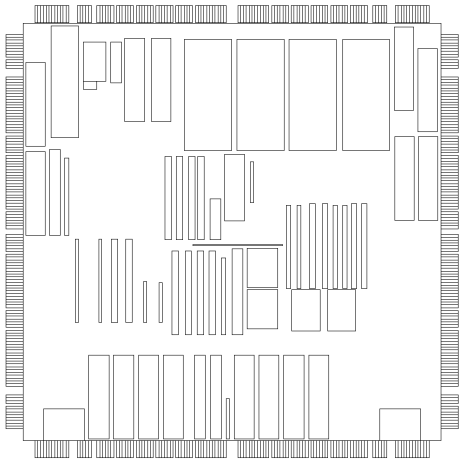
Bigblue1: WL +0.8%

Adaptec2: WL -2.1%

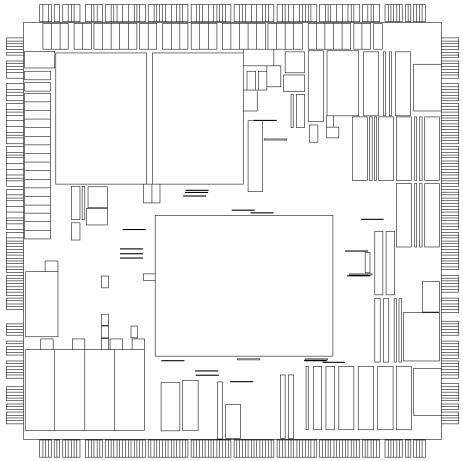


A simple change: linear vs quadratic penalty

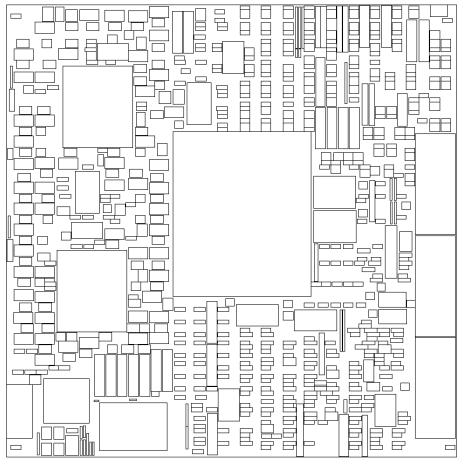
The ISPD05 benchmarks



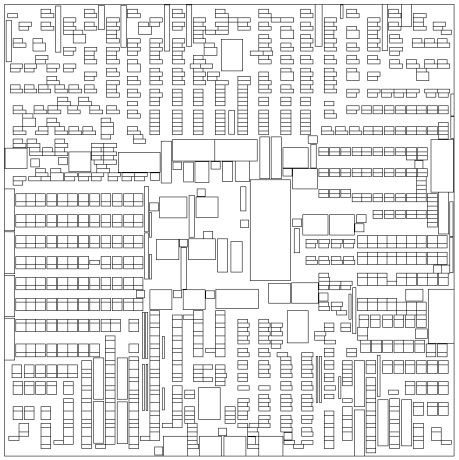
Adaptec1



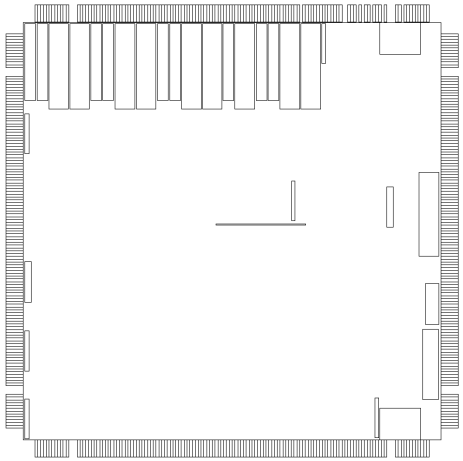
Adaptec2



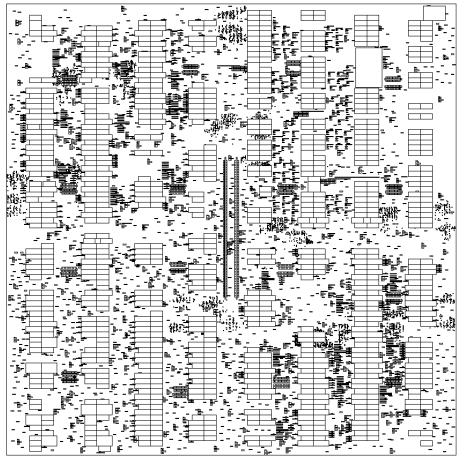
Adaptec3



Adaptec4

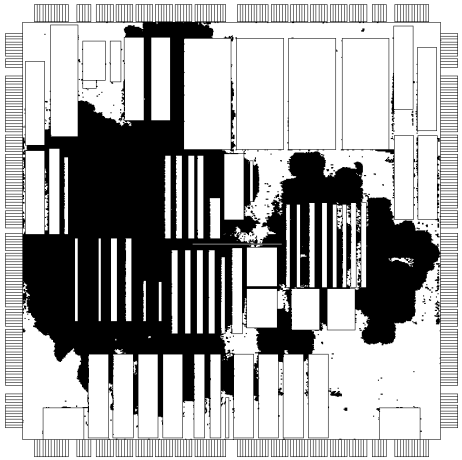


Bigblue1



Bigblue2

ISPD05 placements



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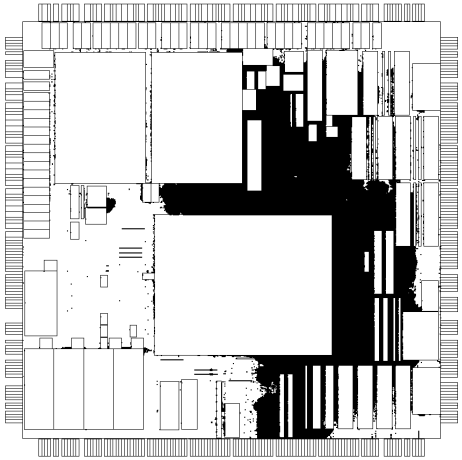
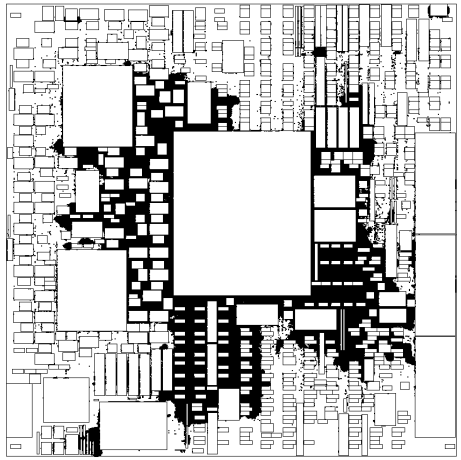
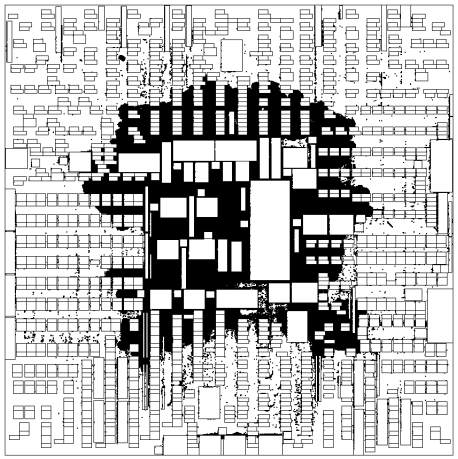


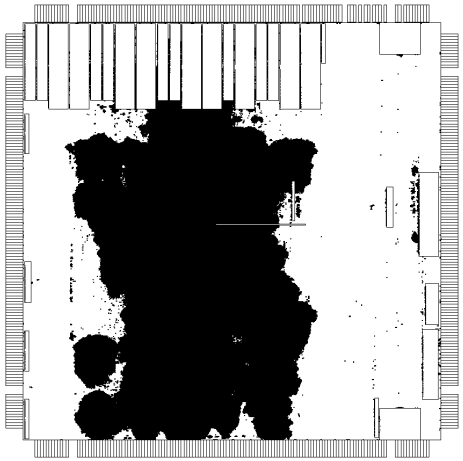
Adaptec2



