Floor Planning via Convex Optimization

Final Projection - EEC 254 (Winter 2018)

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ELECTRICAL AND COMPUTER ENGINEERING

Agenda

- Problem Definition & Motivation
- Problem Formulation
- Project Goal(s)

Problem Definition

- Configure some rectangles within a bounding box
- Objective function is on the bounding box
- Constraints is on the shape and size of rectangles

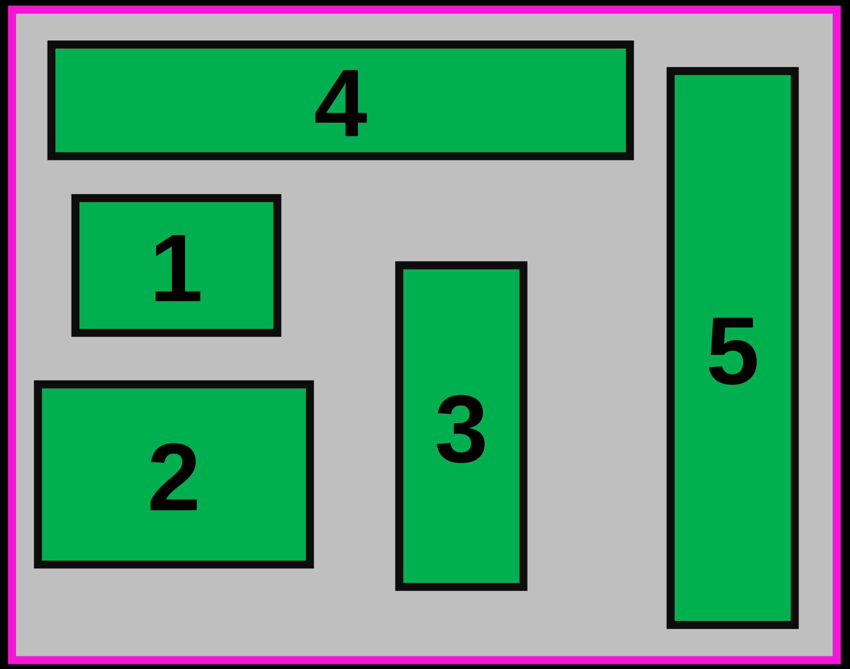
Problem Definition

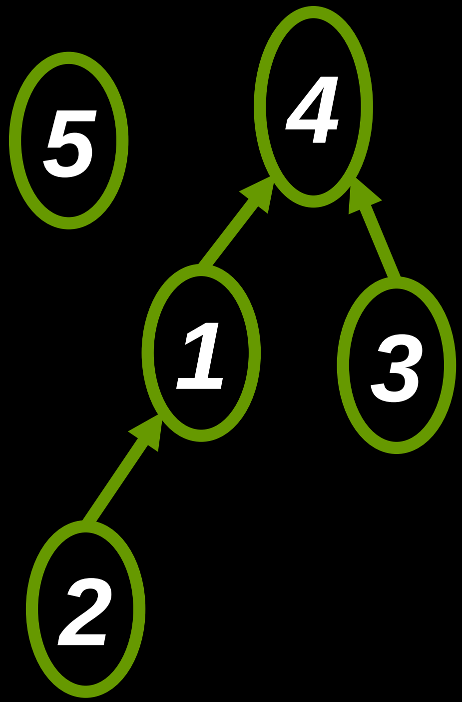
Constraints:

- no overlap
- relative position

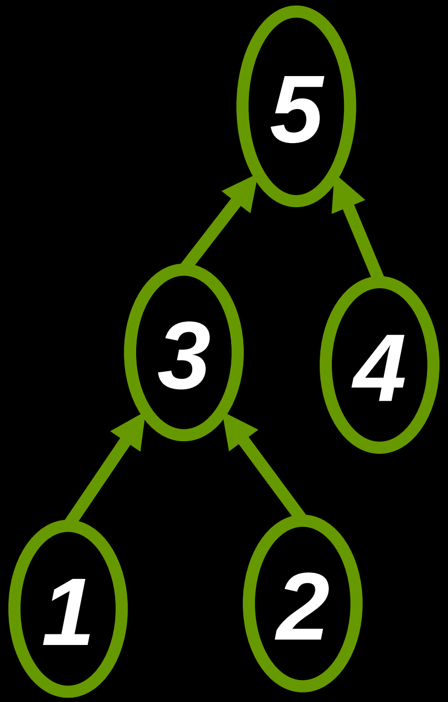
Problem Definition

Constraints:
- no overlap
- relative position





Vertical Graph



Horizontal Graph

Problem Definition

Constraints:

