P5 presentation 06/07/2020

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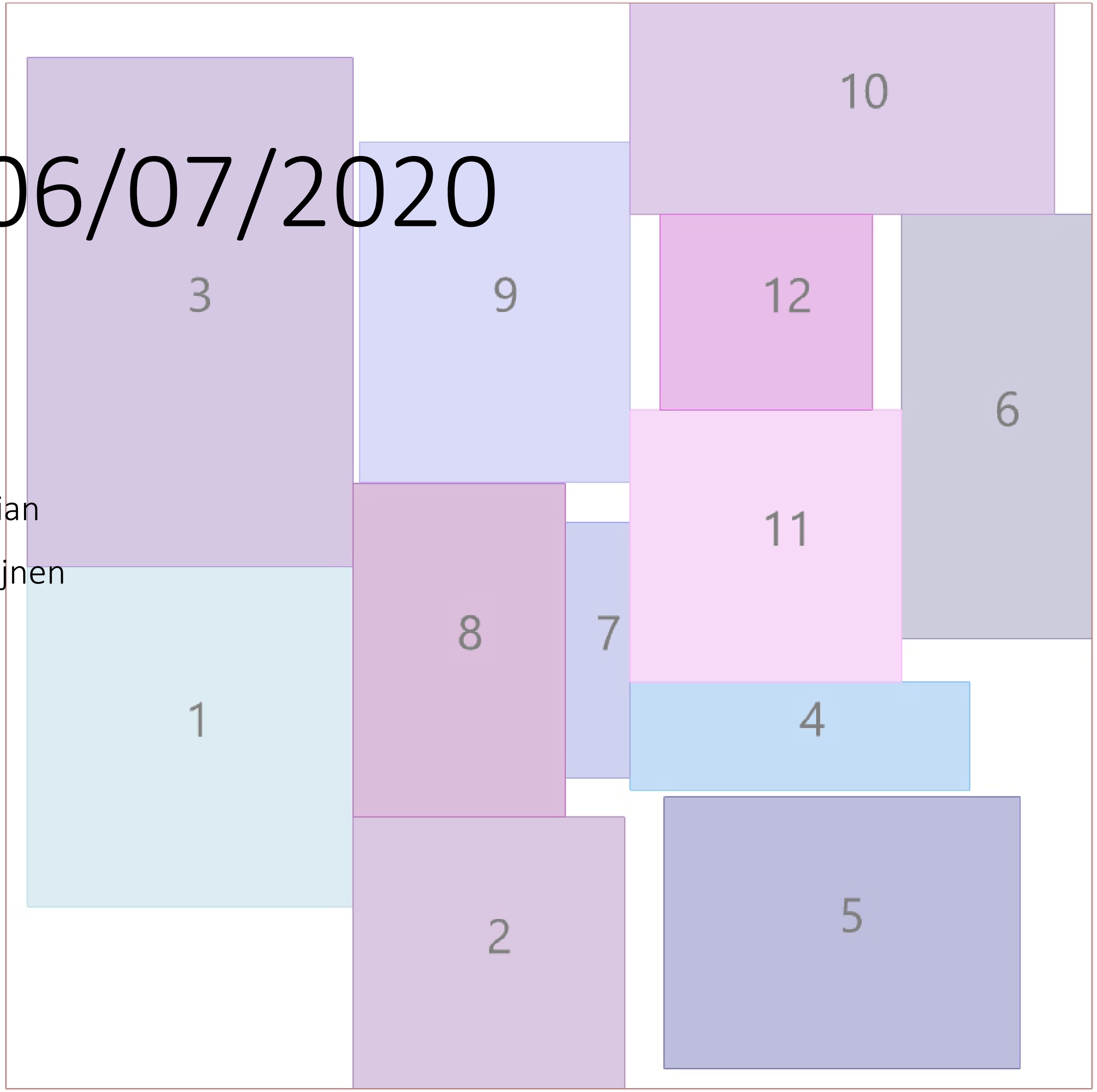
Second mentor: Assistant professor Dr. Ir. Petra Heijnen



Content

Introduction

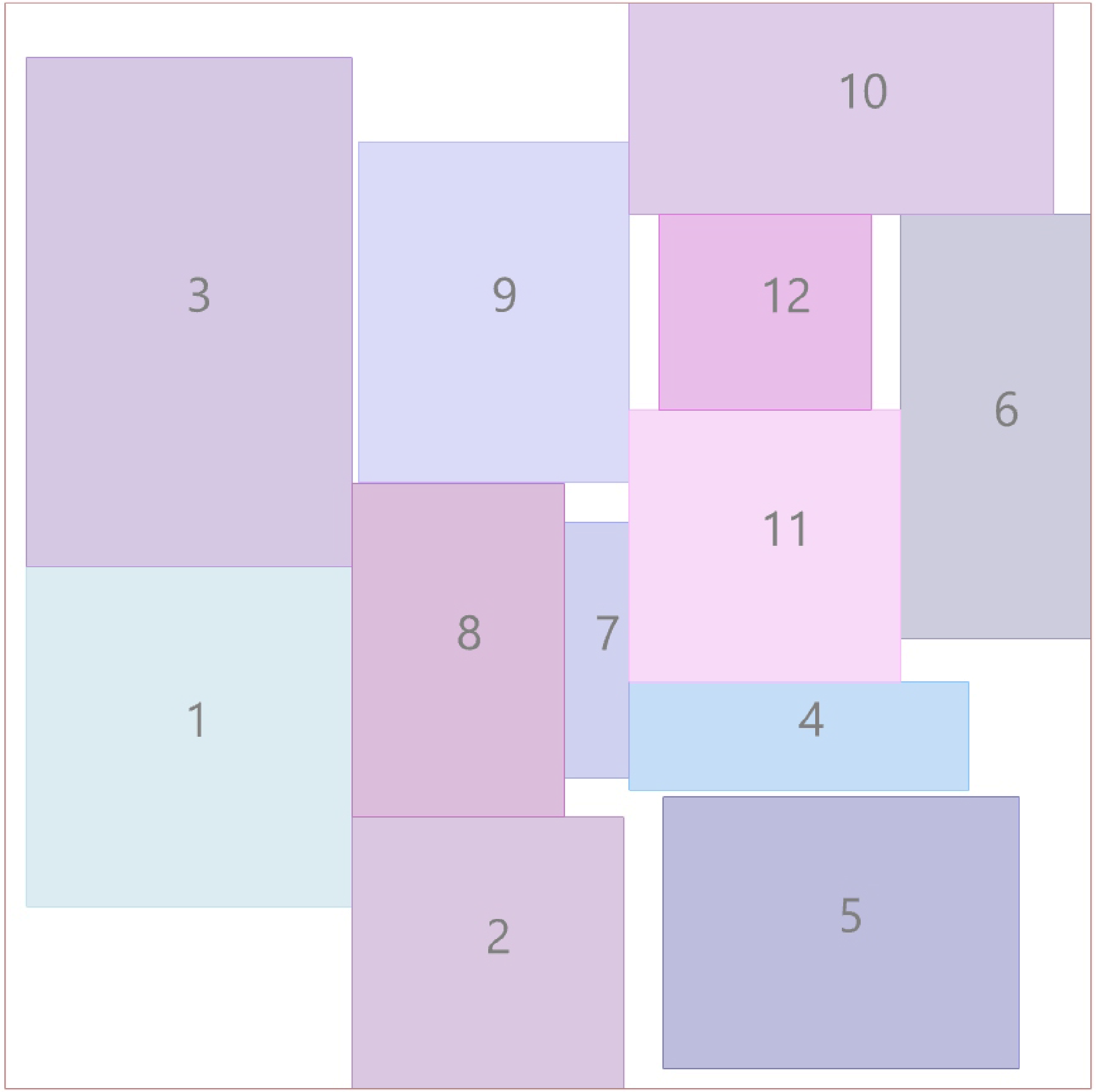
Problem formulation

Proposed methodology

First-stage model

Second-stage model

Conclusions



“A layout of the floor plan can really define how profitable a factory is, it is estimated that in total **20-50%** of total operating expenses can be related to the material handling costs and the layout of a factory. “

- James A Tompkins, John A White, Yavuz A Bozer, and Jose Mario Azaña Tanchoco.Facilitiesplanning. John Wiley & Sons, 2010

“The optimal location of facilities is one of the most important issues that should be resolved early in the design stage.“

- Leonardo Chwif, Marcos Ribeiro Pereira Barretto, and Lucas Antonio Moscato. A solution to thefacility layout problem using simulated annealing.Computers in Industry, 36(1-2):125–132, 1998.ISSN 01663615. doi:10.1016/S0166-3615(97)00106-1

My own experience when it comes to designing factories…

Main research question

"How to computationally generate a layout of a vegetable processing factory given a program of requirements and flows between facilities as a matrix using a mathematical approach, minimizing the travel distance of goods needed for a product to be manufactured?"

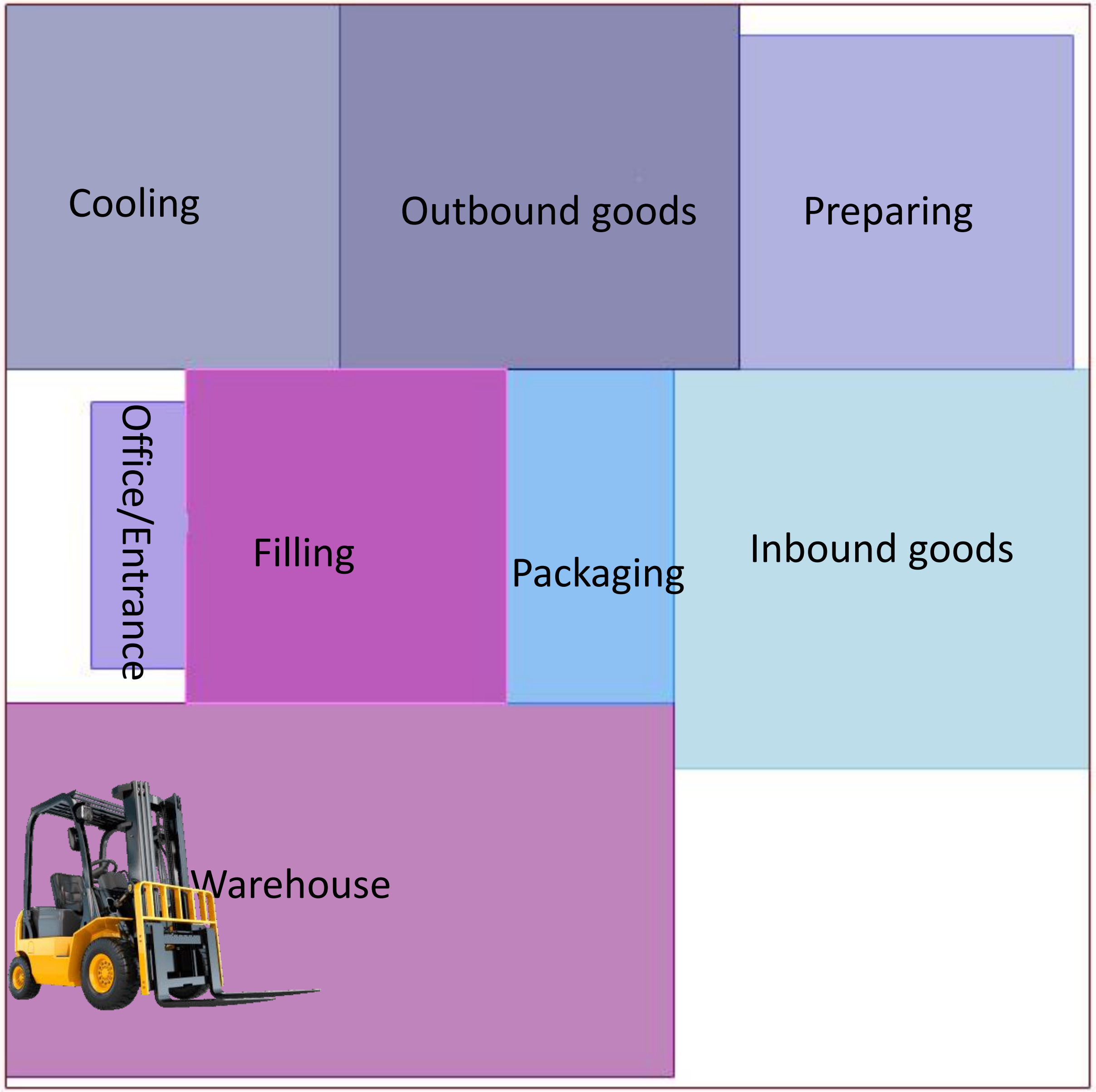
..Or mathematically

$$Minimize F = \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} f_{ij} d_{ij}$$

Where : c is the cost per unit distance and unit flow
f is the flow per unit time
d is the distance

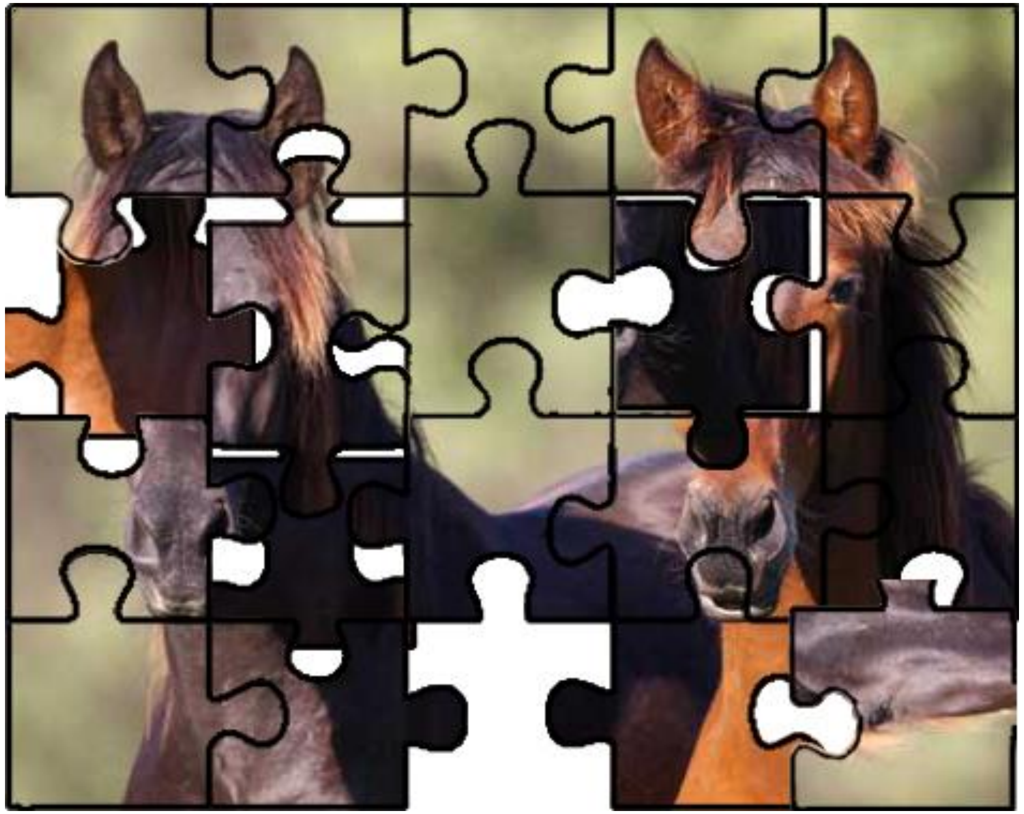
..Or Visually

To let the computer **generate** us **a layout** for a factory that minimizes traveling distance.