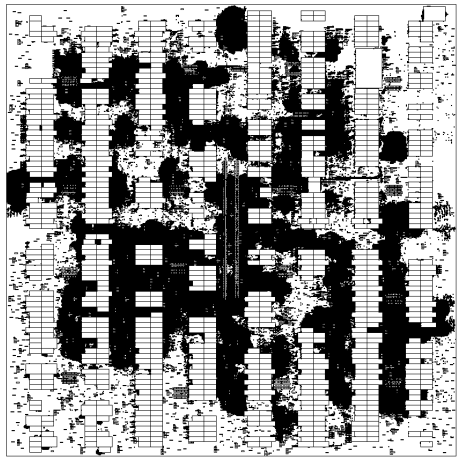
Adaptec3



Adaptec4



Bigblue1



Bigblue2

Not bad

Problem	ePlace	Best quadratic	Etesian	%
Adaptec1	**74.63**	76.36 (Maple)	76.49	+2.49
Adaptec2	**84.84**	86.16 (POLAR)	87.90	+3.61
Adaptec3	**194.57**	201.30 (POLAR)	202.12	+3.88
Adaptec4	**179.02**	179.91 (Maple)	182.27	+1.82
Bigblue1	**90.99**	93.74 (Maple)	94.76	+4.14
Bigblue2	141.83	143.95 (POLAR)	**141.16**	**-0.47**
Bigblue3	**308.77**	317.17 (Bonn)	#	#
Bigblue4	**753.20**	775.71 (Maple)	#	#

Quality comparison: HPWL (10^6 units)

Further work: performance

Further work: performance

- Easy in hindsight

Further work: performance

- Easy in hindsight
- Rewrite + parameter tuning

Further work: the hard part

Integrating with other tools:

