2-Dimensional Rectangles-in-Circles Packing & Stock Cutting with Particle Swarm Optimization

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Presentation Plan

Packing and Cutting Problems

- Both problems consider a set of source material and a set of product types
- In packing problems:
  - product types are characterized by their value
  - the goal is to maximize the value
- In cutting problems:
  - product types are characterized by their demand
  - the goal is to fulfill the demand (get as close as possible)

Quality functions I

- Quality function is computed as a sum of product values in each of the input materials

  n - number of products,

  s - size of a product

  v - value of a product

  d - demand for a product

  m - number of pieces of an input material type

  S - size of an input material

  P - placement of products

Quality functions II

- Waste minimization

$$f_{waste}(P) = \sum_{j=1}^{|Material|} m_j \left(S_j - \sum_{i=1}^{|Placed\ products|} s_i \right) \quad (1)$$

- Profit maximization

$$f_{profit}(P) = \sum_{j=1}^{|Material|} m_j \left(\sum_{i=1}^{|Placed\ products|} v_i \right) \quad (2)$$

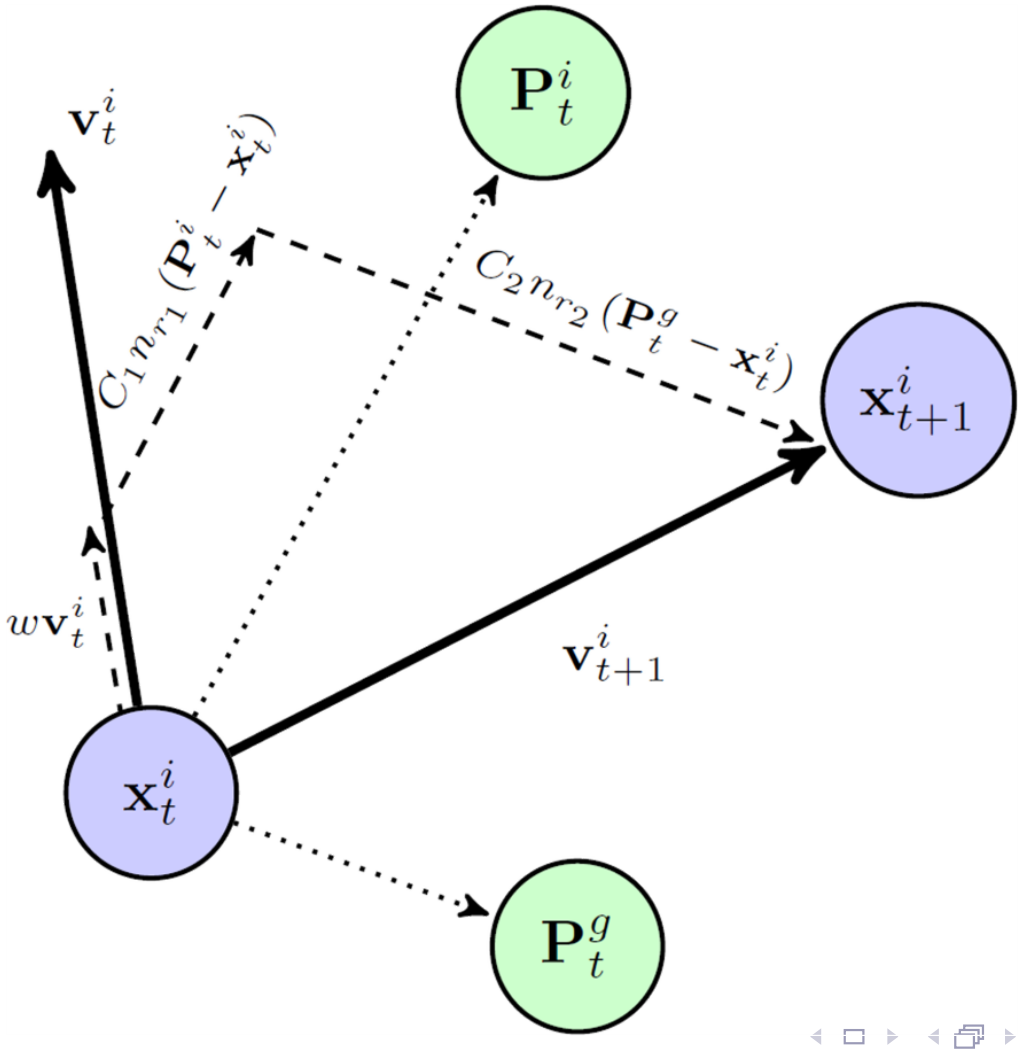
- Demand fulfillment maximization

$$f_{demand}(P) = \min_{i=1}^{|Placed\ products|} \frac{\sum_{j=1}^{|Material|} m_j n_{i,j}}{d_i} \quad (3)$$