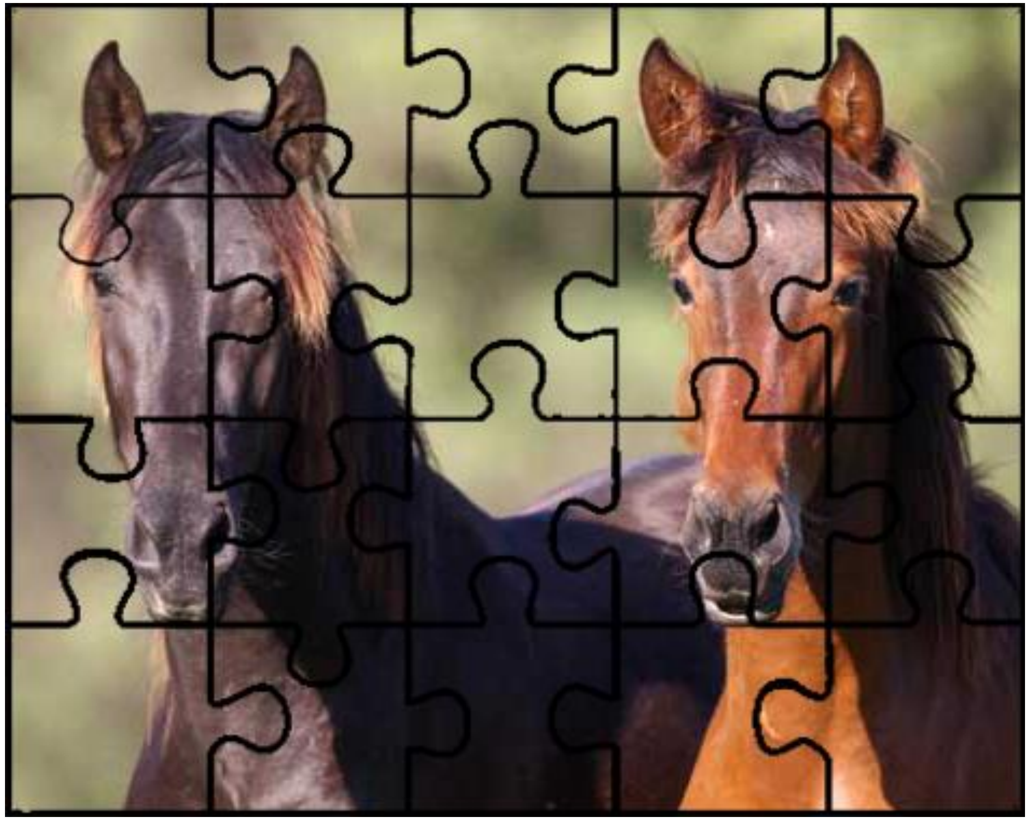


It’s like solving a puzzle

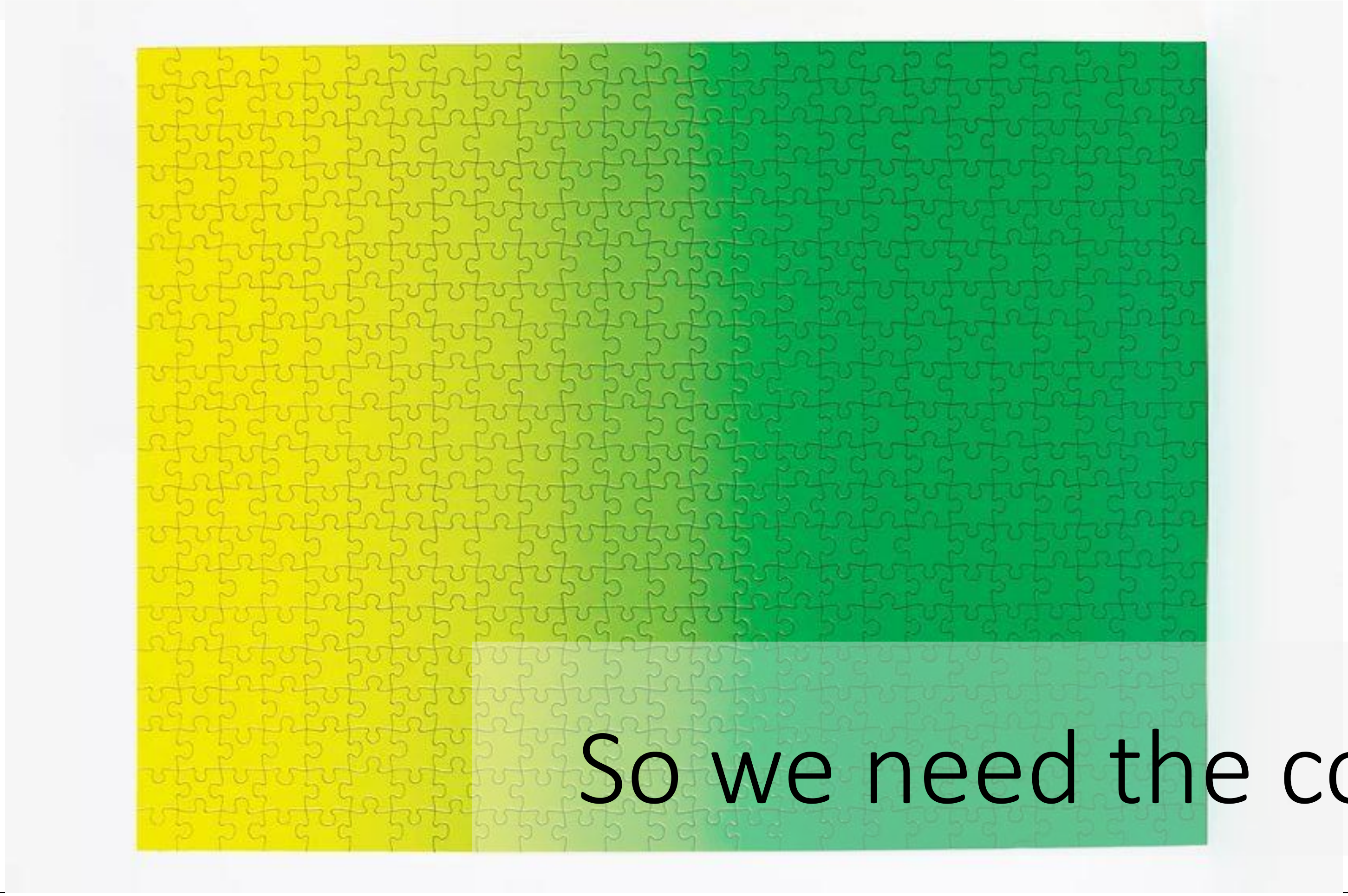
With lots of solutions..



But only one optimal one



Except this puzzle isn't easy

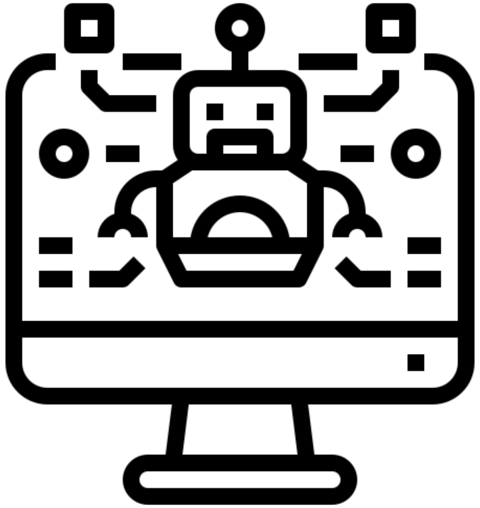


So we need the computer

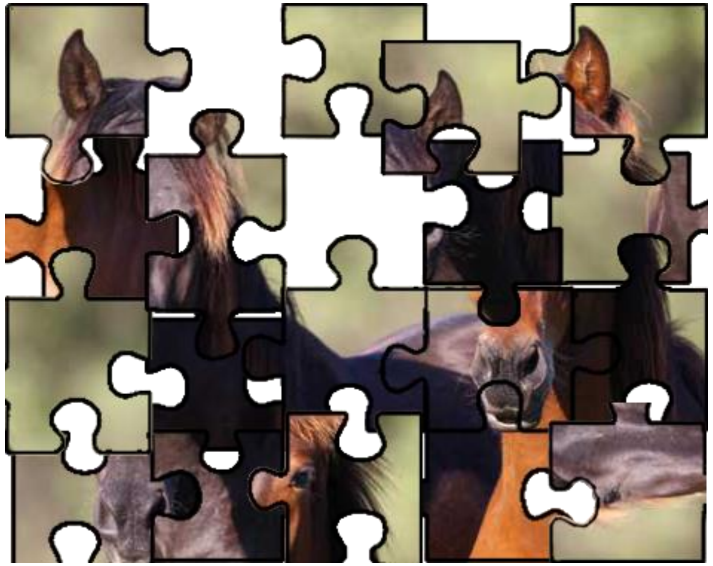
Proposed methodology

Computer solves the puzzle

Model all the "puzzle pieces" with all constraints



Feed it to the computer



Solution space is too large!

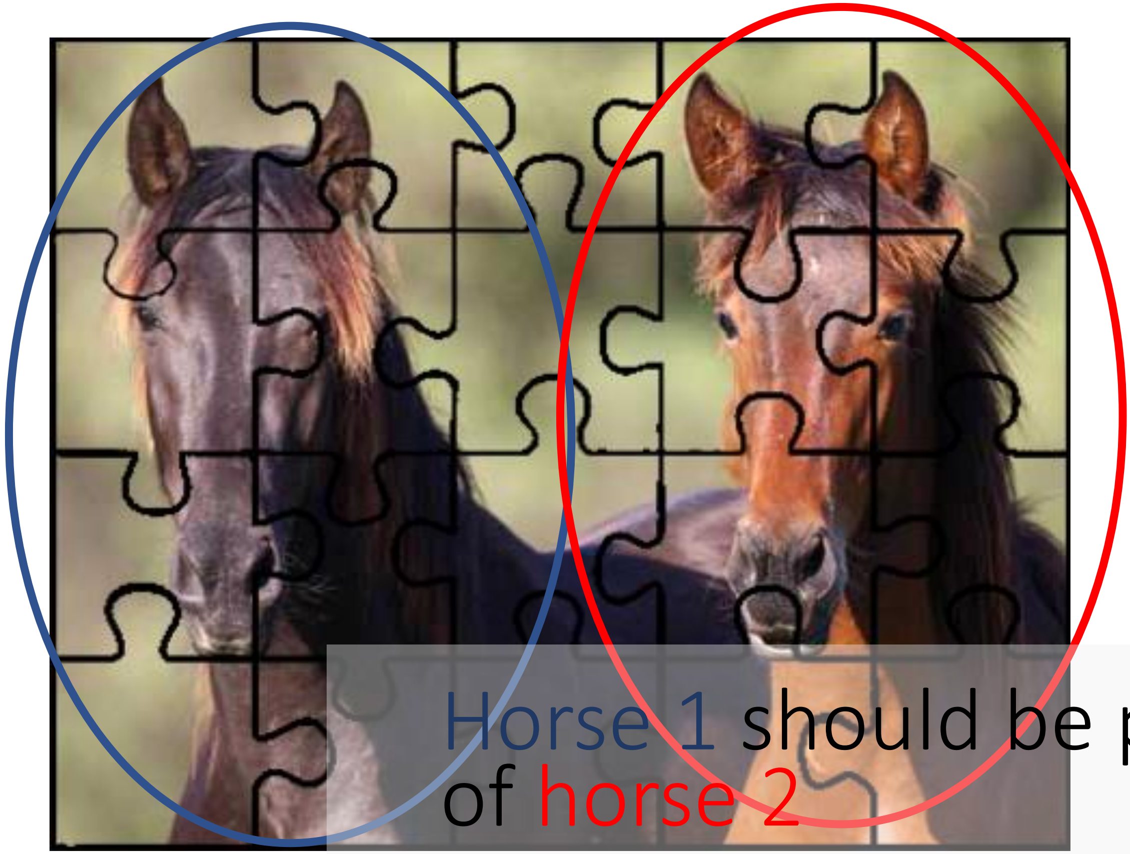
Why is the solution space so large?

There is 10 or more departments
Each department has 4 variables: x position, y position, width and height
Each variable could have over 1000 different configurations

10 departments * **1000** configurations for x position * **1000** configurations for y position * **1000** configurations for width * **1000** configurations for height

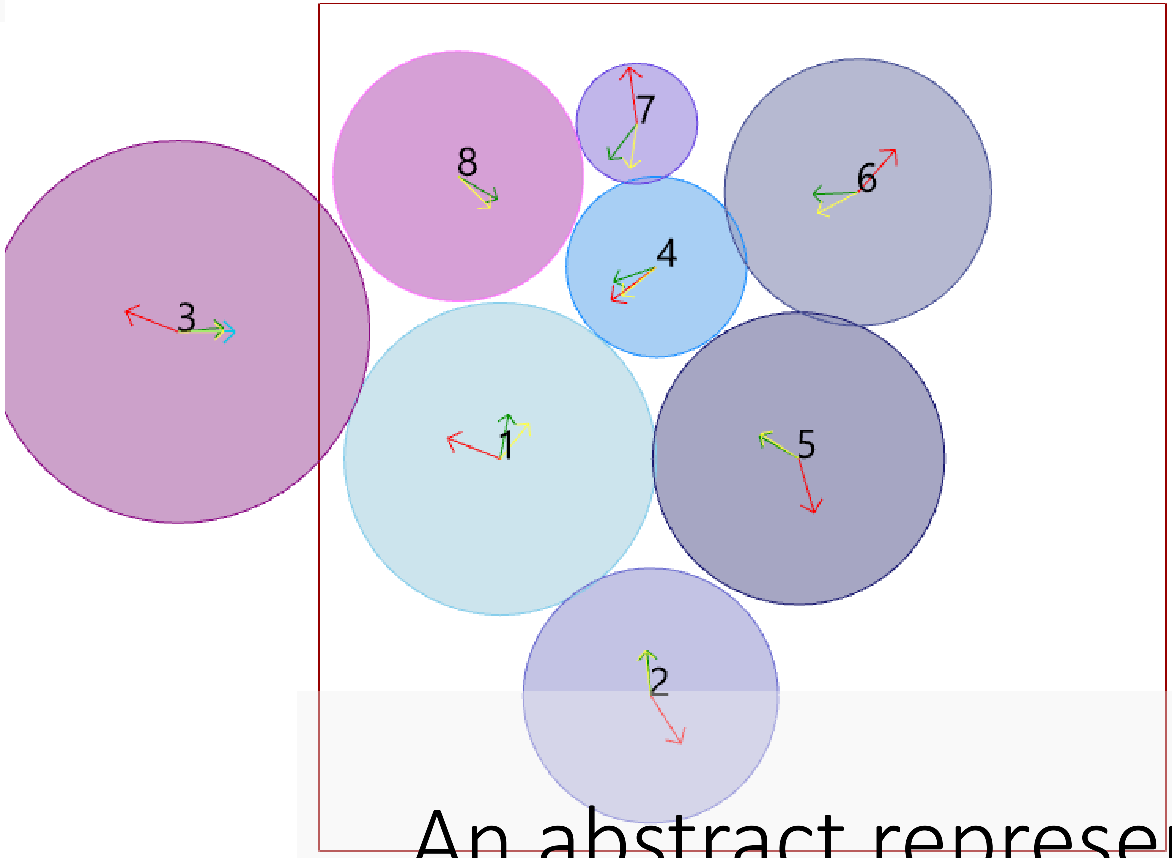
>10,000,000,000,000 Solutions

A first-stage model to find constraints to potential good solutions



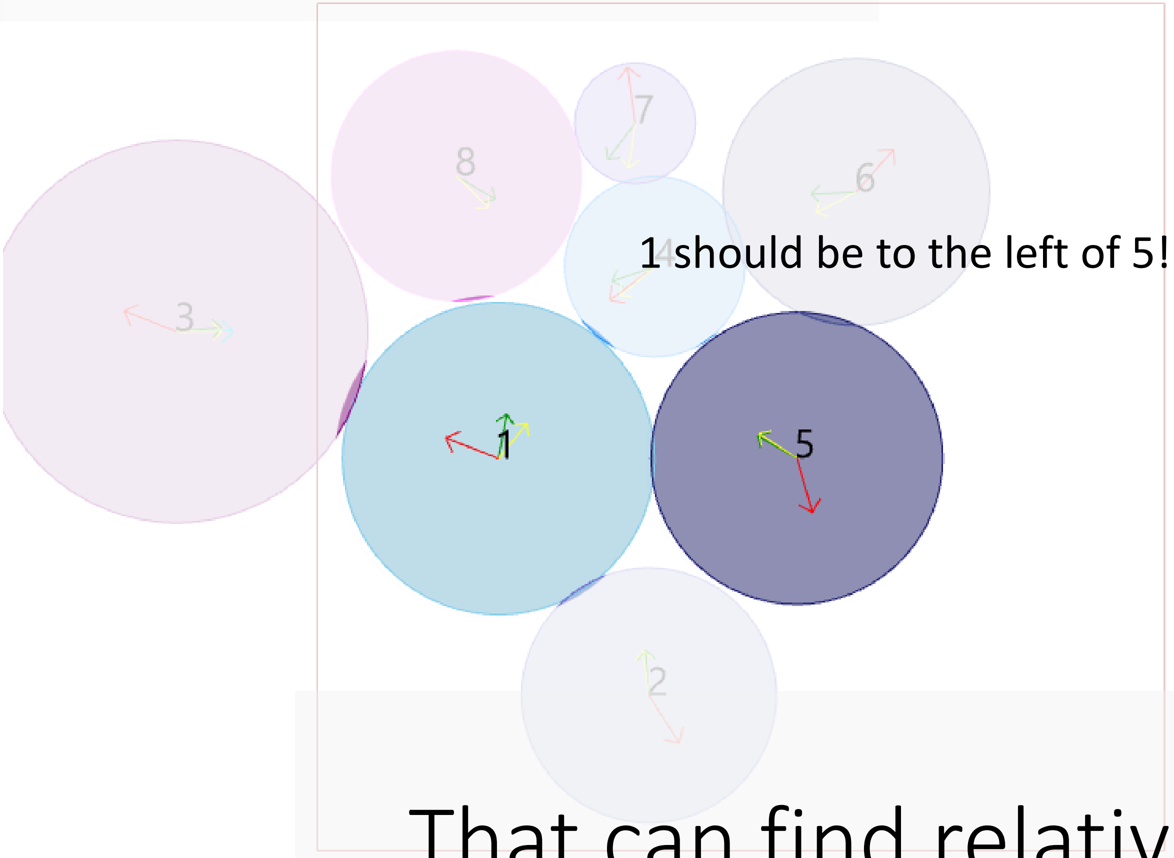
Horse 1 should be positioned to the left of horse 2