- Usability
- Router
- Timing

References I

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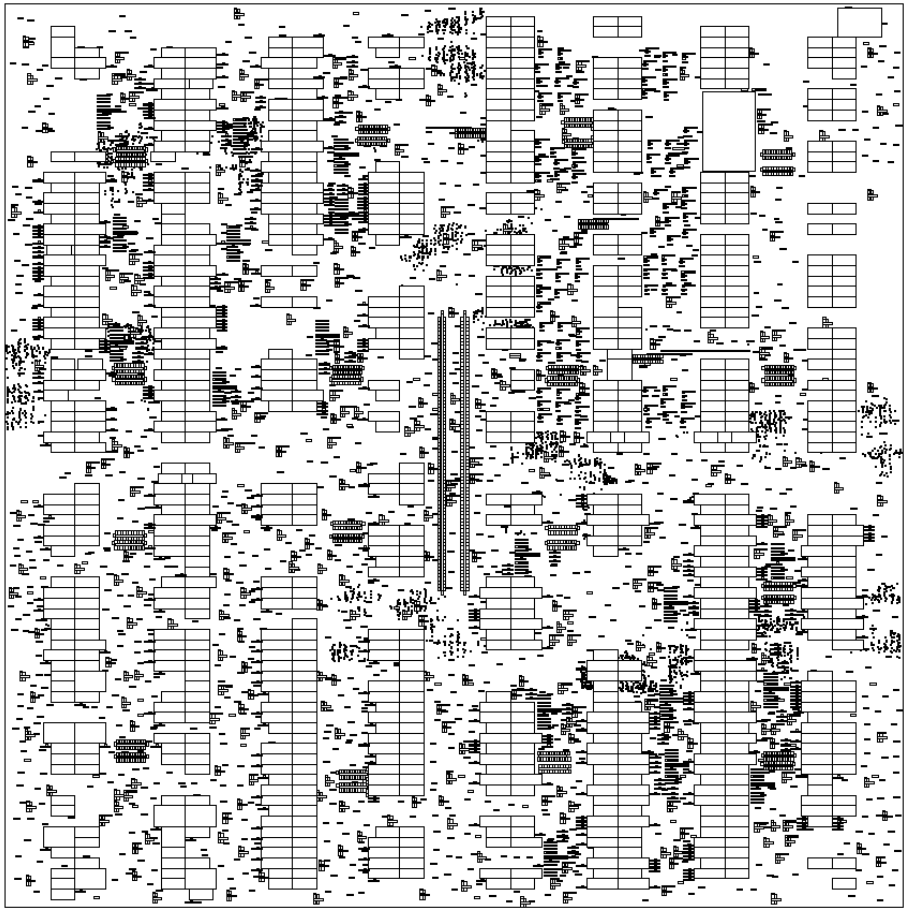
Questions

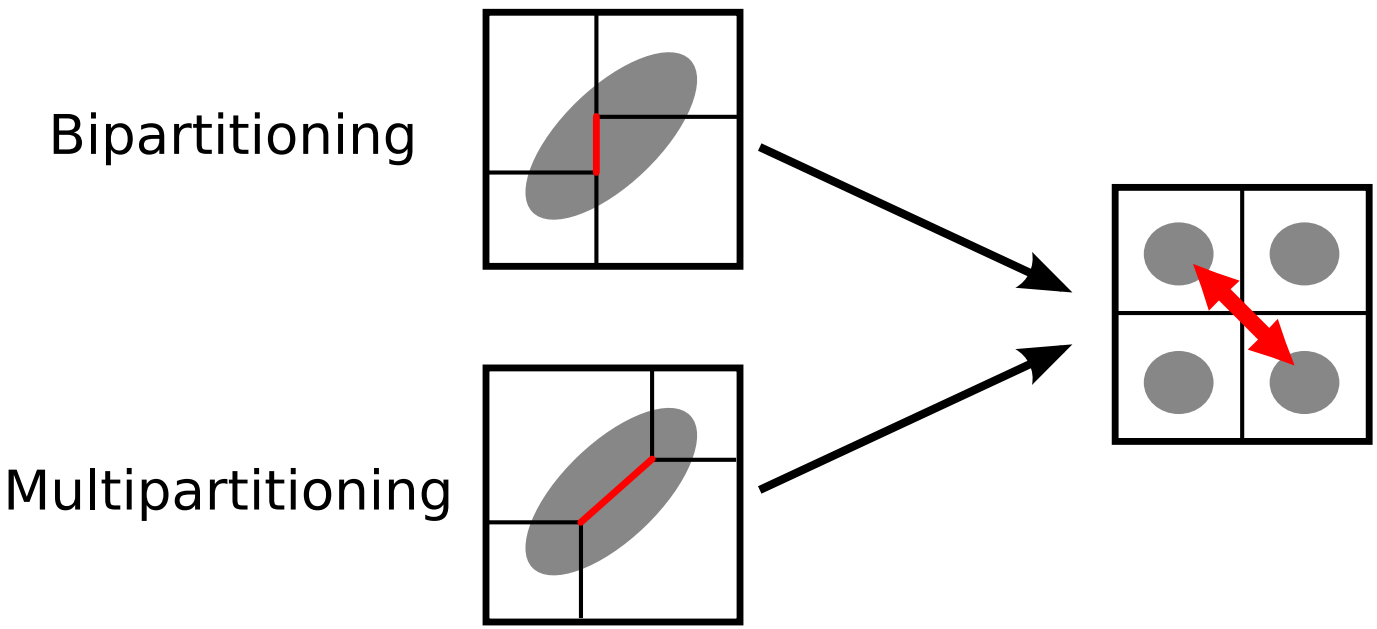


Lookahead legalization

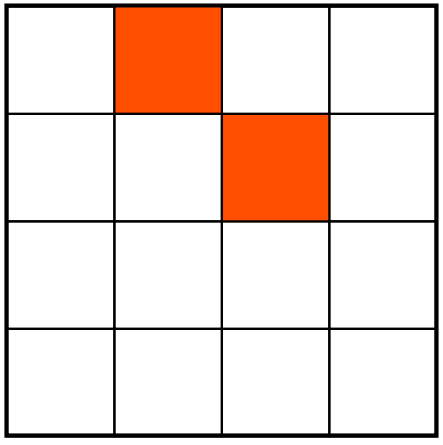
- Introduced by SimPL [2]