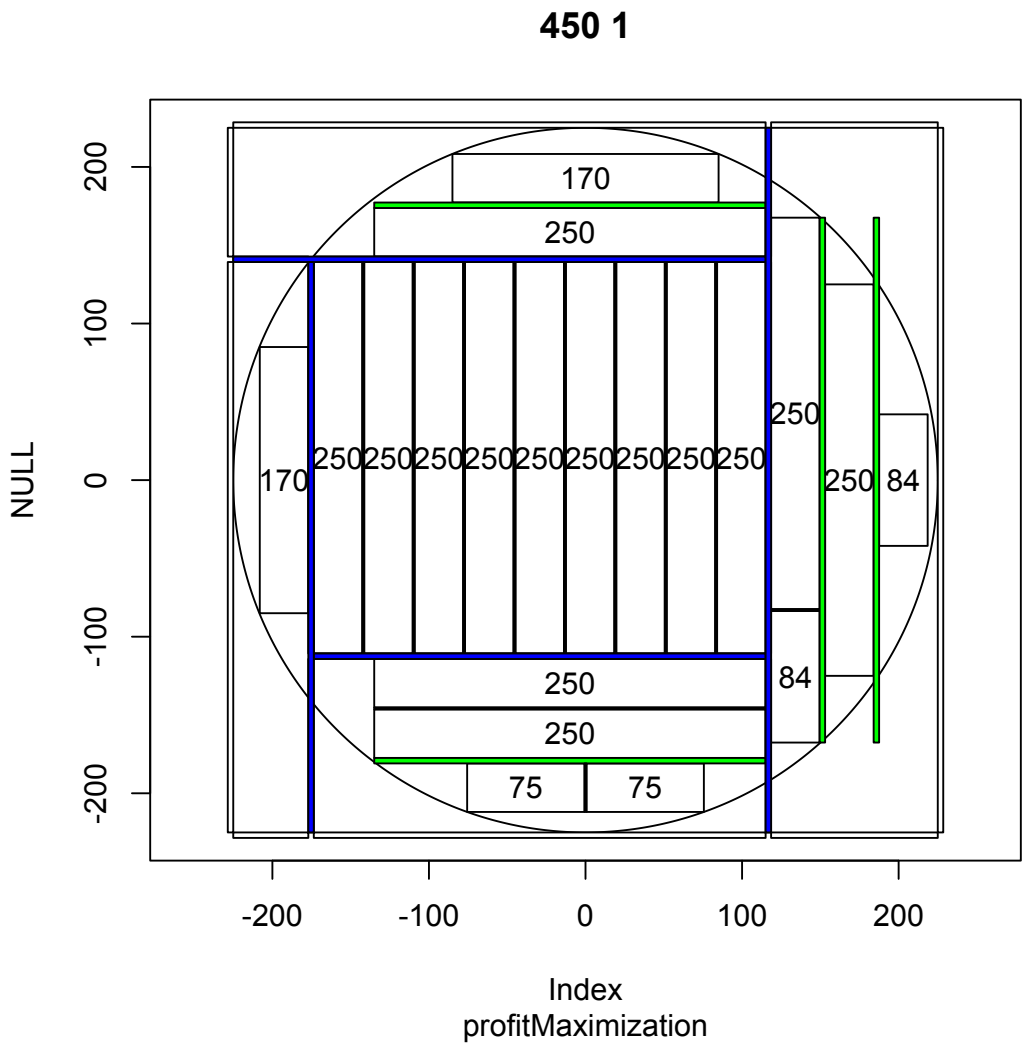
2D Log Cutting Problem

- Material is a set of tree logs (circles)
- Products are a set of sawn timber/planks (rectangles)
- Products are cut from material by guillotine cuts
- Material may be rotated by 90 degrees after each cut
- Number of rotations should be limited
- Each sawn timber size has a different value per m^3

Particle Swarm Optimization (for presentation consistency)



Continuous Search Space for LCP



- Search space is formed by the coordinates of subsequent cuts after which clockwise rotation is performed (blue cuts)
- $[110, 140, -180, -110]$ in this case

Placing products within a single shape

- 1-D solution dictionary
- 2-D greedy heuristic
- The stripes from the dictionary are tested horizontally and vertically
- Stripes are placed starting from the center of the log
- The inner shape is considered first
- Coordinates of the shape are tightened in order to fit the stripes (local optimization)