A first-stage model to find constraints to potential good solutions



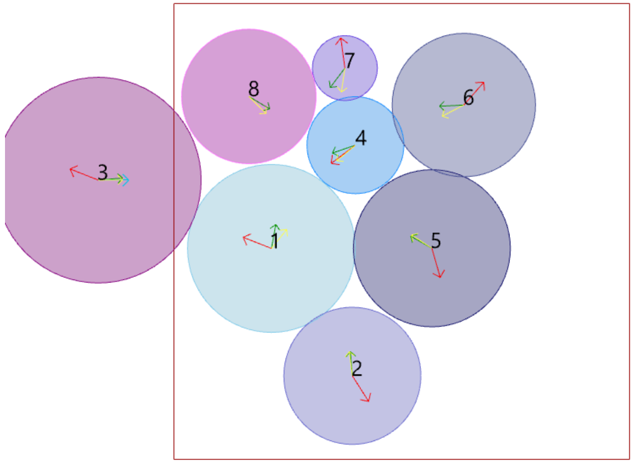
An abstract representation

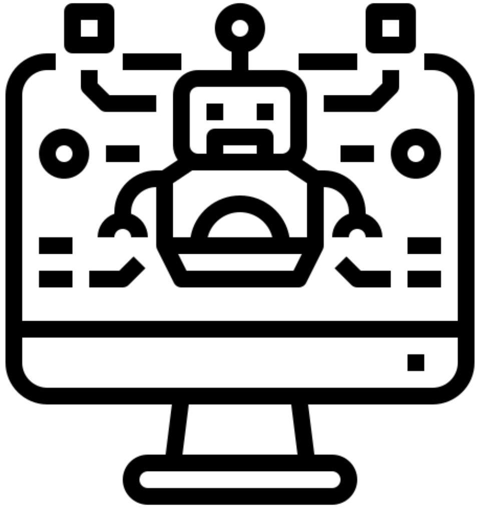
A first-stage model to find constraints to potential good solutions

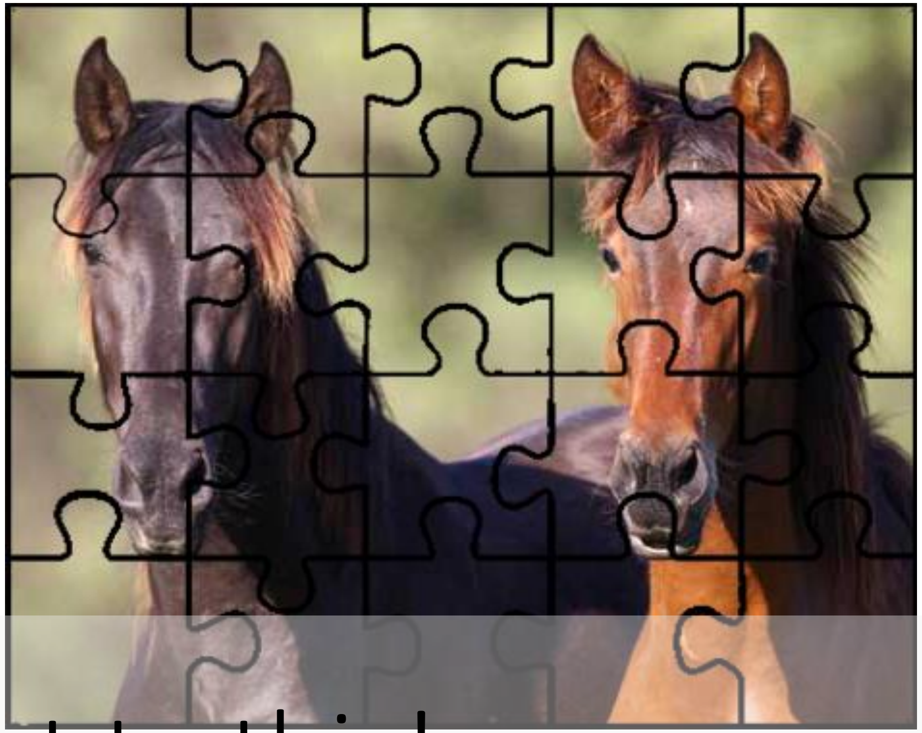


That can find relative locations

So instead of this..







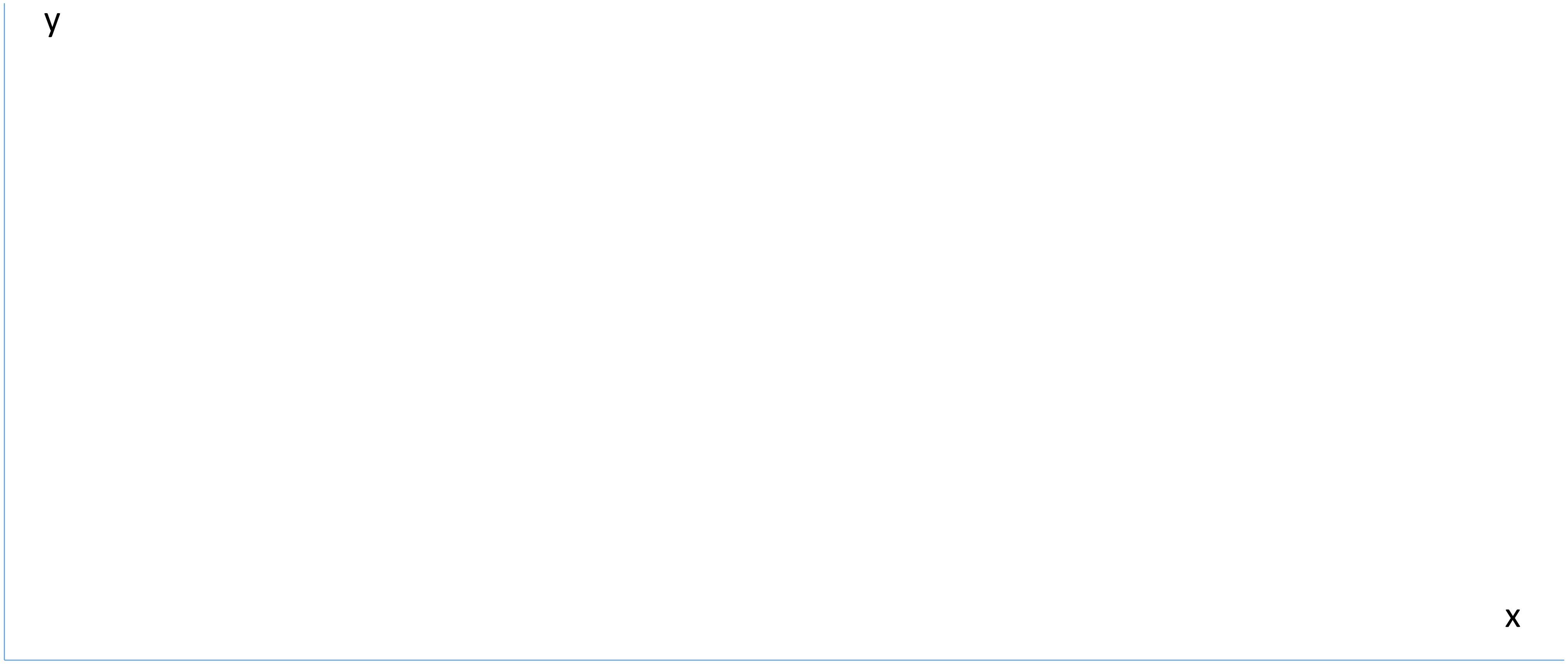
We can get to this!

First-stage model

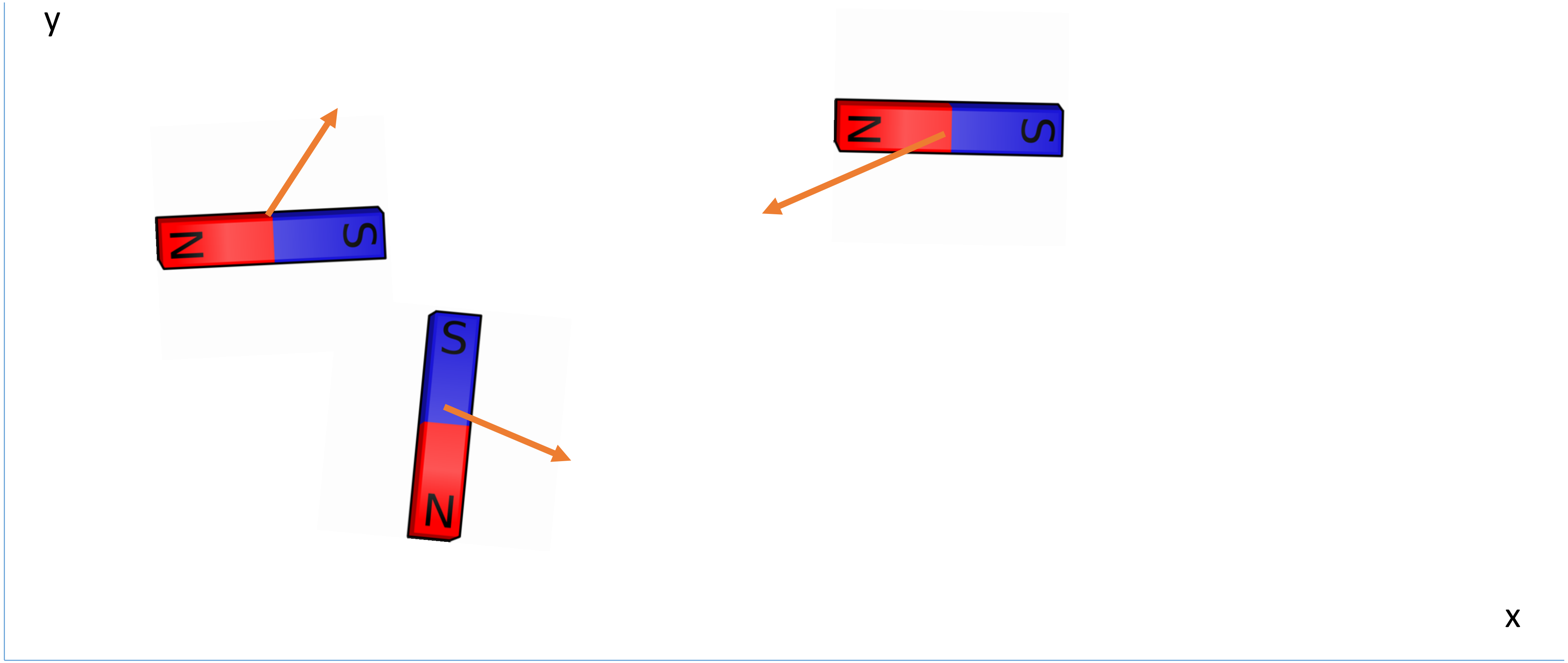
The gradient descent approach

The departments are randomly placed on the plane and are moved iteratively in the direction that has the greatest impact on the objective.