Lookahead legalization

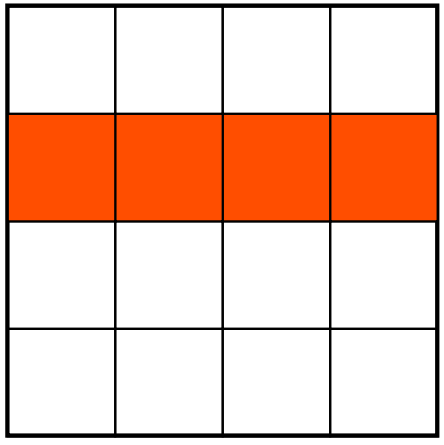
- Introduced by SimPL [2]
- Always based on partitioning



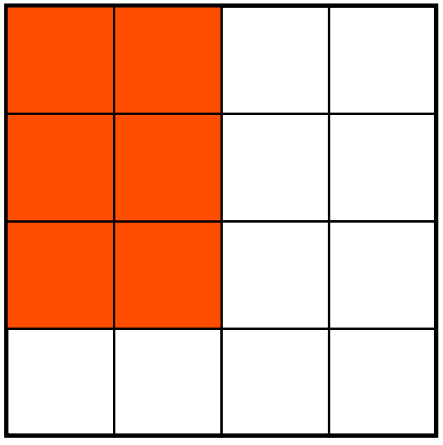
In Etesian: local optimizations



Two regions

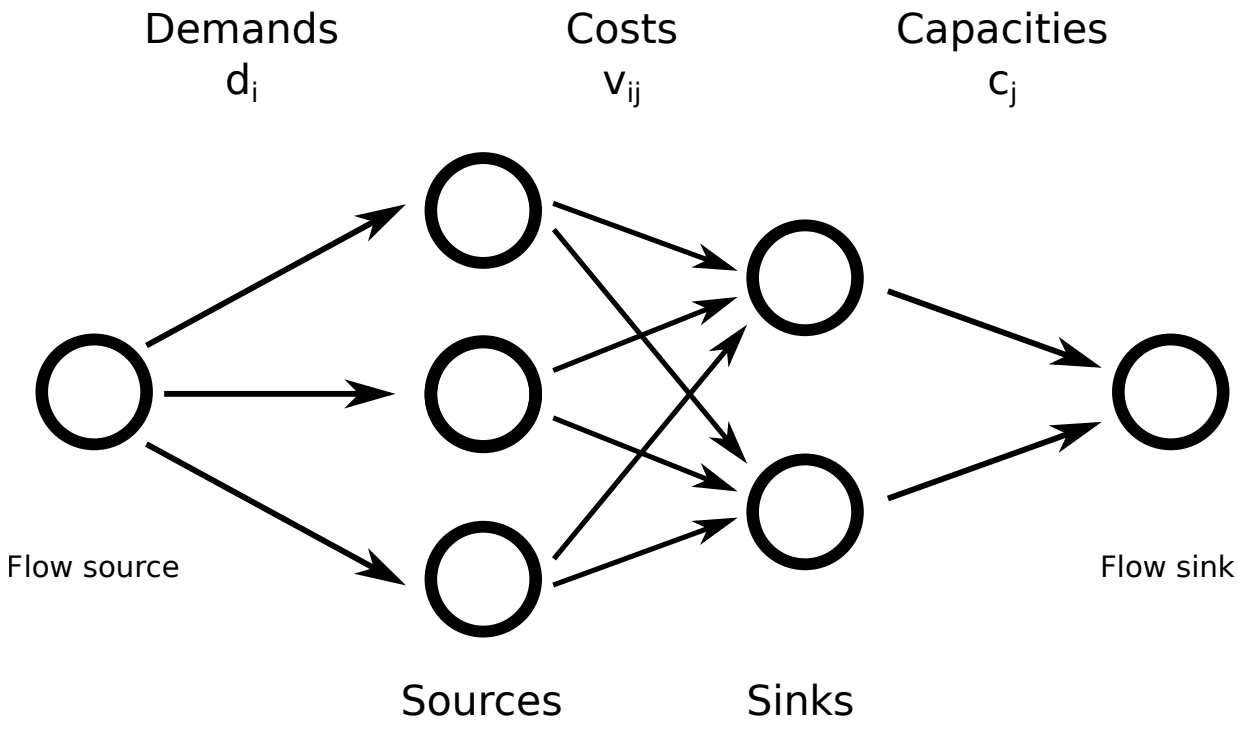