- no overlap
- relative position *(implies no overlap)*
- all rectangles inside the bounding box
- minimum rectangle area/aspect ratio/perimeter
- symmetry
- alignment
- similarity

Problem Definition

Objective:

- minimize the size (area, perimeter) of the bounding box
- or, maximize the size of the rectangles given a fixed bounding box

Variables:

- rectangles’ positions
- rectangles’ sizes
- bounding box size

Motivation

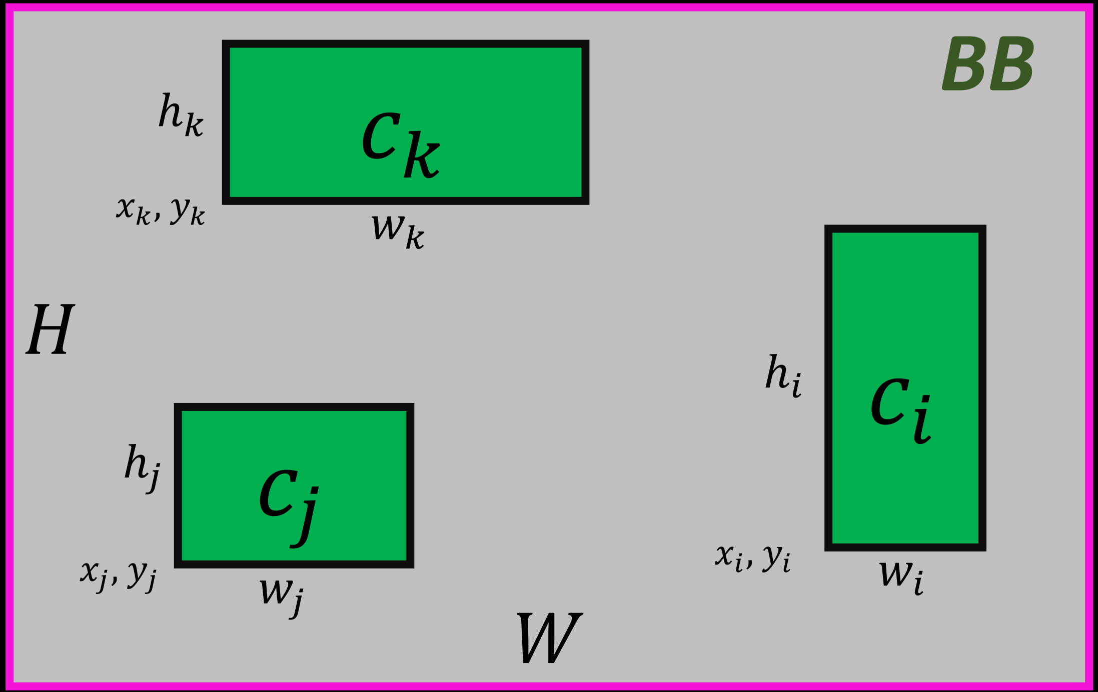
Architecture:

- the rectangles are rooms/floors
- arrange rooms within fixed bounding box

VLSI:

- minimize the area of the blocks which decompose a circuit

Formulation



Bounding Box (BB):

- width W and height H
- starts at $(0,0)$

Cells:

- N cells
- cell c_i is defined by its lower left corner (x_i, y_i), width w_i and height h_i