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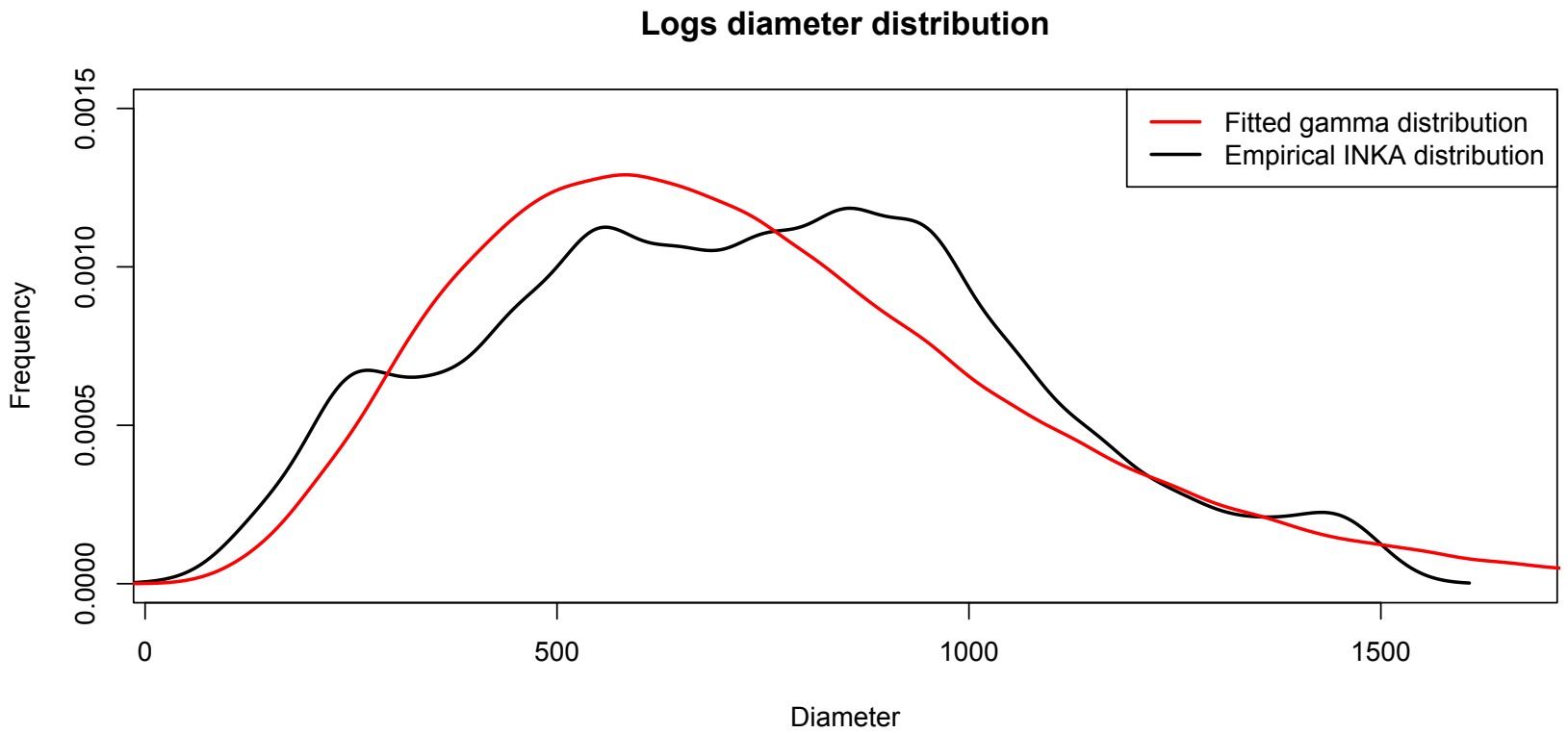
Artificial data set