Row/Column

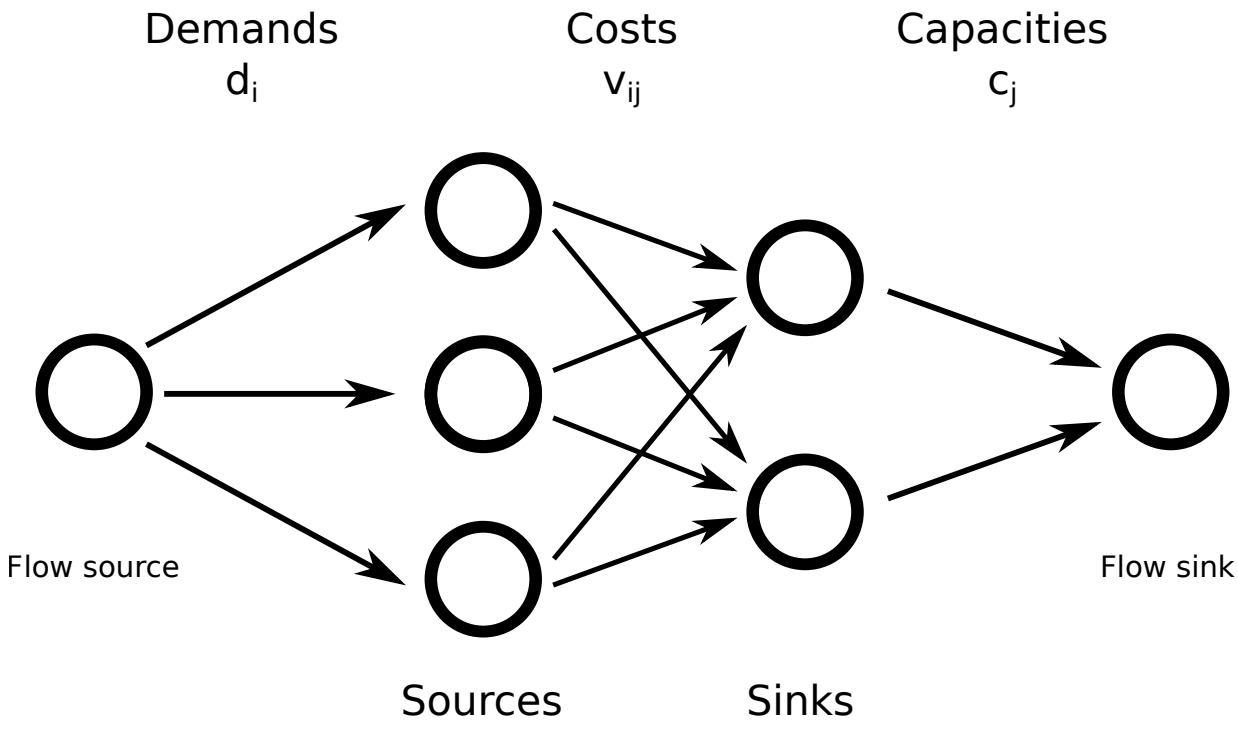


Multipartitioning

A transportation problem



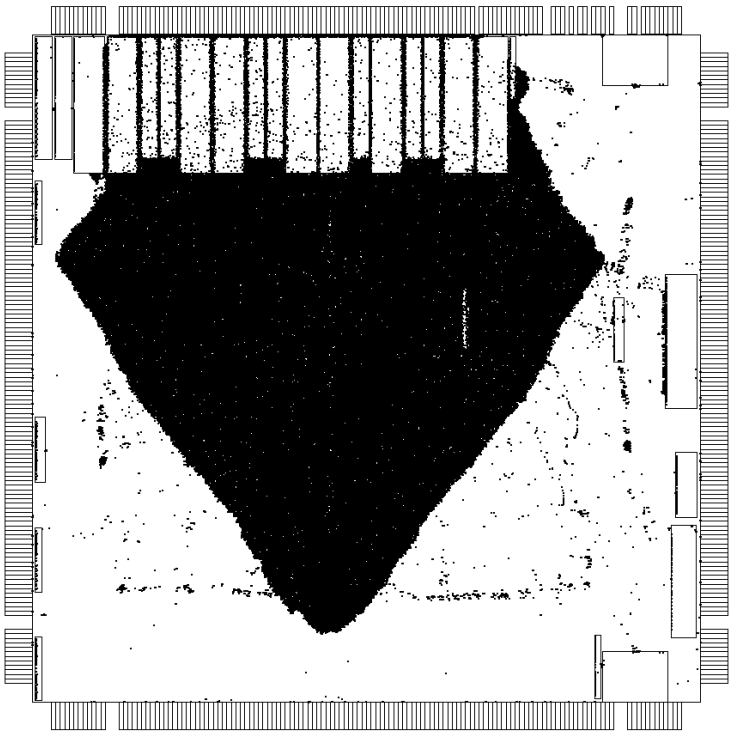
A transportation problem



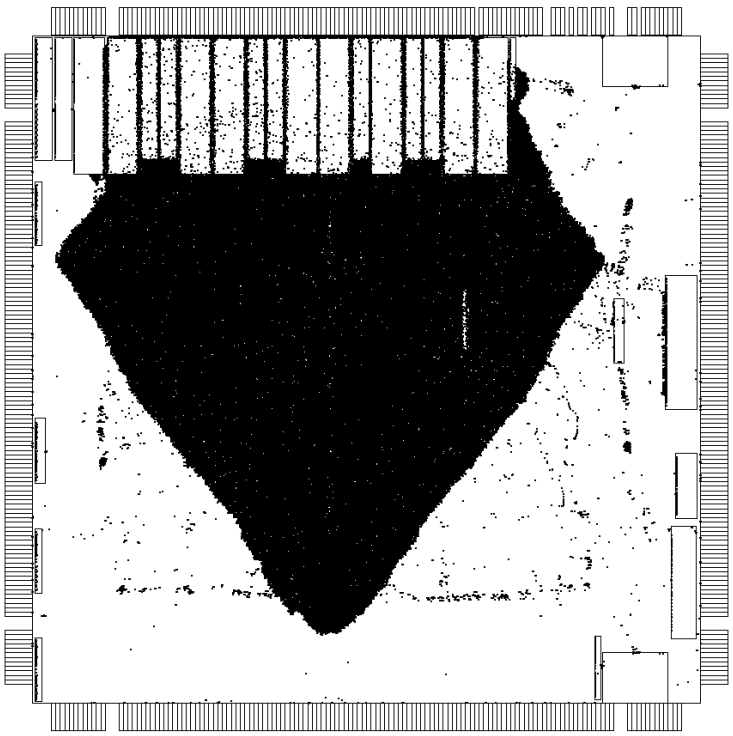
$\Omega(n^3)$ algorithms