Formulation

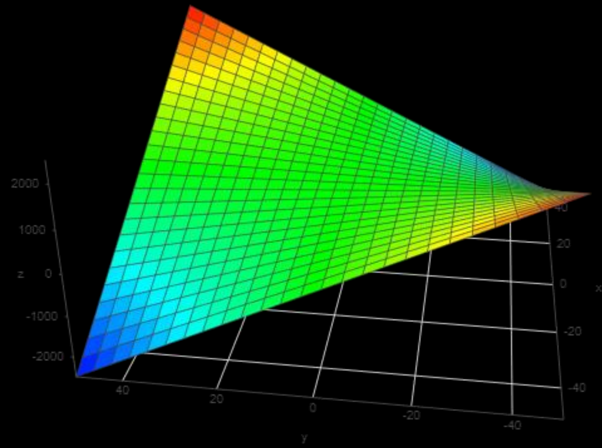
Objective Functions

Minimize BB area:

$$A = H.W$$

Formulation

Objective Functions



Minimize BB area:

$$A = H.W$$

Hessian's minimum eigenvalue <*0* ⇒ non-convex

Take log

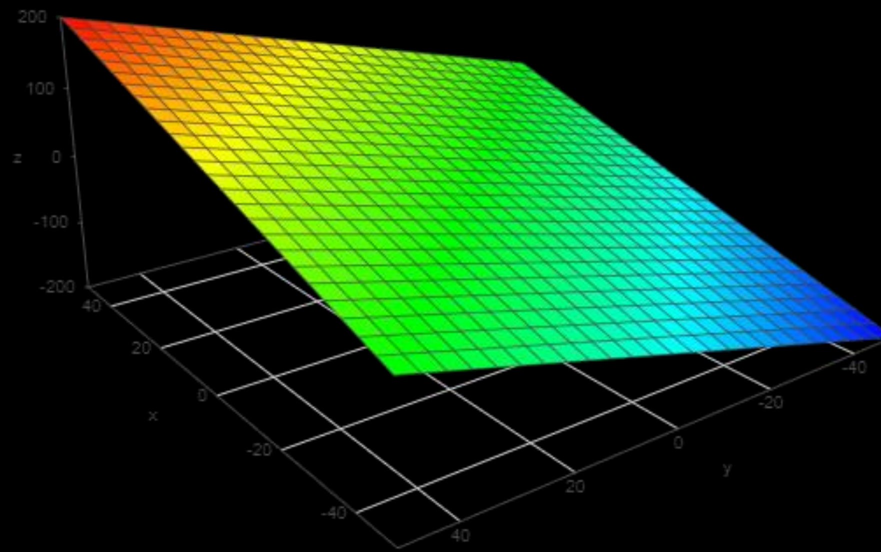
$$log(A) = log(H) + log(W)$$ ⇒ concave

Formulation

Objective Functions

Minimize BB *perimeter*:

$$p = 2(H + W)$$



Affine, tend to form equal sides BB

Formulation

Objective Functions

Maximize cells area:

concave function

$$max\ (log(w_i) + log(h_i))\,, \mathrm{i} = 1, \dots, \mathrm{N}$$

multi-criterion with N objective function

scalarization

$$max\ \sum_{i=1}^{N}(log(w_i) + log(h_i))$$

Formulation

Constraints

Basic constraints:

- Everything inside the bounding box

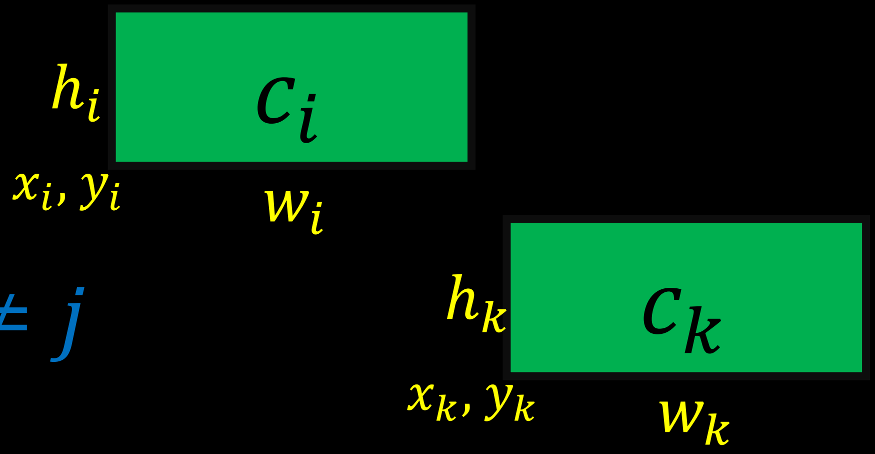
$$x_i \geq 0,$$
$$y_i \geq 0,$$
$$x_i + w_i \leq W,$$
$$y_i + h_i \leq H, \qquad i = 1, \ldots, N$$