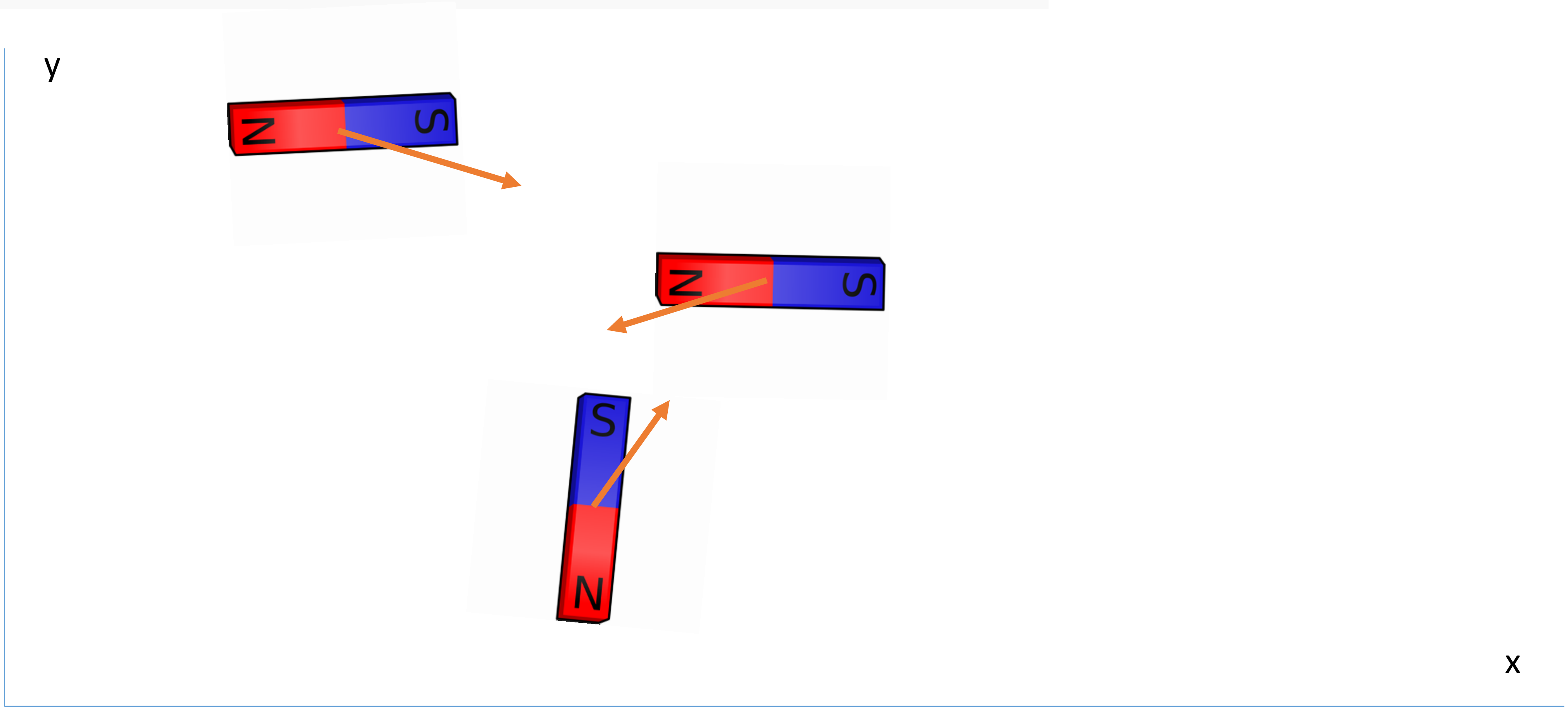
And now in English



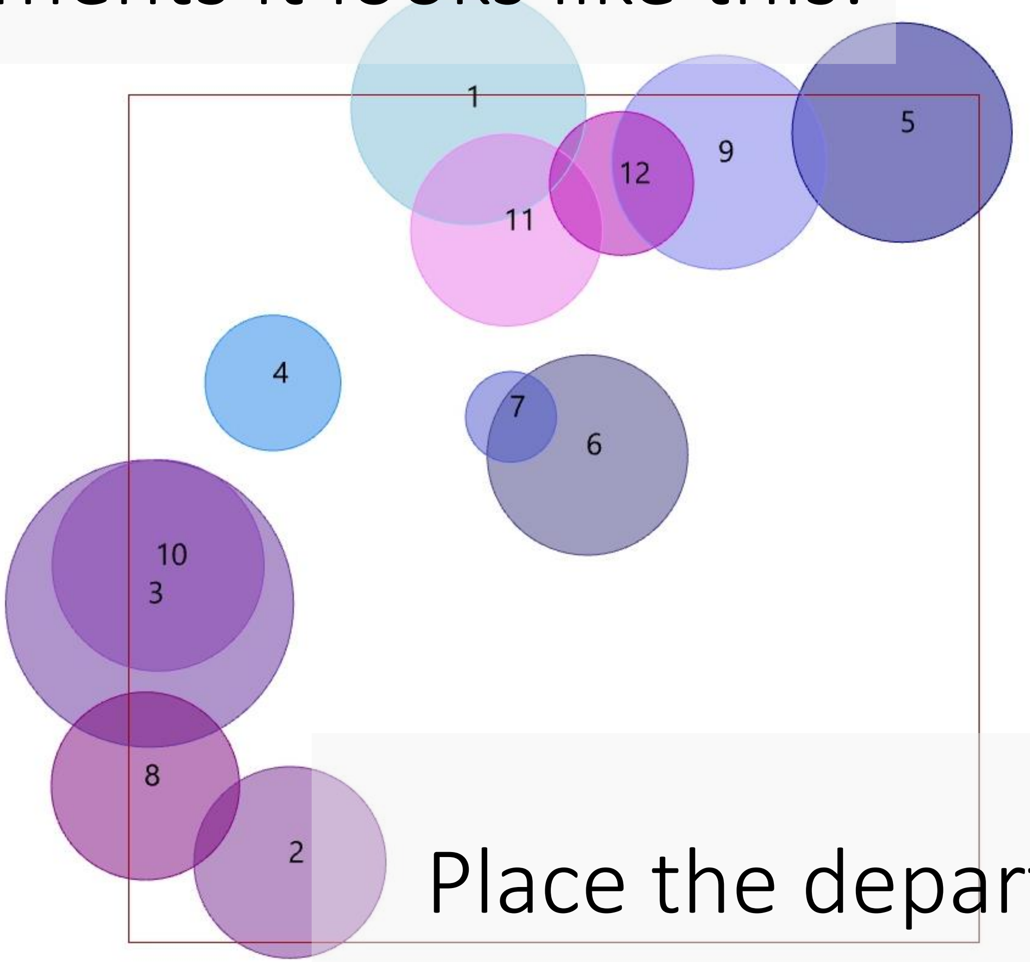
And now in English



And now in English

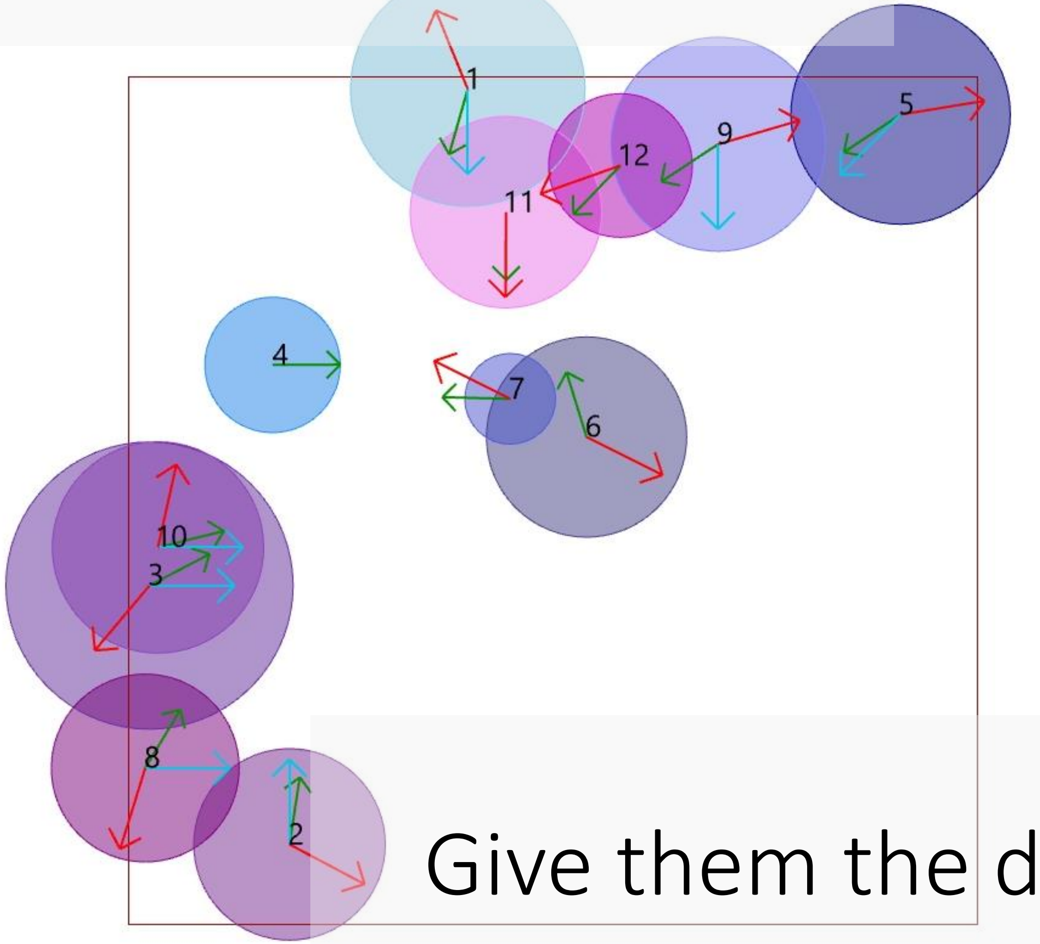


With departments it looks like this:



Place the departments on the plane

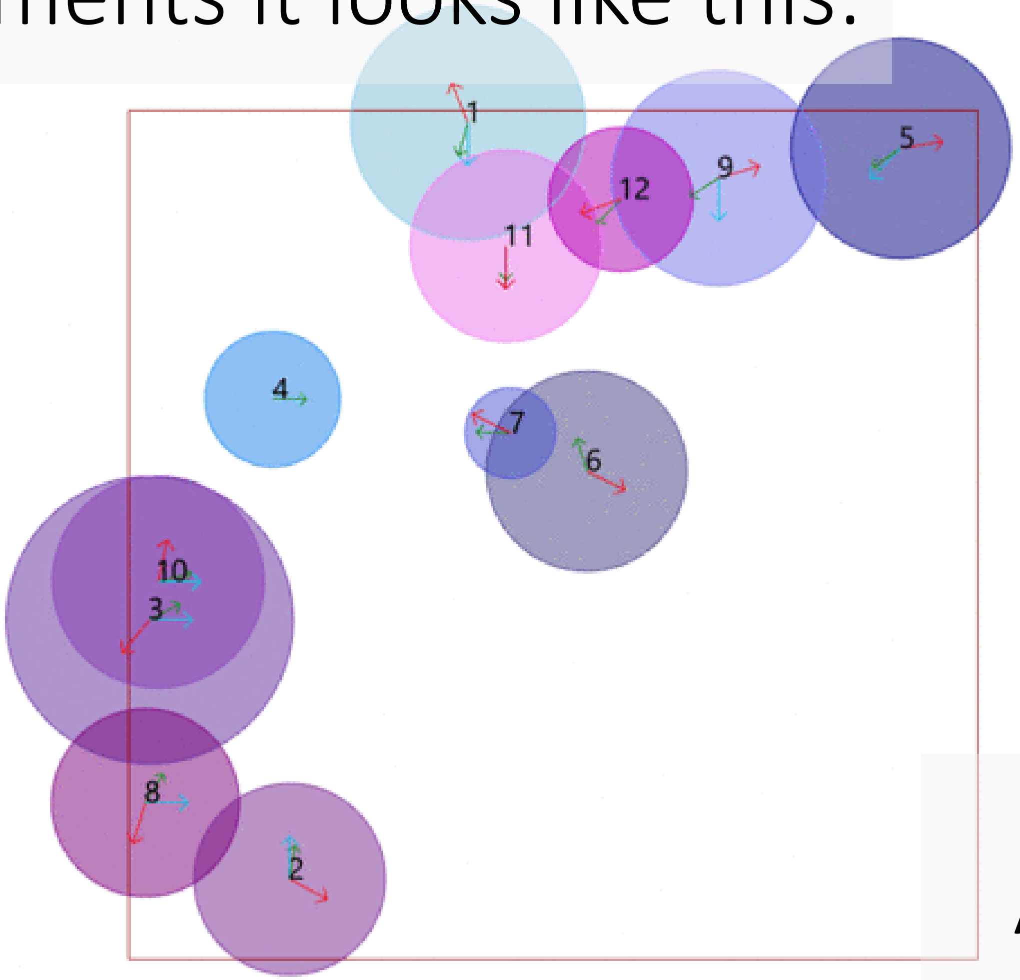
With departments it looks like this:



	1	2	3	4	5	6	7	8	9	10	11	12
1	x	5	2	4	1	0	0	6	2	1	1	1
2	5	x	3	0	2	2	2	0	4	5	0	0
3	2	3	x	0	0	0	0	5	5	2	2	2
4	4	0	0	x	5	2	2	10	0	0	5	5
5	1	2	0	5	x	10	0	0	0	5	1	1
6	0	2	0	2	10	x	5	1	1	5	4	0
7	0	2	0	2	0	5	x	10	5	2	3	3
8	6	0	5	10	0	1	10	x	0	0	5	0
9	2	4	5	0	0	1	5	0	x	0	10	10
10	1	5	2	0	5	5	2	0	0	x	5	0
11	1	0	2	5	1	4	3	5	10	5	x	2
12	1	0	2	5	1	0	3	0	10	0	2	x

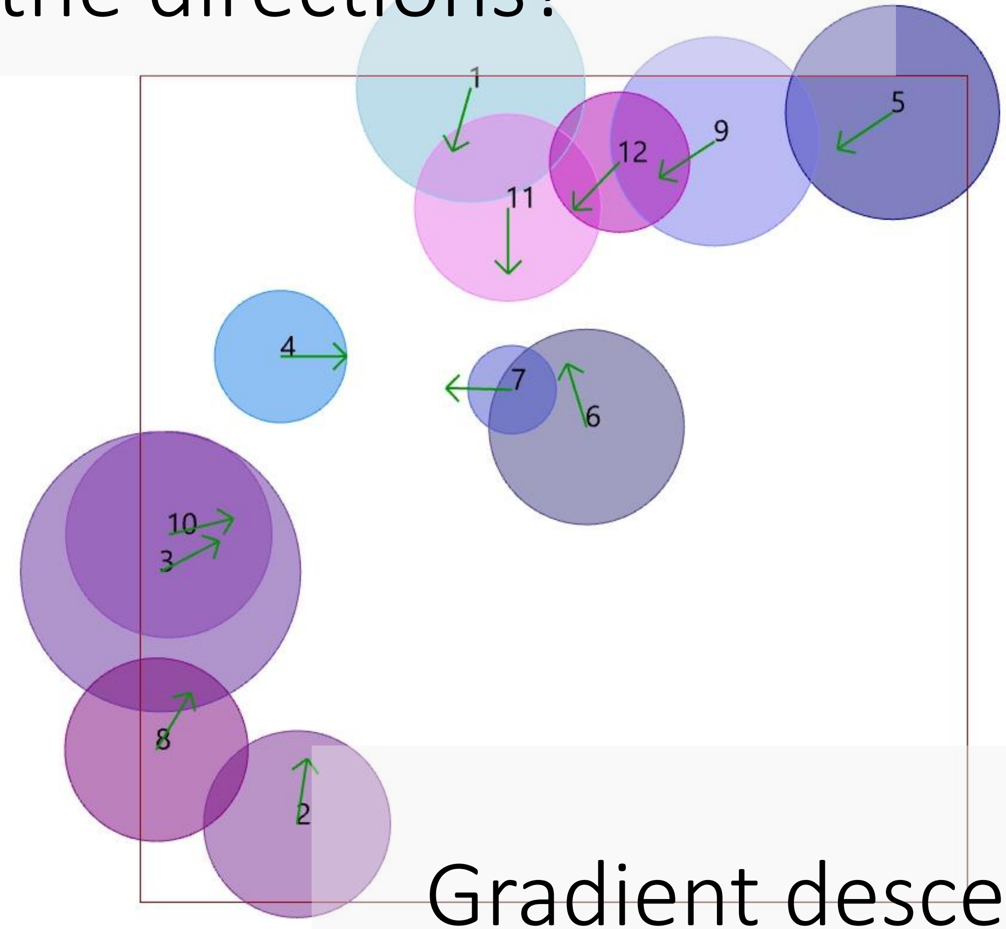
Give them the direction to move in..

With departments it looks like this:



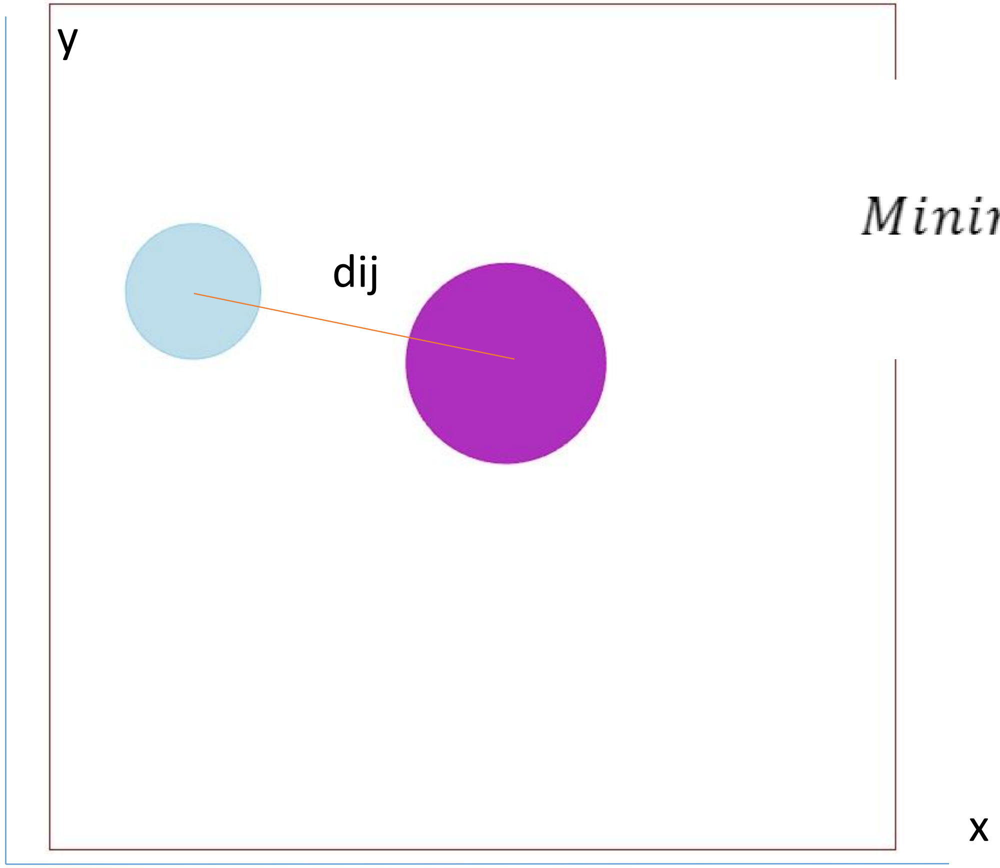
And start the loop

How to find the directions?