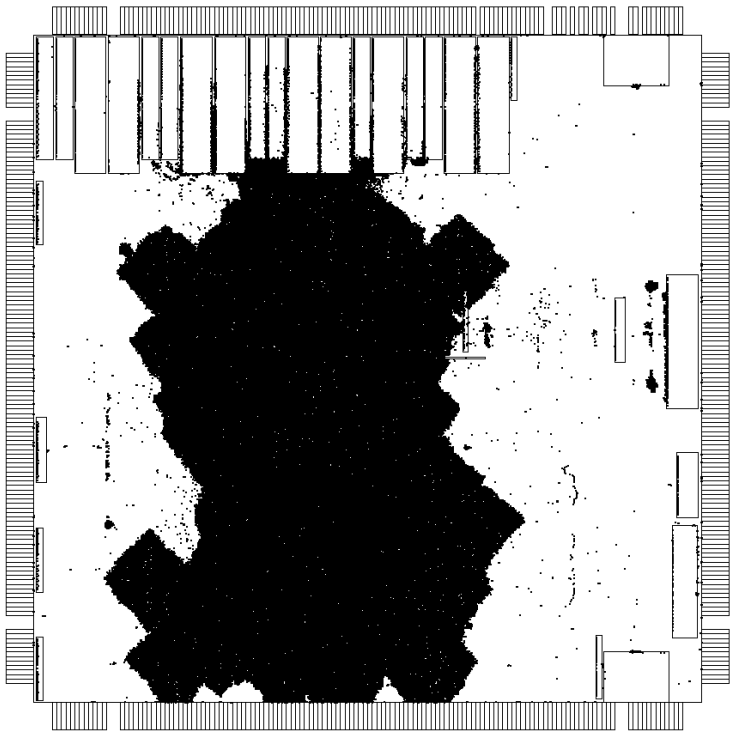
Visual results

Visual results



Visual results



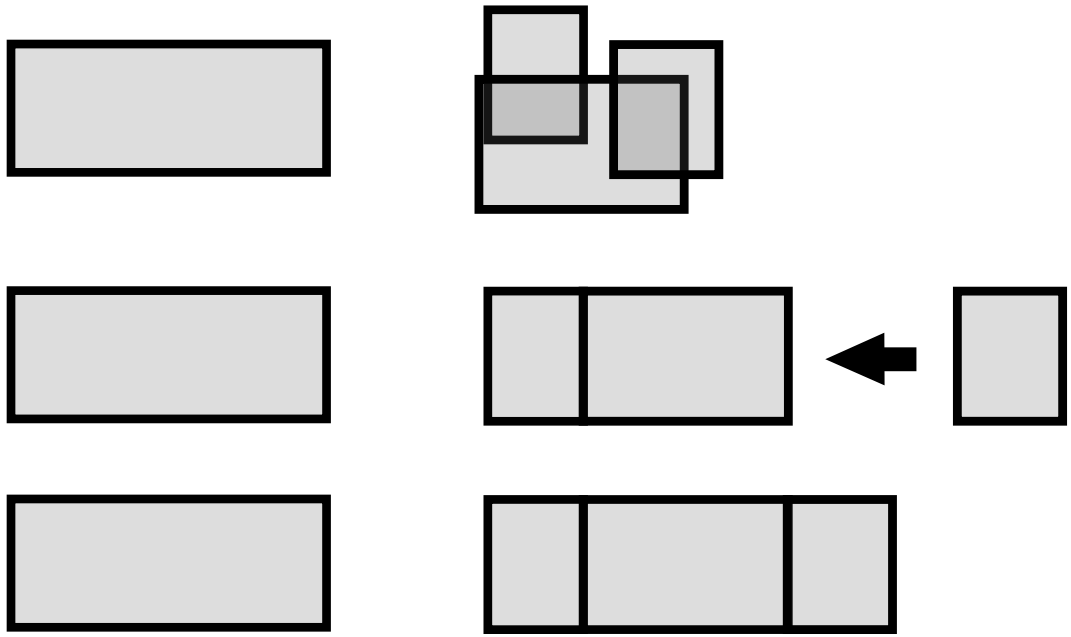


True legalization

Usually greedy

True legalization

Usually greedy



True legalization in Etesian

Push the previous cells [7]