- Widths and length should be positive

$$w_i \geq 0,$$
$$h_i \geq 0, \qquad i = 1, \ldots, N$$

Formulation

Constraints



No overlap:

$$int(x_i \cap x_i) = \emptyset, i \neq j$$

Use relative position:

$$x_i + w_i \leq x_k \rightarrow c_i\ to\ the\ left\ of\ c_k$$

$$y_k + h_k \leq y_i \rightarrow c_k\ below\ c_i$$

Minimum clearance:

$$x_i + w_i + \rho \geq x_j, \quad \rho \geq 0$$

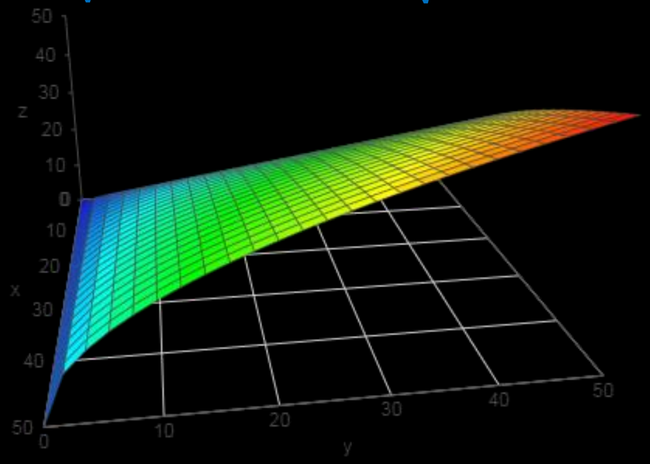
Formulation

Constraints

Minimum area:

Avoid zero area

$$\sqrt{h_i w_i} \geq \sqrt{A_{min}} \quad \text{or} \quad log(h_i) + log(w_i) \geq \log(A_{min})$$



Formulation

Constraints

Aspect ratio:

- Ratio between height to width

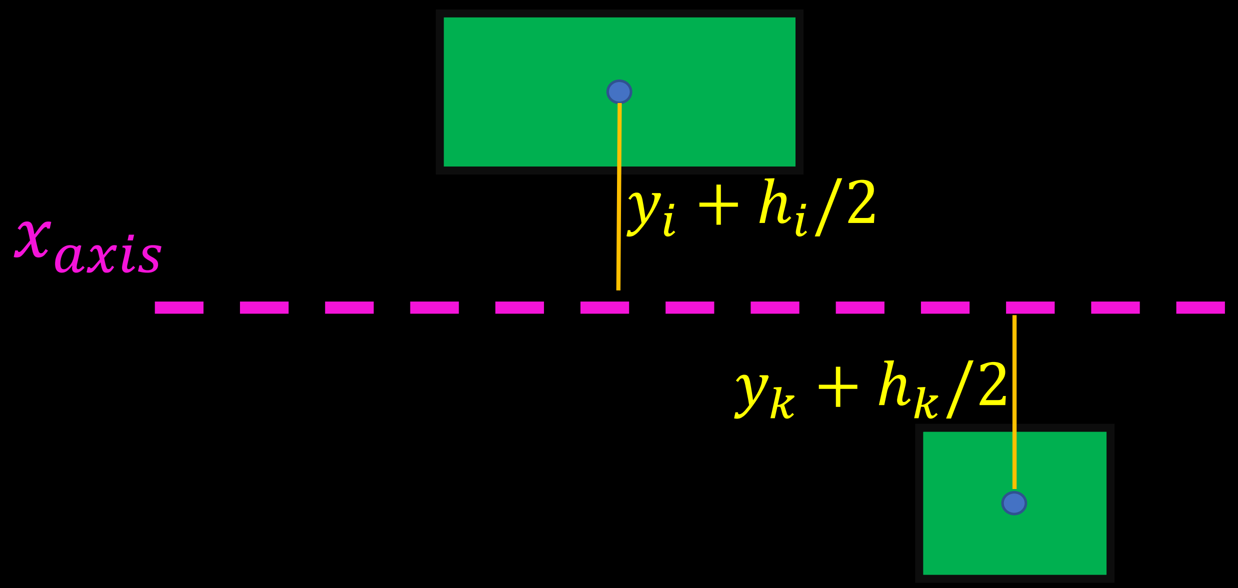
$$\sigma_i^{min} \leq h_i / w_i \leq \sigma_i^{max}$$