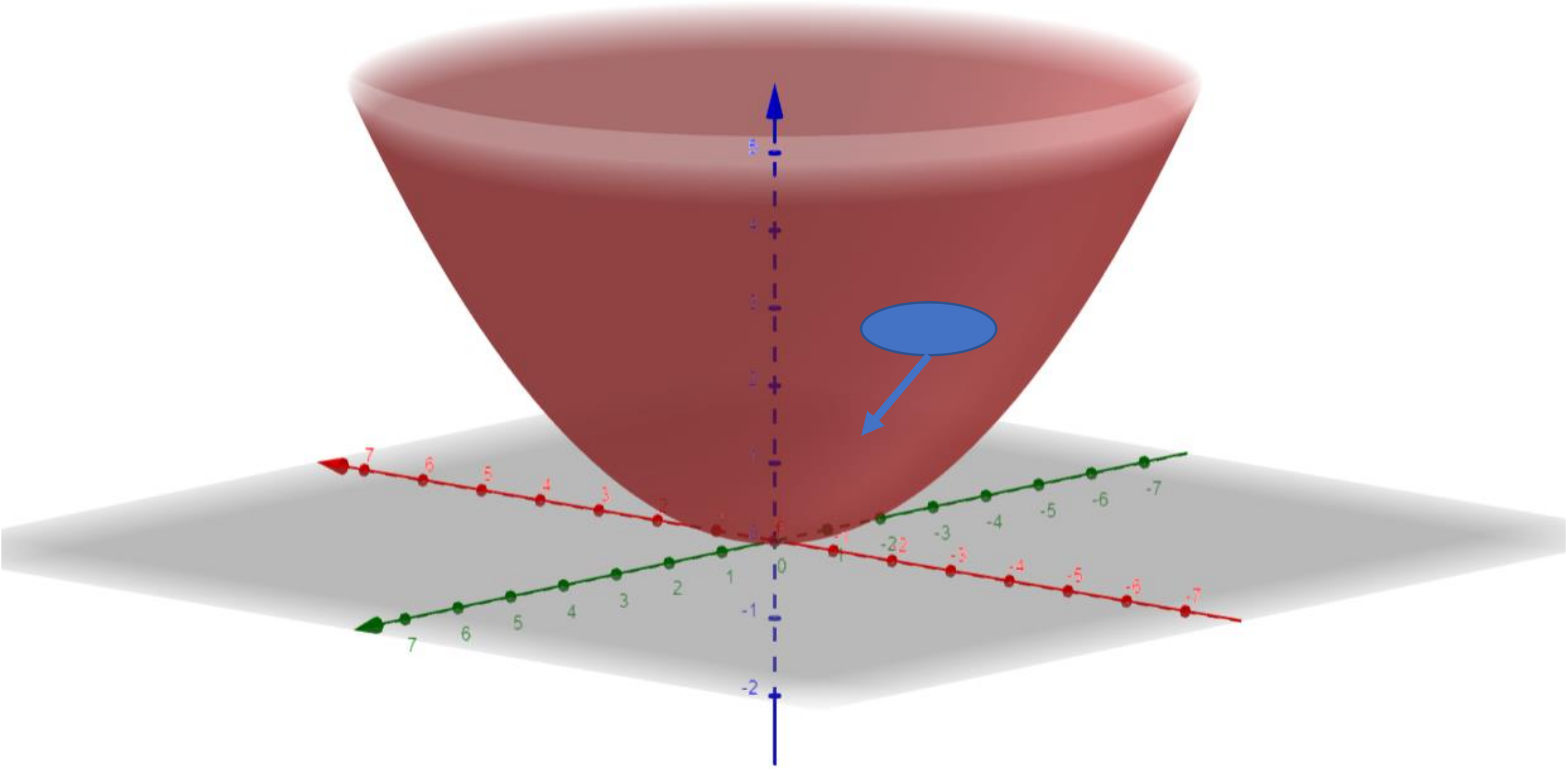
Gradient descent approach

Imagine just two departments

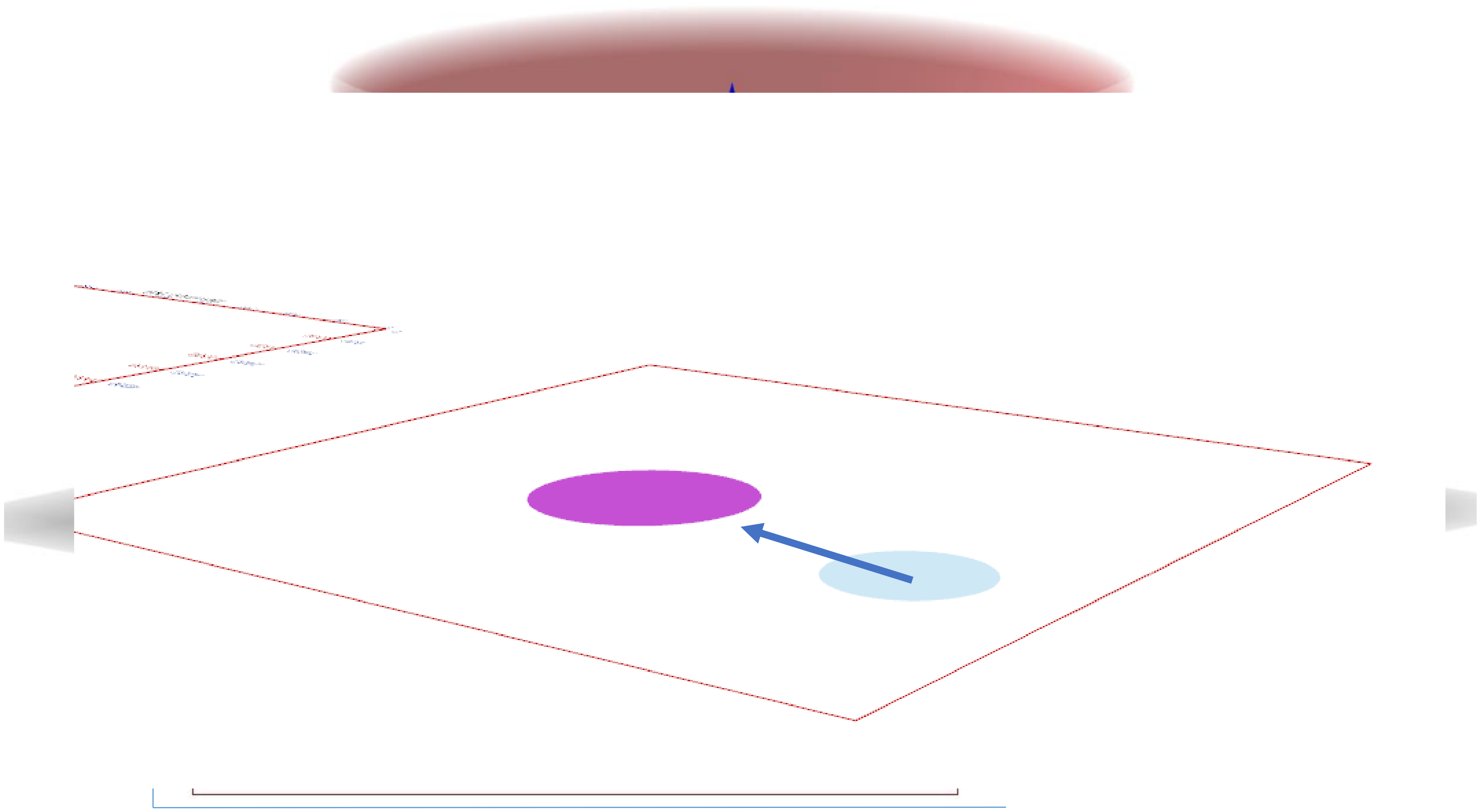


$$Minimize F = \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij} f_{ij} d_{ij}$$

Imagine just two departments



Imagine just two departments



The gradient descent approach

$$\nabla f = \begin{bmatrix} \frac{df}{dx} \\ \frac{df}{dy} \end{bmatrix}$$

$$MinimizeF = \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij} f_{ij} d_{ij}$$

$$\frac{df}{dx_i} = \sum_{j=1}^{n} \frac{(x_i - x_j) f_{ij}}{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}$$

$$\frac{df}{dy_i} = \sum_{j=1}^{n} \frac{(y_i - y_j) f_{ij}}{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}$$

With multiple departments

Its like climbing a mountain

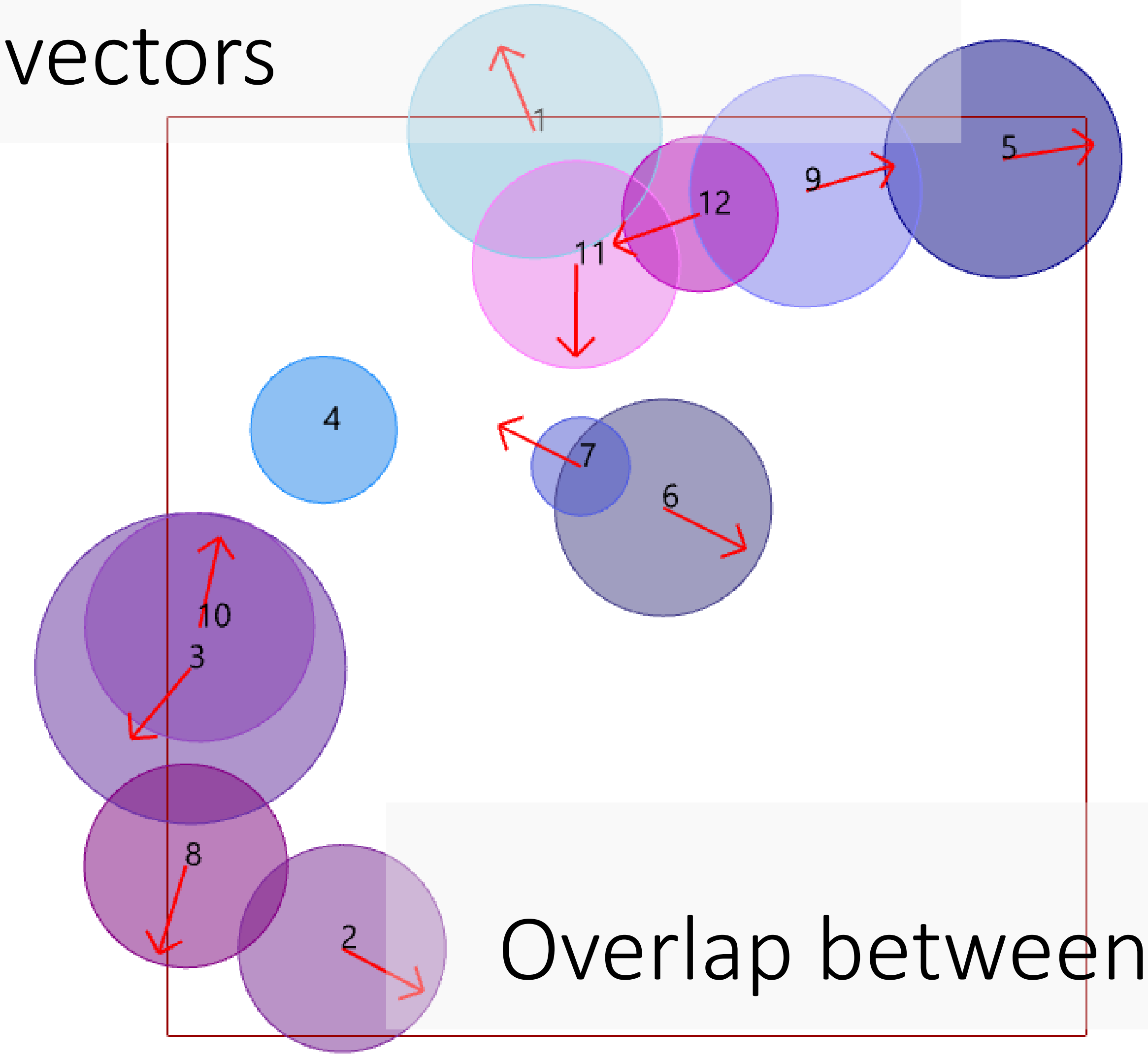
Why don’t we just warp to the top?

Why don’t we just wao the top?

Why don’t we just wa  o the top?

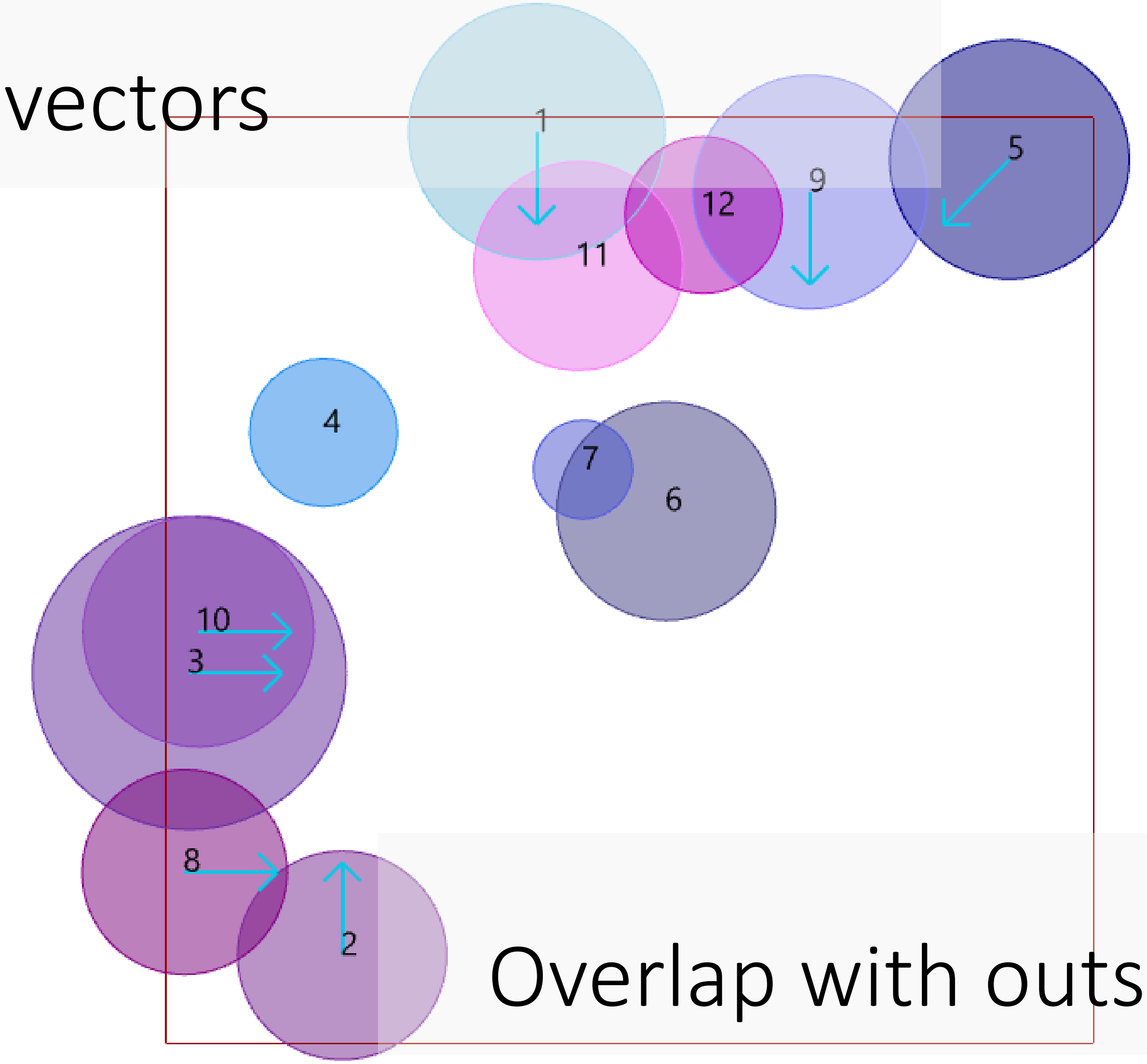
Because all departments move and therefor the mountain range changes