True legalization in Etesian

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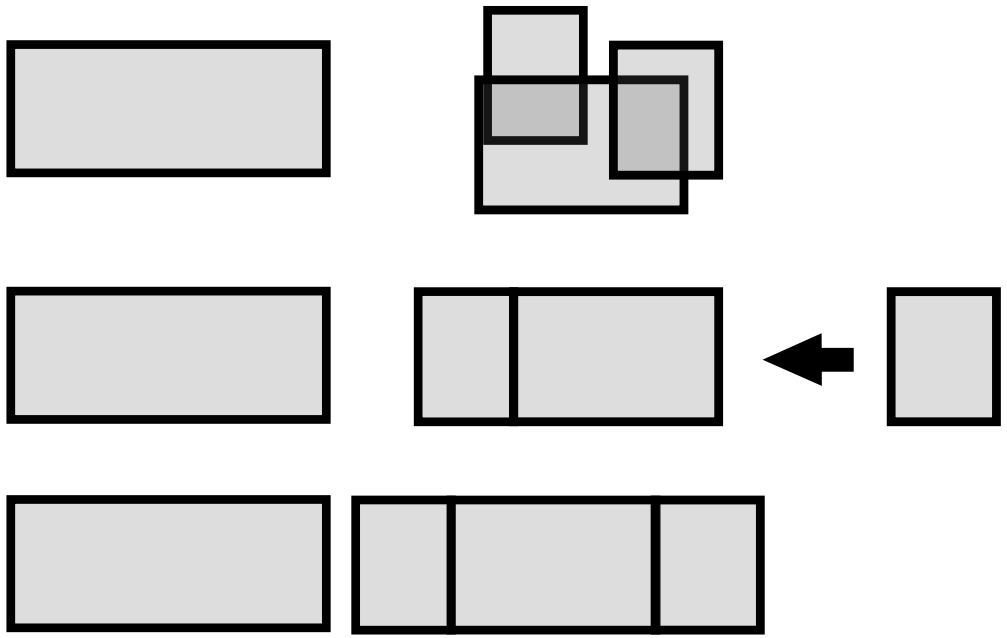
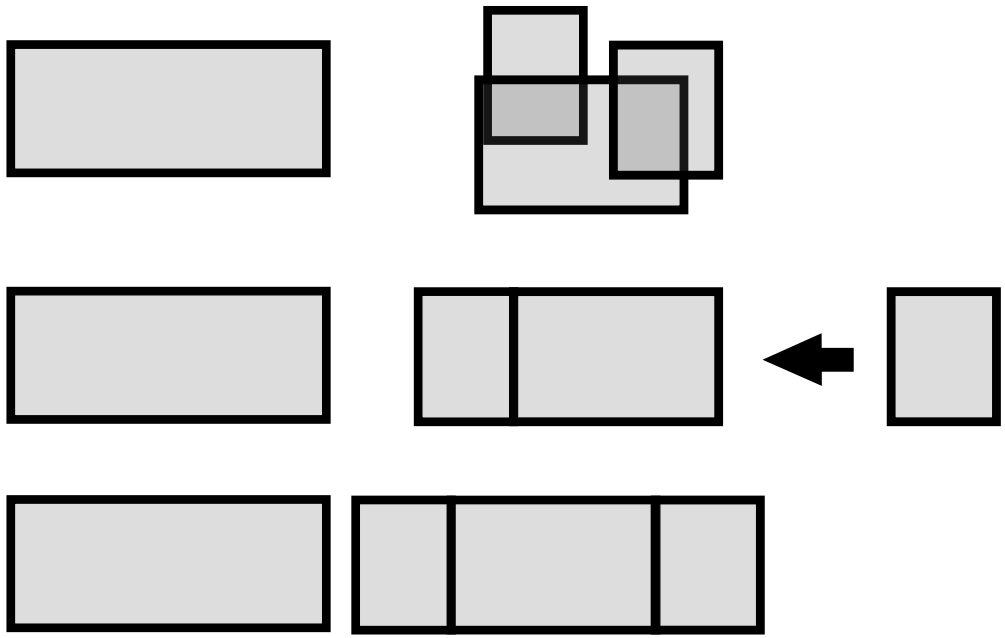


True legalization in Etesian

Push the previous cells [7]



Even better: after a rough legalization

Placement $\approx$ scheduling

Machines $\Leftrightarrow$ Rows

Tasks $\Leftrightarrow$ Uniform-height cells

? $\Leftrightarrow$ Wirelength

Our cost function is complicated

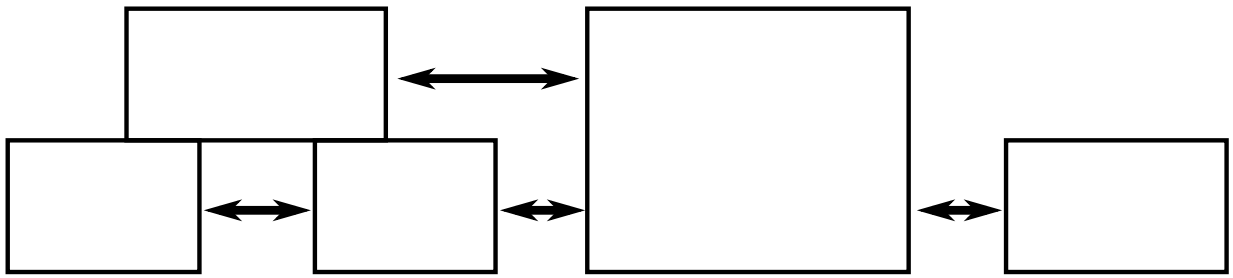
$\Rightarrow$ The cells are not independent