$$\sigma_i^{min}.w_i \leq h_i \leq \sigma_i^{max}.w_i$$

Formulation

Constraints

Symmetry:



$$x_{axis} + (y_i + h_i/2) = x_{axis} - (y_k + h_k/2)$$

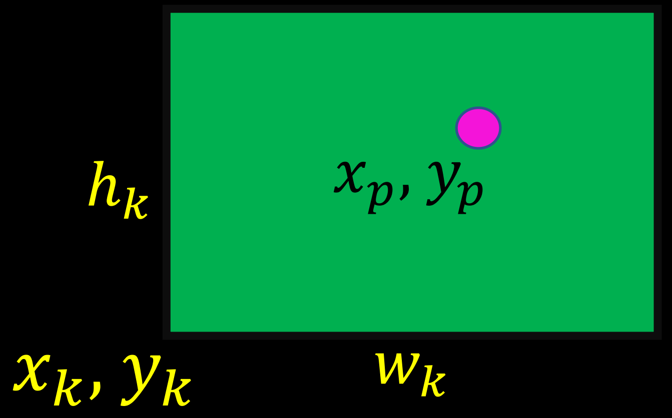
Formulation

Constraints

Containment:

- Impose that the cell to contain a point or to be contained inside a polyhedron

$$0 \le x_p - x_i \le w_i, \qquad 0 \le y_p - y_i \le h_i$$



Formulation

Primal Problem

Basic Problem:

Mini *BB* area, no overlapping cells, each block has minimum area

Variables:

- $W, H \in \mathbb{R}$
- (x_i, y_i, h_i, w_i) for N cells

Formulation

Primal Problem

Relative Position (functions):

Using two relations on $\{1, \ldots, N\}$

$$\mathscr{L} \text{ (left to), } \beta \text{ (below)}$$

C_i is left to C_j if $(i, j) \in \mathscr{L}$

C_i is below C_j if $(i, j) \in \beta$

Relation is anti-symmetric

$$(i, j) \in \mathscr{L} \leftrightarrow (j, i) \notin \mathscr{L}$$

Formulation

Primal Problem

Relative Position (matrices):

$$L_{i,j} = \begin{cases} 1, (i,j) \in \mathscr{L} \\ 0, \ otherwise \end{cases}$$

$$B_{i,j} = \begin{cases} 1, \ (i,j) \in \beta \\ 0, \ otherwise \end{cases}$$

Formulation

Primal Problem

min $2(H+W)$

s.t $-x \preccurlyeq 0, \quad -y \preccurlyeq 0, \quad -w \preccurlyeq 0, \quad -h \preccurlyeq 0, -H \leq 0, -W \leq 0$

$$x + w - W.1 \preccurlyeq 0, \qquad y + h - H.1 \preccurlyeq 0$$

$$A_i/h_i\text{-}w_i \leq 0, i = 1, \ldots, N$$

$$L_{i,j}.\left(x_i + w_i - x_j\right) \leq 0, \; B_{i,j}.\left(y_i + h_i - y_j\right) \leq 0, \; i,j = 1, \ldots, N, i \neq j$$

Project Goal

- Formulate the problem as a geometric programming
- Add new constraints
- Numerical results using CVX

Thank You!