The other vectors



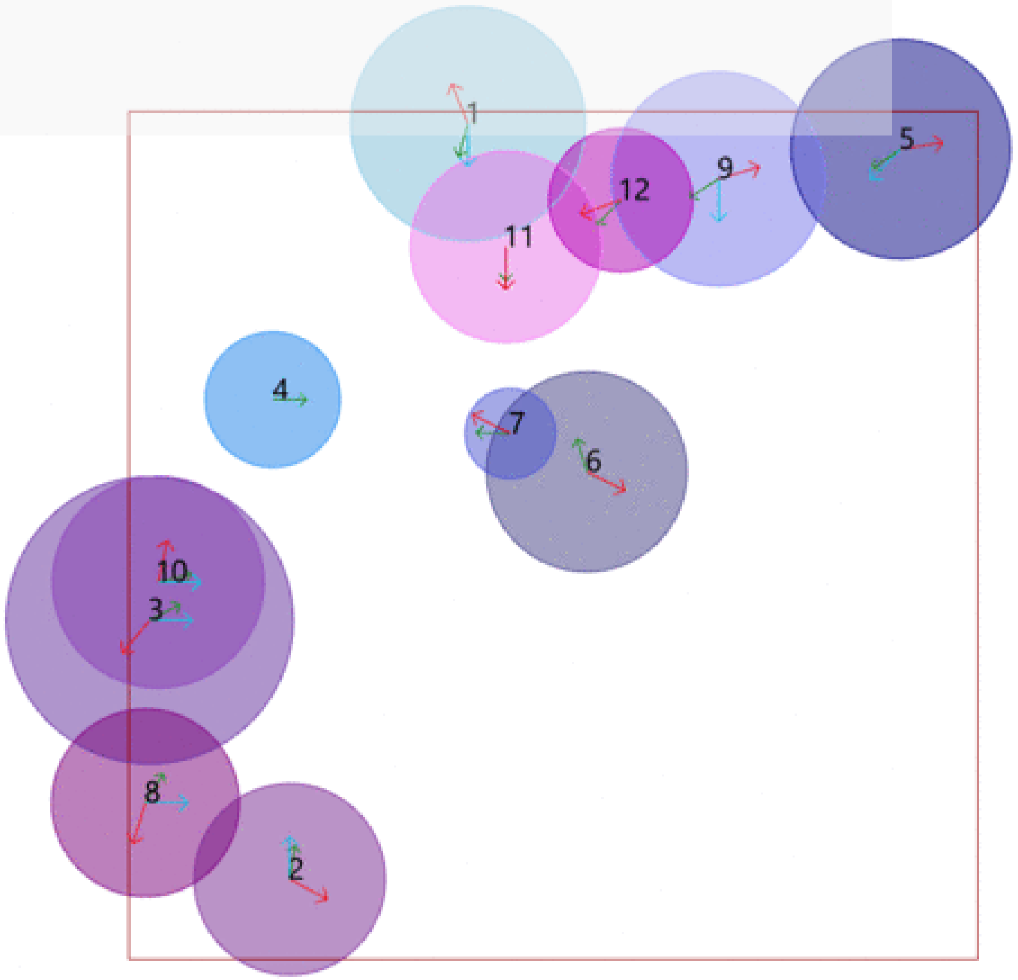
Overlap between departments

The other vectors

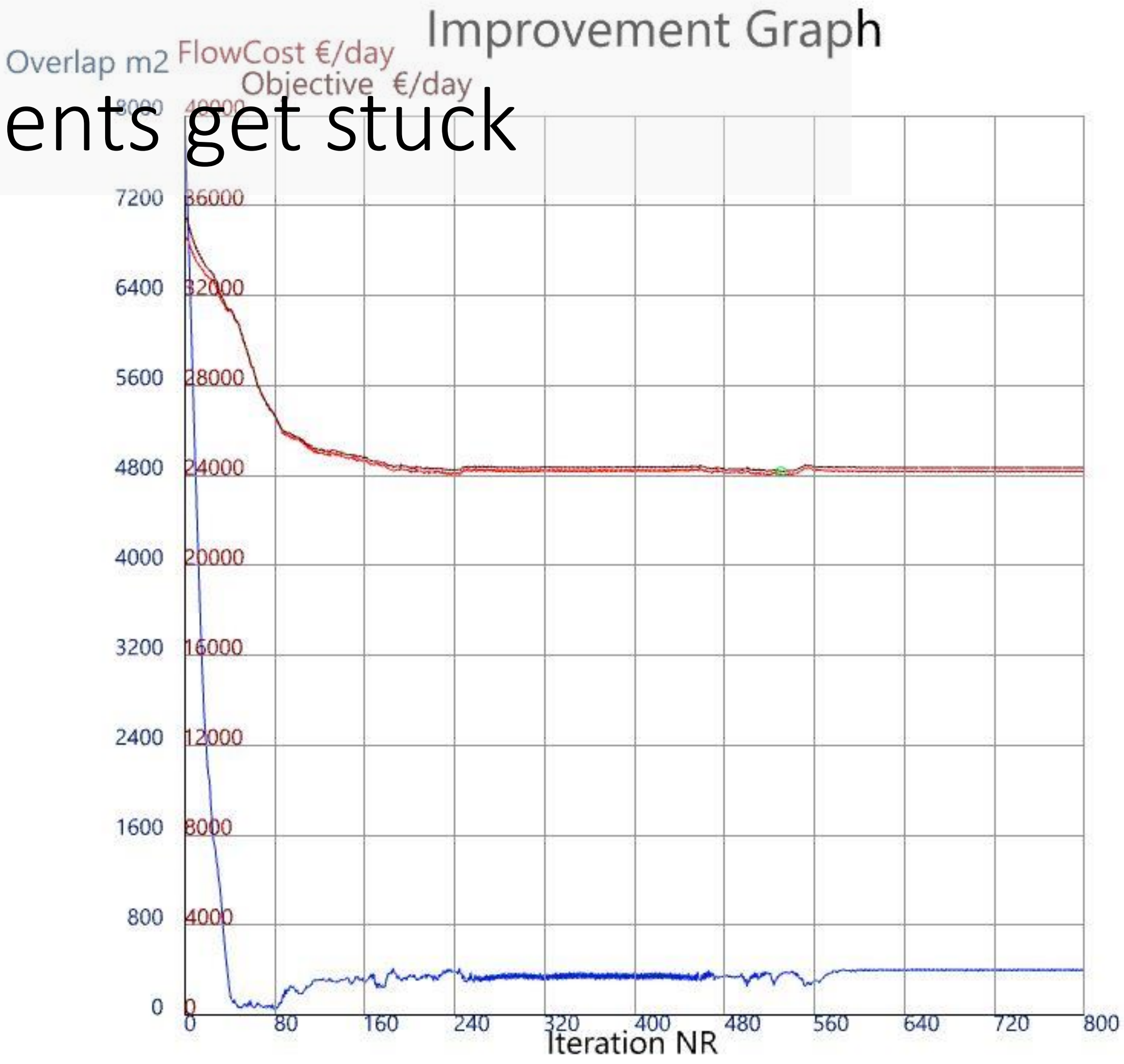


Overlap with outside facility

The result

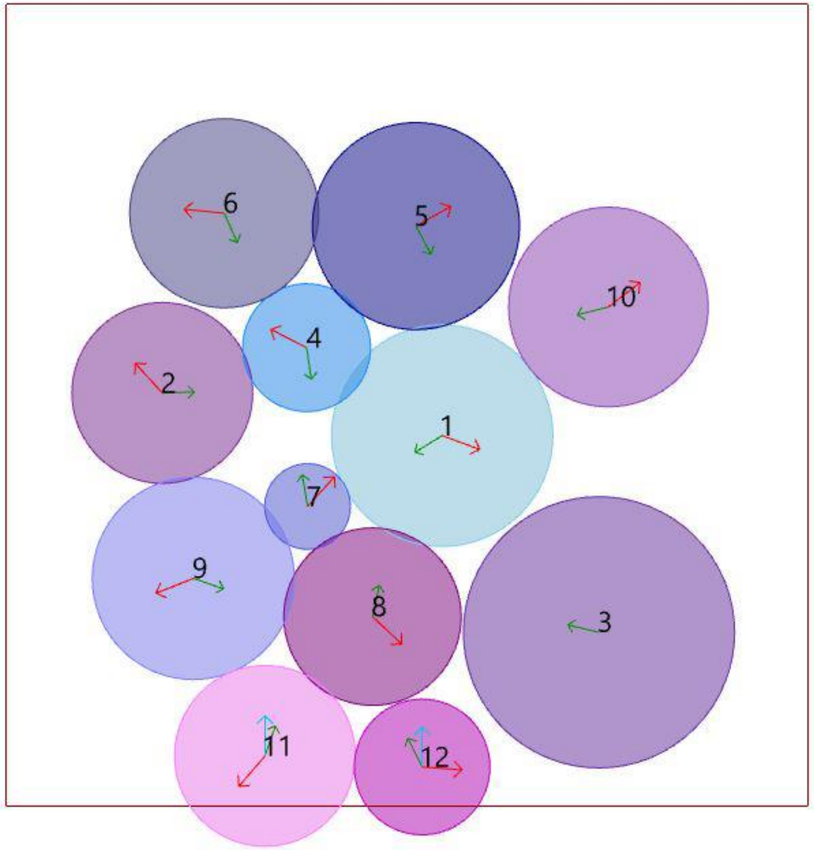


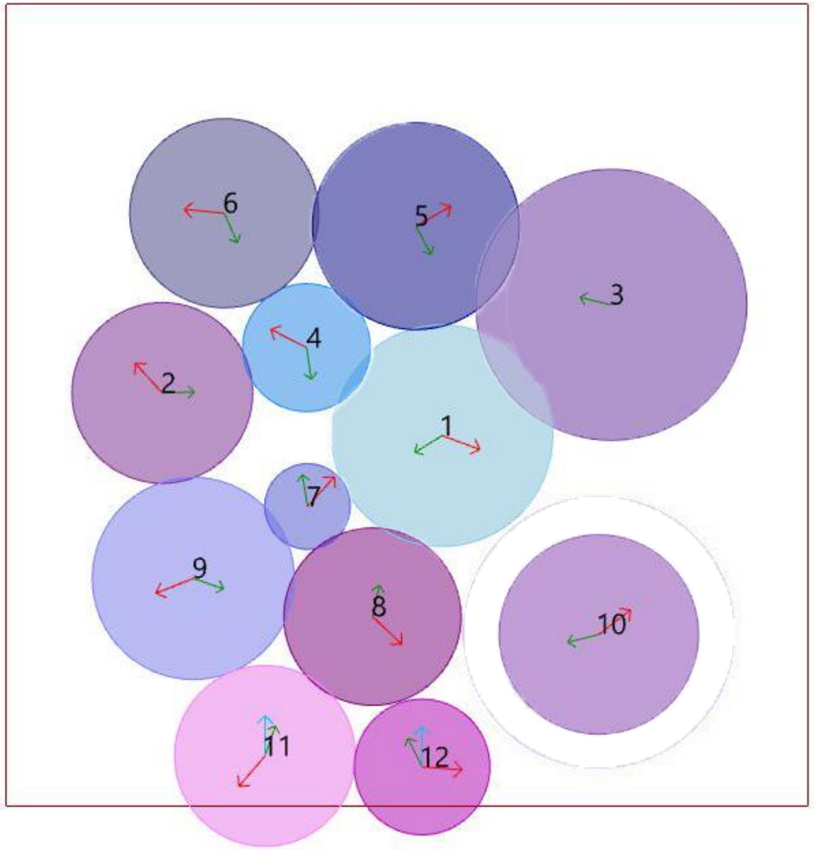
The departments get stuck



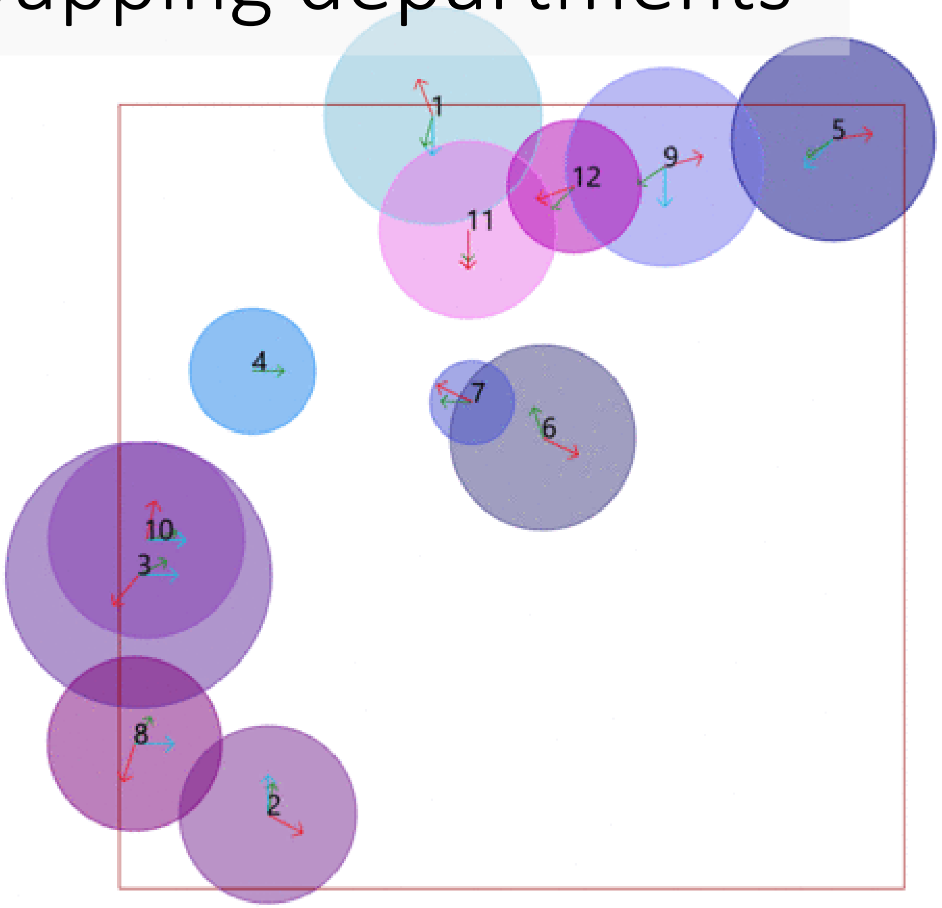
Trapped in local optimum

Solution 1: swapping departments



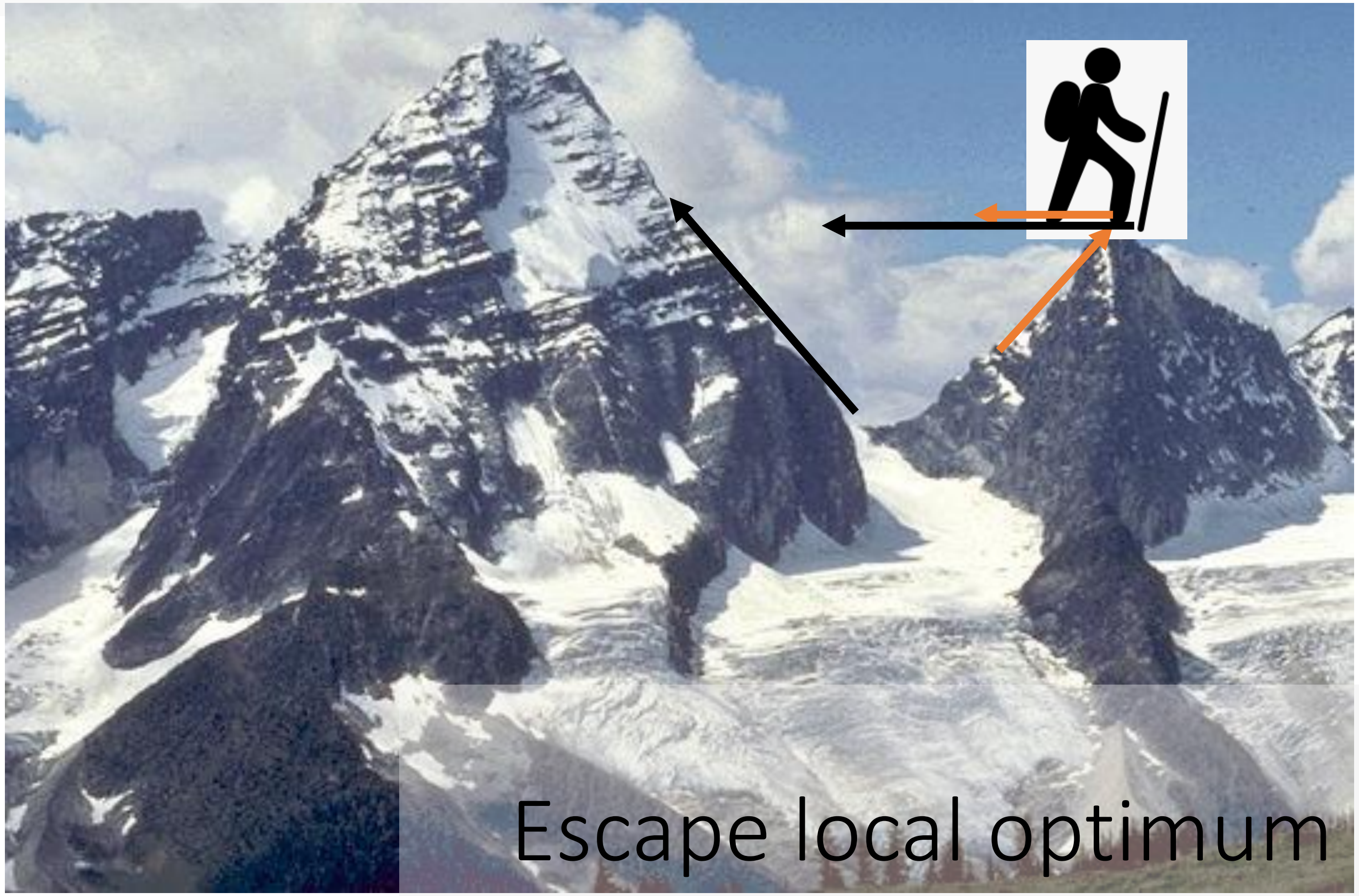