Our cost function is complicated

$\Rightarrow$ The cells are not independent

At fixed scheduling-order, dual of a Minimum-cost flow problem

Minimize $\sum \alpha_i x_i$
Subject to $x_{i_k} - x_{j_k} \leq d_k$



A simplified problem

Single row with fixed ordering

=

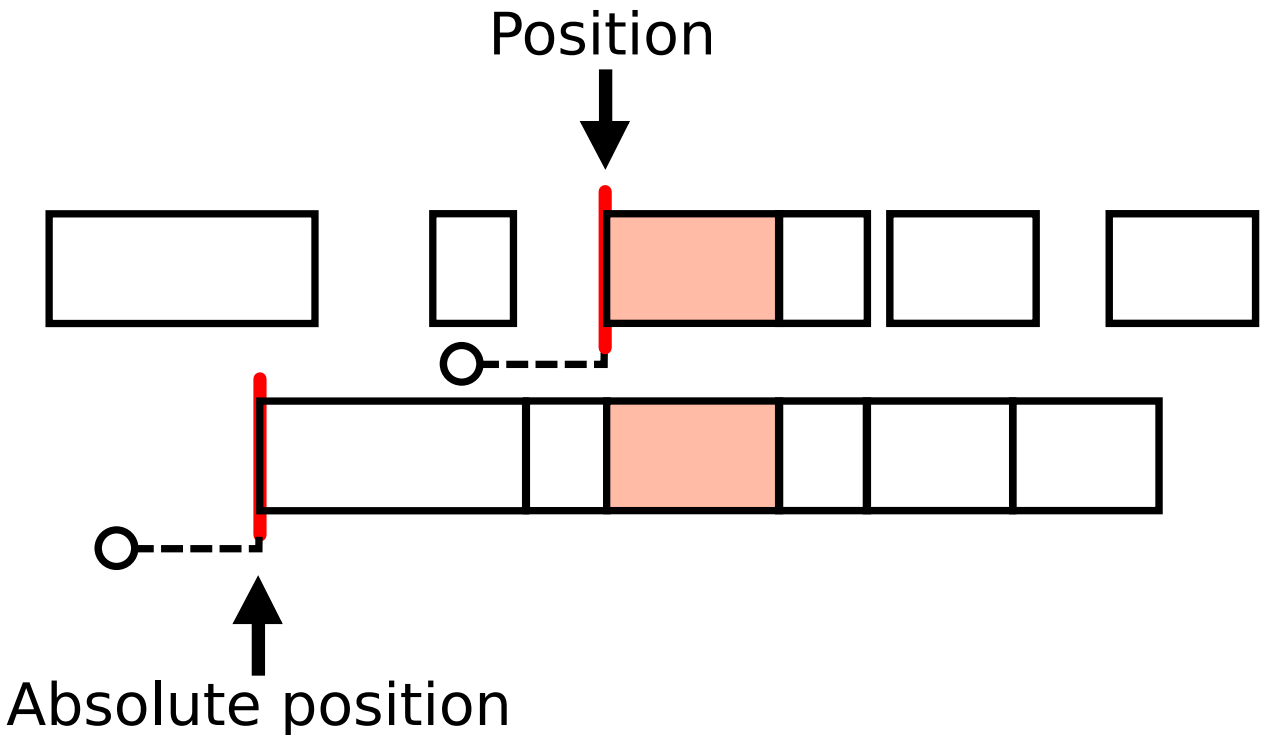
Single machine with fixed ordering

The cascading descent algorithm

Greedy algorithm with a single heap

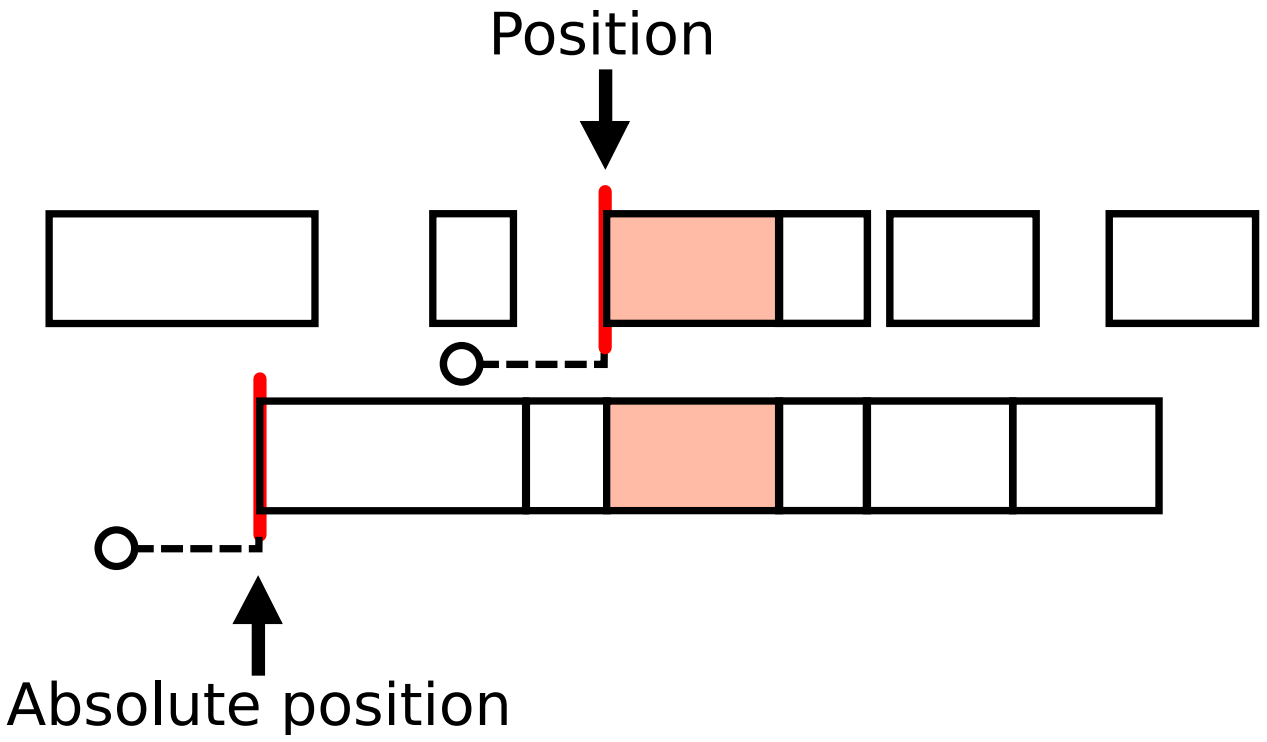
The cascading descent algorithm

Greedy algorithm with a single heap



The cascading descent algorithm

Greedy algorithm with a single heap



$O(n \log n)$ [4]

First use for placement

Everywhere in Etesian:

First use for placement

Everywhere in Etesian:

- Lookahead legalizer
- True legalizer
- Detailed placement reordering
- Whitespace allocation in detailed placement