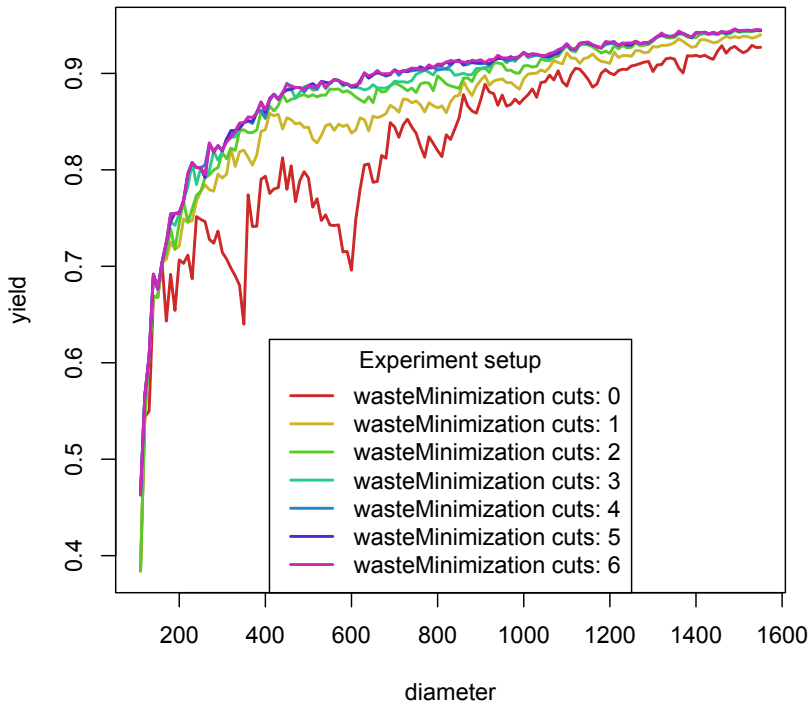


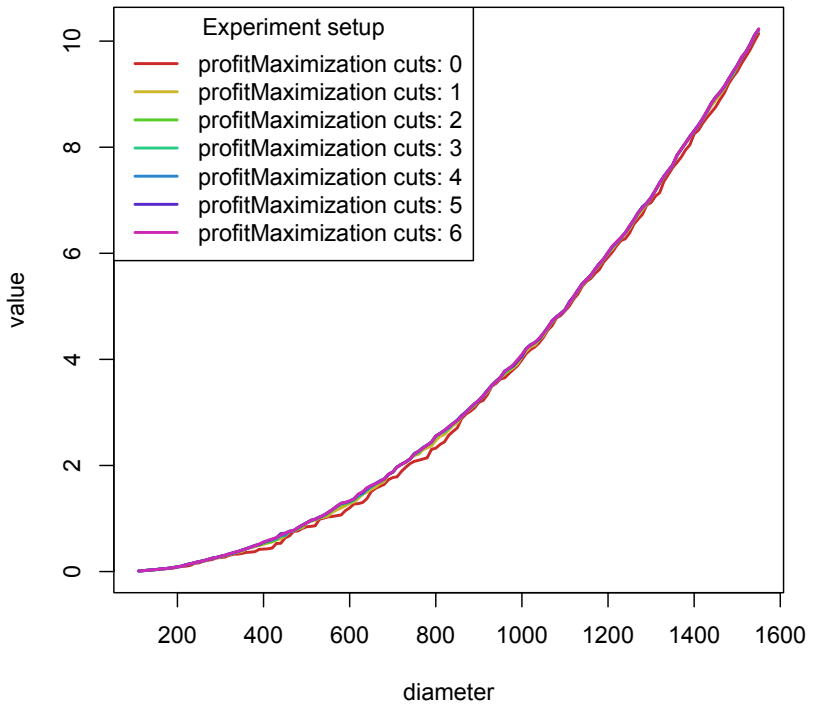
Artificial data set

Table: Artificial products

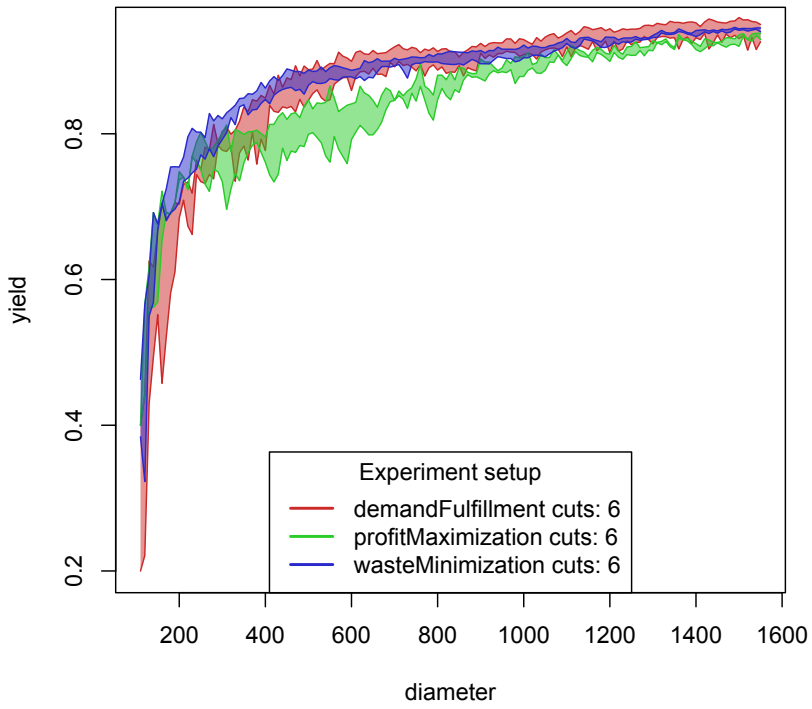
	Thickness	Width	Length	Value m^3	Demand
1	19	100	2000	1.00	500000
2	25	100	2000	1.15	500000
3	32	100	2000	1.30	500000
4	38	100	2000	1.41	500000
5	38	125	2000	1.58	500000
6	50	73	2000	1.39	500000
7	50	100	2000	1.62	500000
8	50	125	2000	1.81	500000
9	50	150	2000	1.99	500000
10	50	175	2000	2.15	500000
11	50	200	2000	2.29	500000
12	75	200	2000	2.81	500000
13	75	225	2000	2.98	500000

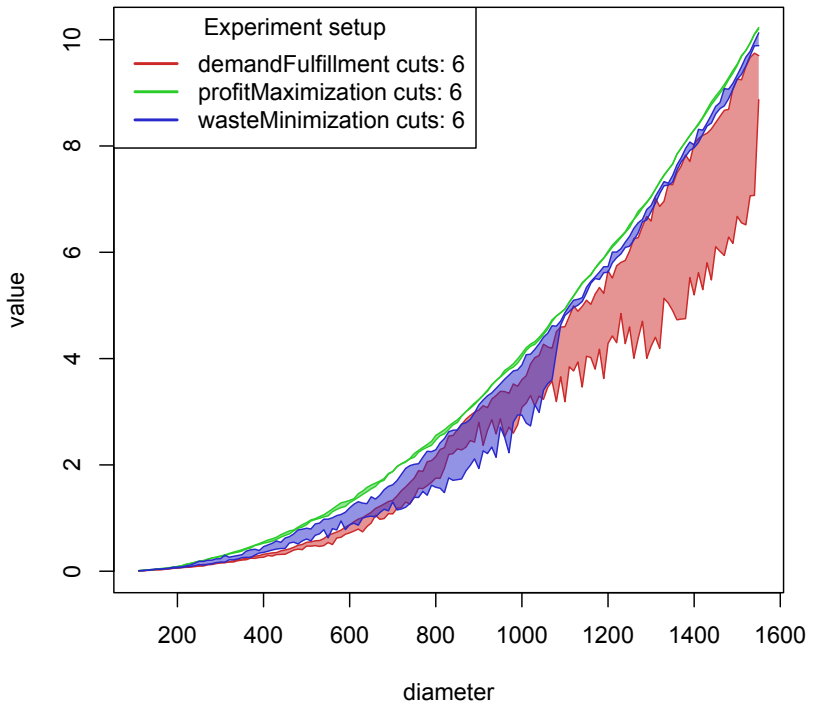
Number of cuts analysis





Solutions distribution analysis





Conclusions

- Proposed approach allowed for creating a stable optimization results (at least within the optimization criterion)
- Having a greedy heuristic inside may lead to unexpected results (yield in demand fulfillment better than in yield maximization)
- Having more than 3 cuts is probably economically unwise
- With random algorithms special care should be put to
  - maintaining the best result over subsequent calls for the same set of input parameters
  - presentation of the solutions (despite their numerical quality)

Benchmark files

Benchmark dataset:

http://www.mini.pw.edu.pl/~okulewiczm/downloads/lcp

```
{
  "rotateLimit": 3,
  "optimCriterion": "profitMaximization",
  "planks": [
    {
      "id": 1,
      "thickness": 19,
      "width": 100,
      "price": 1,
      "length": 2000,
      "demand": 500000
    },
    ...
     ],
  "logs": [
    {
      "length": 2000,
      "diameter": 110,
      "importance": 0.053
    },
    ...]
    }
```

Future work

- Comparison with a constructive discrete approach
- Testing other heuristic approaches as an inner search algorithm
- Development of a multiobjective approach allowing for balancing waste and profit
- Providing algorithm with the data about the actual logs (irregular circular shapes)
- Enhancing the algorithm to solve a 3D model