Solution 1: swapping departments



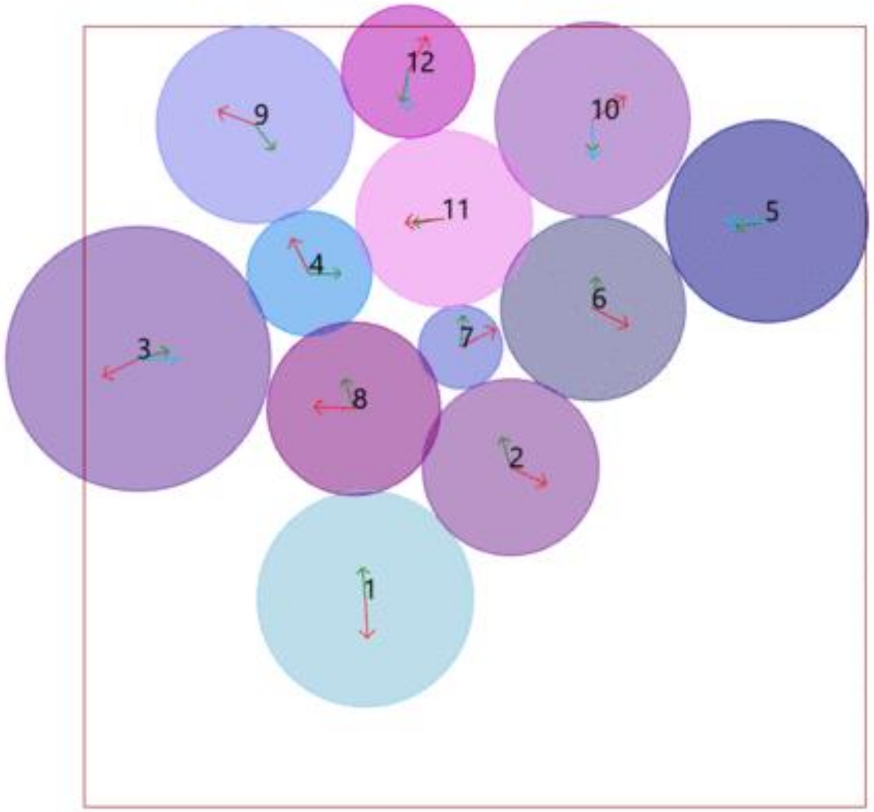
Solution 1: swapping departments

Solution 2: Shooting departments

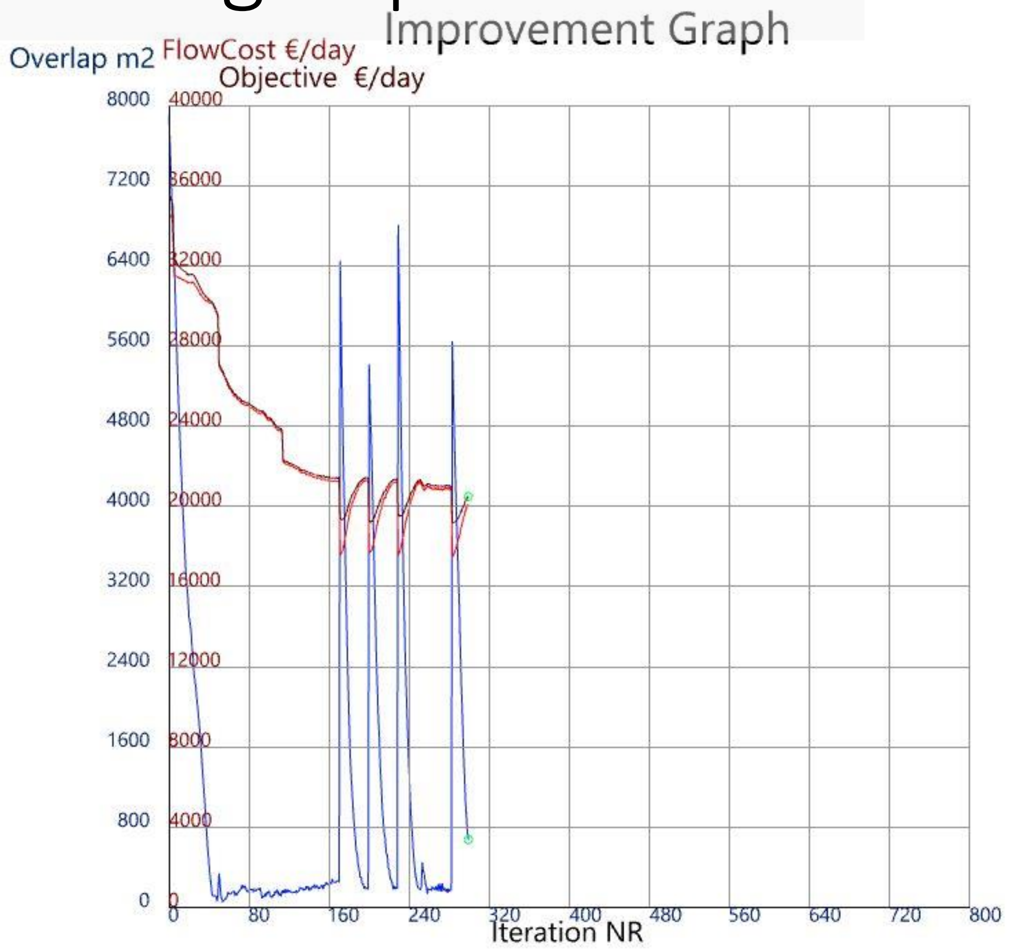


Escape local optimum

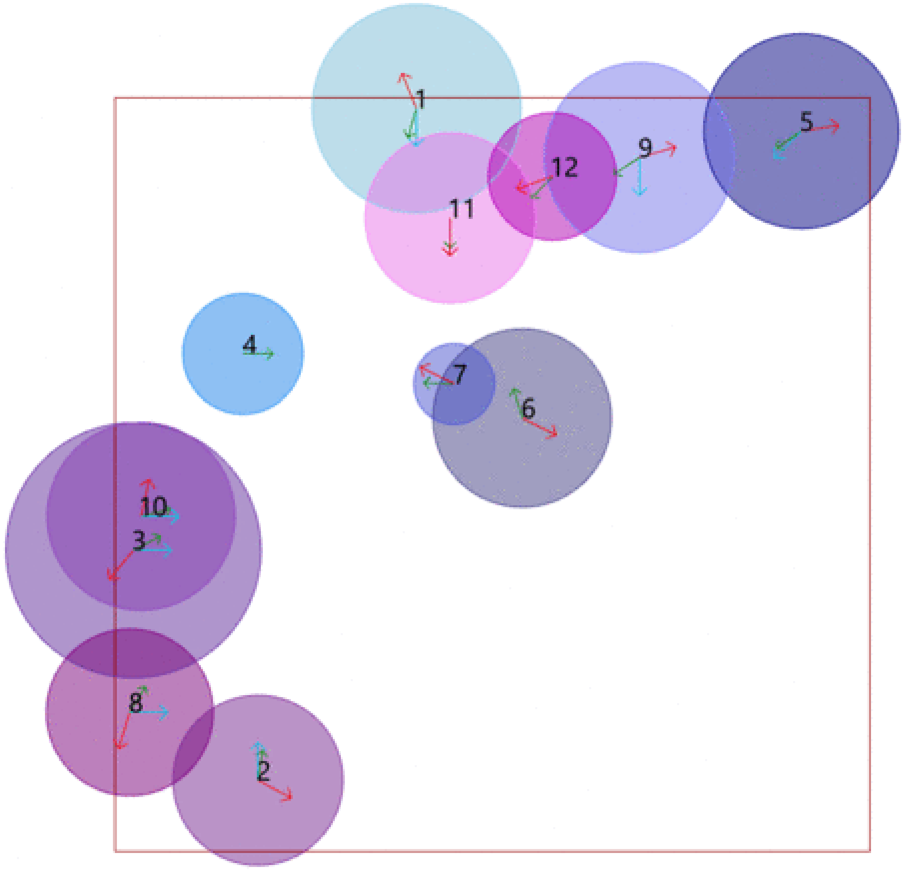
Solution 2: Shooting departments



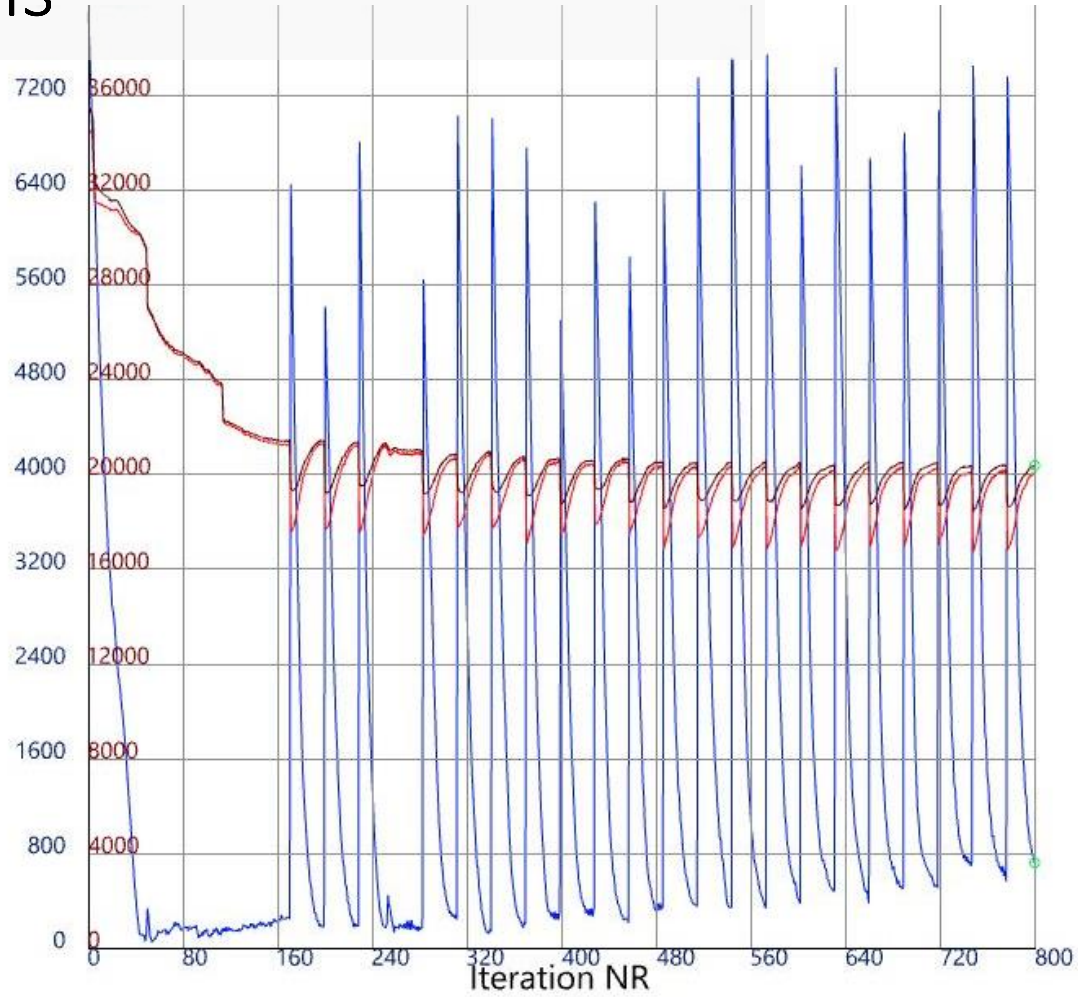
Solution 2: Shooting departments



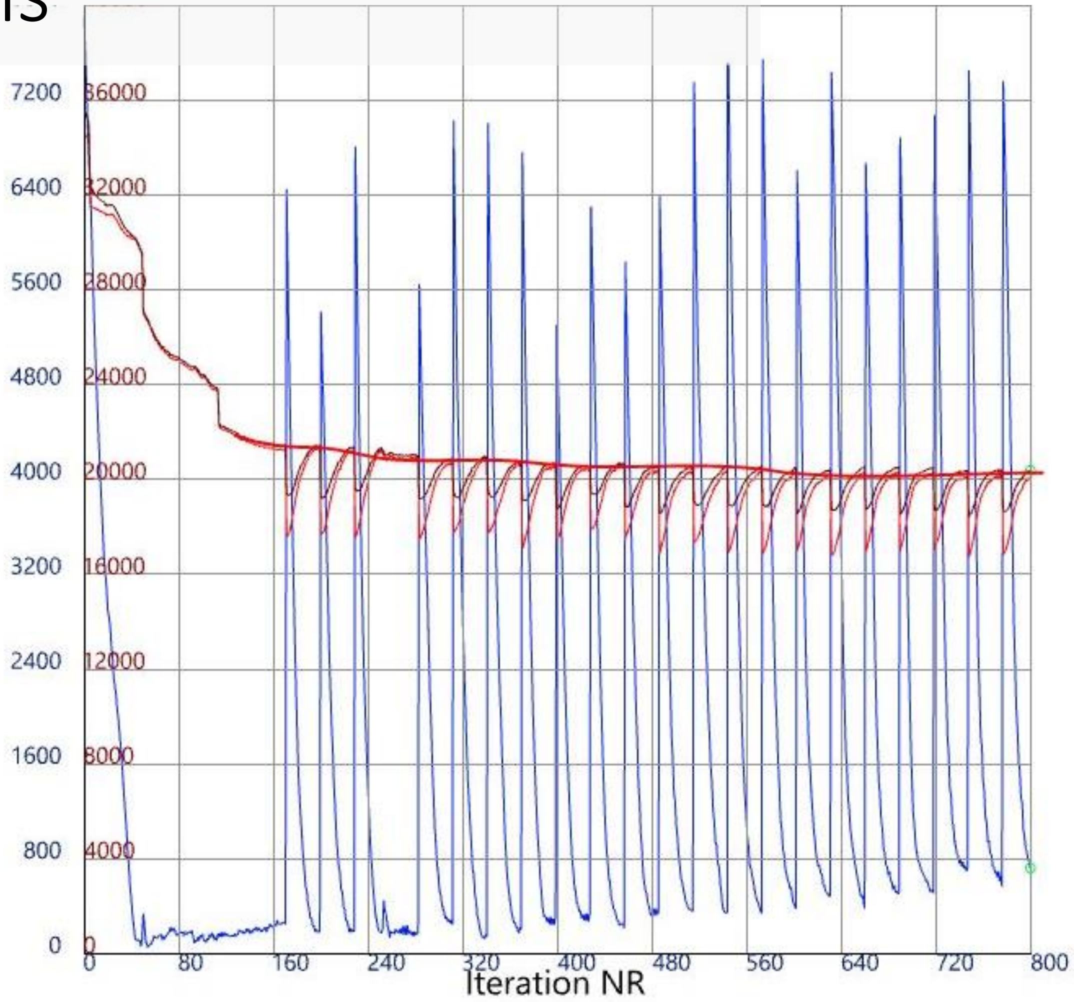
Result with both shooting and swapping over 800 iterations



Result with both shooting and swapping over 800 iterations



Result with both shooting and swapping over 800 iterations



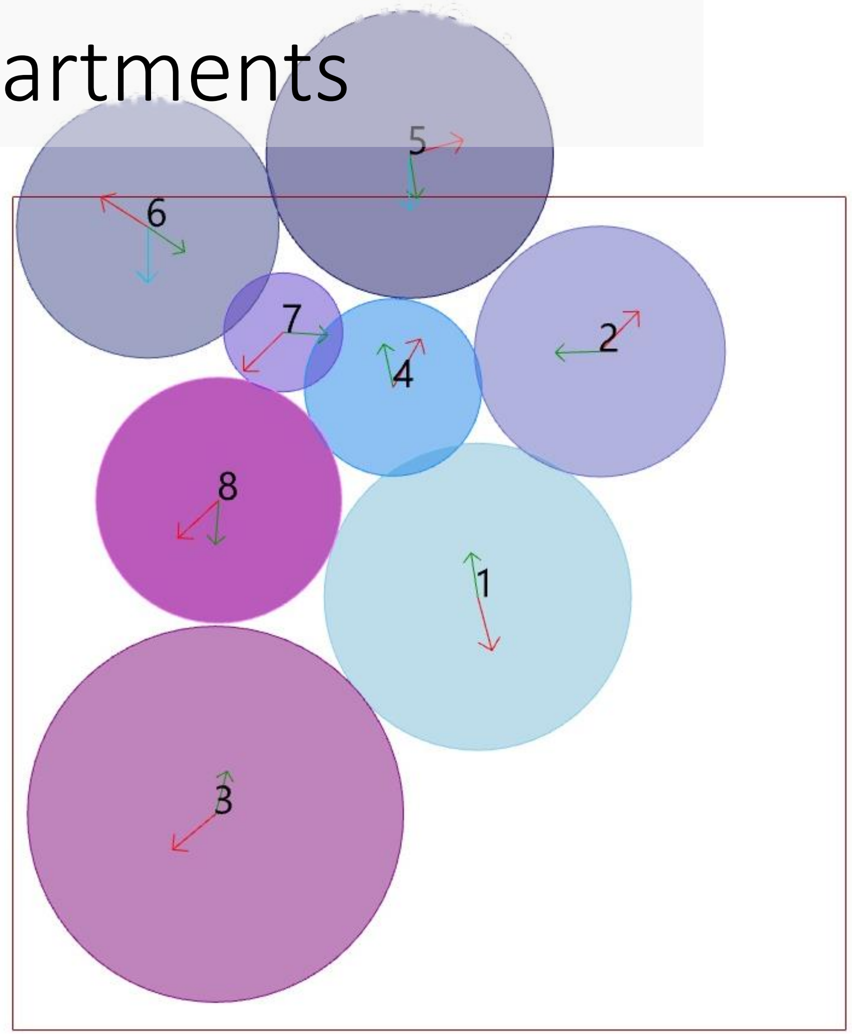
Results for the different appraoches compared

	Vanilla	Swapping	Shooting	Both
Objective				
Average	905.8	766.4	864.7	767.6
Minimum	760.6	745.1	747.9	742.5
Maximum	1225.7	829.6	1207.9	977.9
Standard deviation	96.7	16.9	99.2	33.8
Overlap				
Average	4.9	1.47	3.14	2.04
Minimum	0.46	0.62	0.7	0.61
Maximum	146.41	3.34	40.7	5.73
Standard deviation	20.46	0.77	5.63	1.16
Flow-cost				
Average	894.1	757.3	854.6	755.8
Minimum	568	727.7	741	723.1
Maximum	1220.5	816.8	1200.8	971.4
Standard deviation	104.5	17.5	99.9	35
Iterations				
Average	475.8	521.9	613.1	518.8
Minimum	0	141	8	118
Maximum	799	799	796	790
Standard deviation	238.3	197.1	181.2	169.1

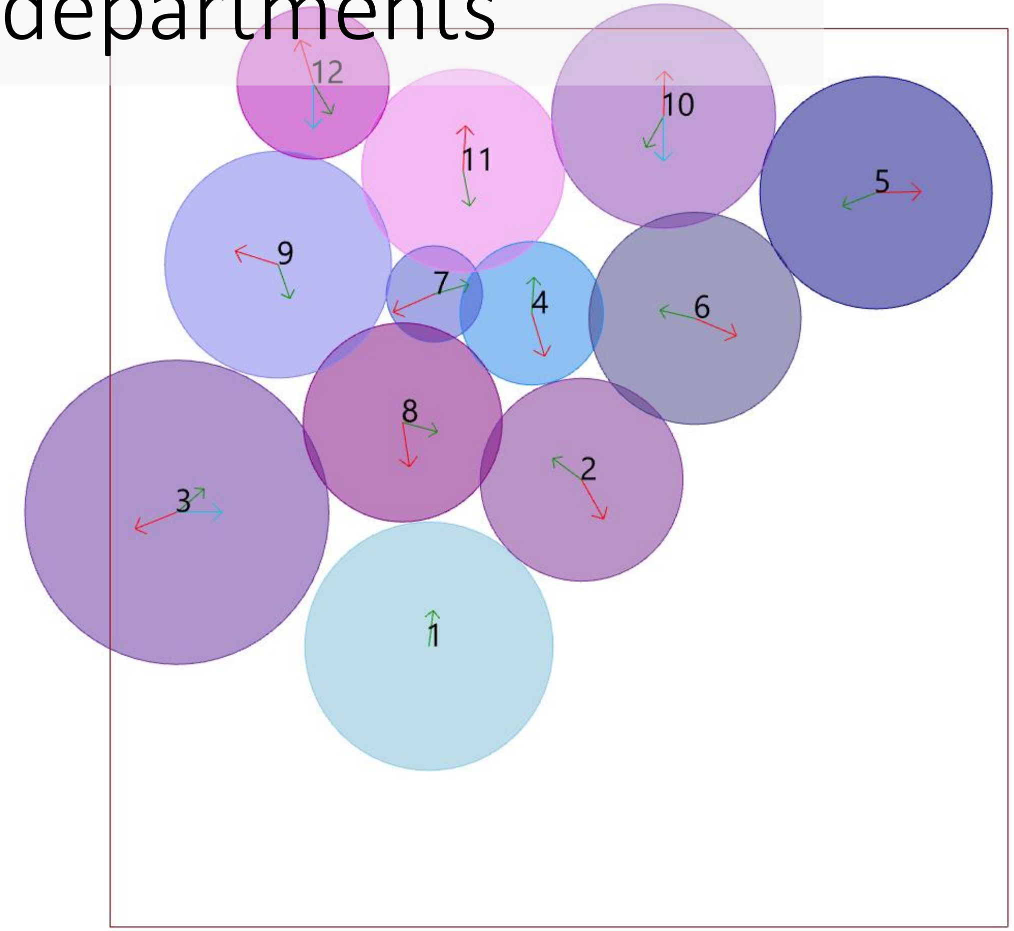
Results for the different appraoches compared

	Swapping	Shooting	Both
Objective			
Average	-15%	-5%	-15%
Minimum	-2%	-2%	-2%
Maximum	-32%	-1%	-20%
Standard deviation	-83%	3%	-65%
Overlap			
Average	-70%	-36%	-58%
Minimum	35%	52%	33%
Maximum	-98%	-72%	-96%
Standard deviation	-96%	-72%	-94%
Flow-cost			
Average	-15%	-4%	-15%
Minimum	28%	30%	27%
Maximum	-33%	-2%	-20%
Standard deviation	-83%	-4%	-67%
Iterations			
Average	10%	29%	9%
Minimum	-	-	-
Maximum	0%	0%	-1%
Standard deviation	-17%	-24%	-29%

Best result: 8 departments

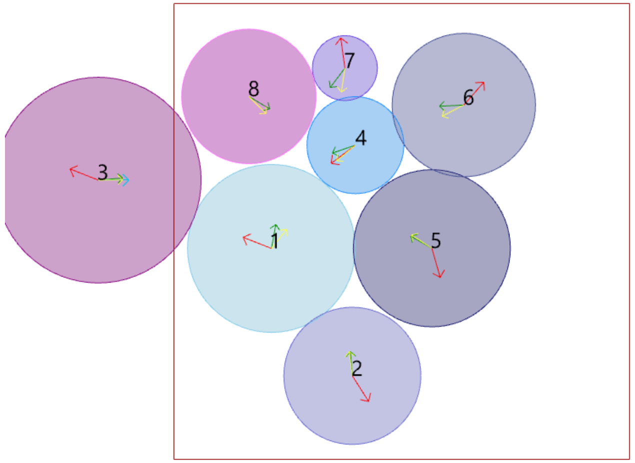


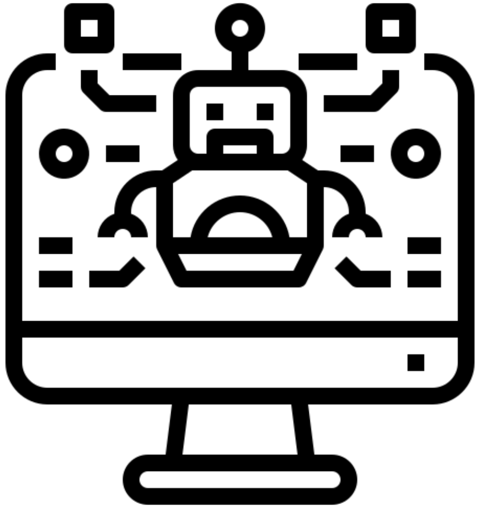
Best result:12 departments



Second-stage model

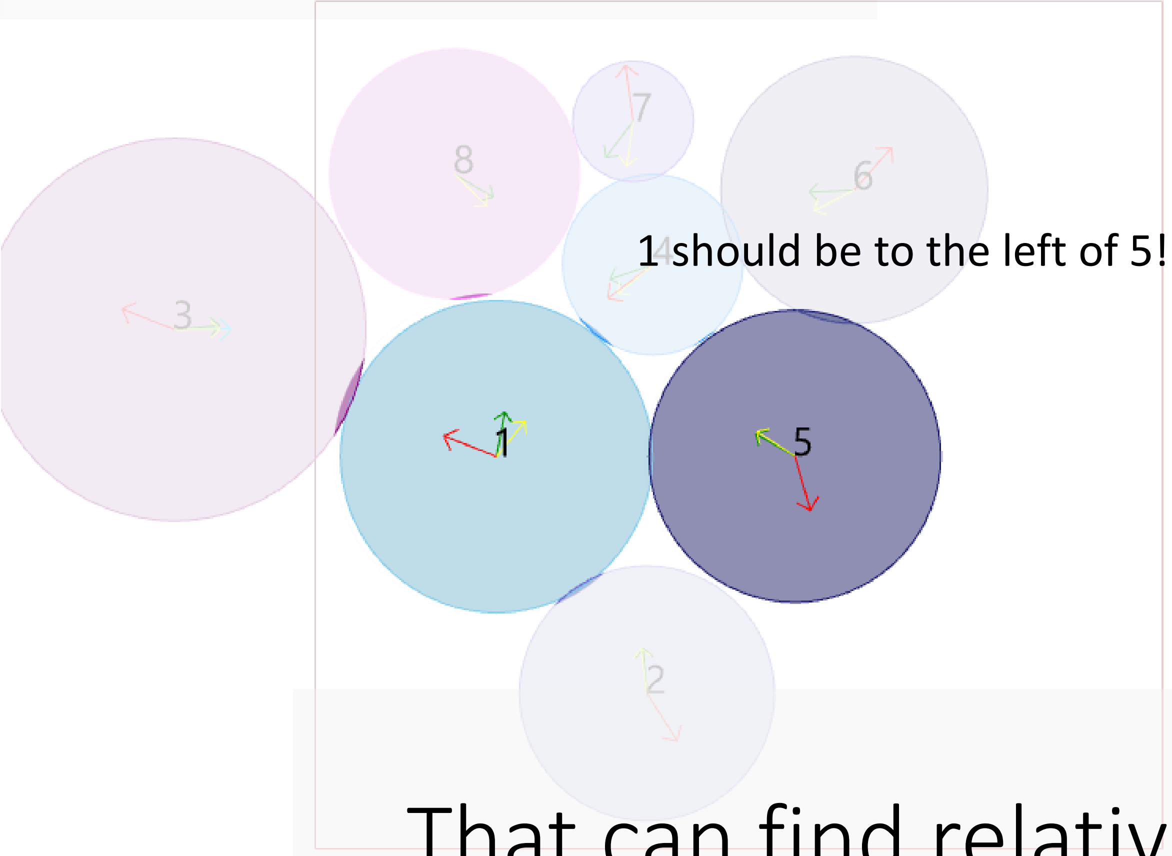
Reminder





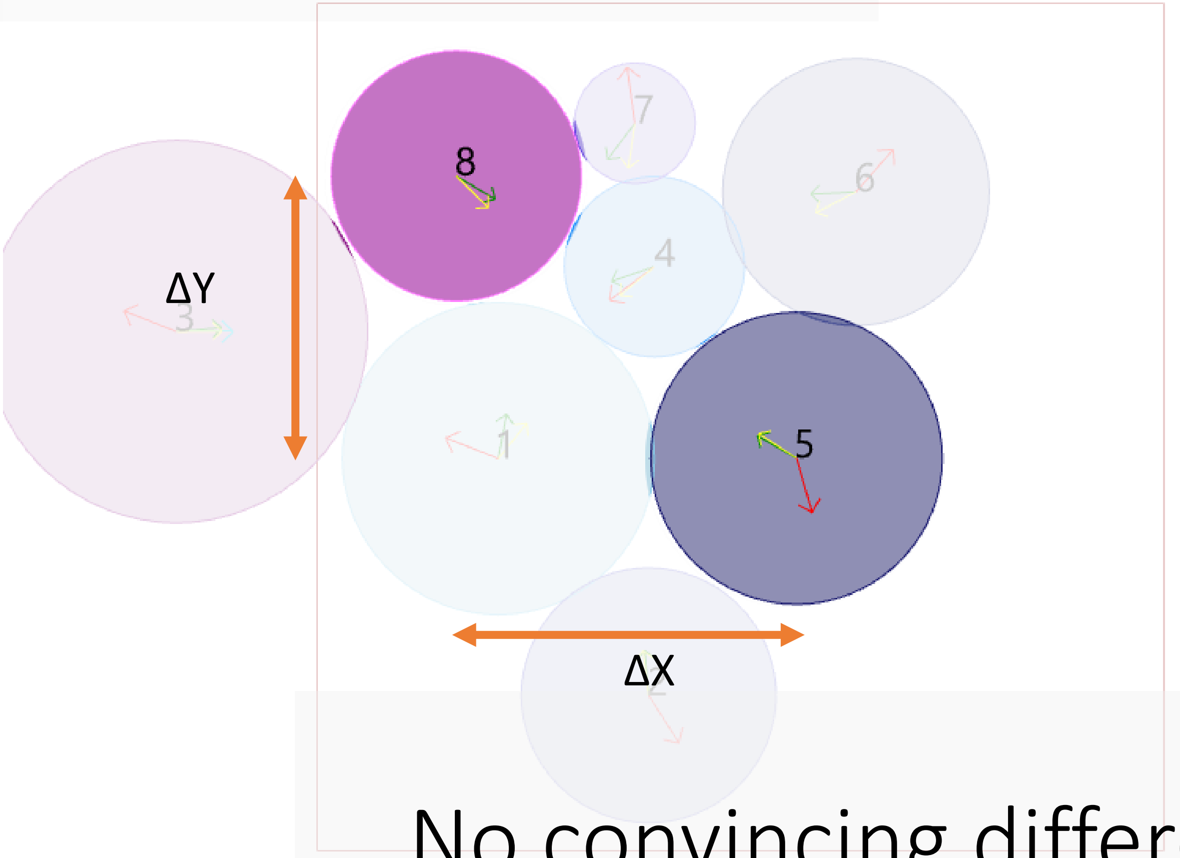
First model needed to reduce the solution space

A first-stage model to find constraints to potential good solutions



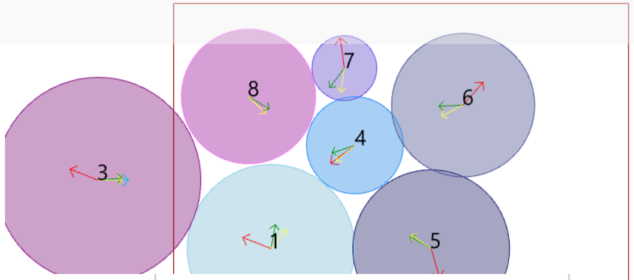
That can find relative locations

Some deparments relative locations are to vague for a constraint

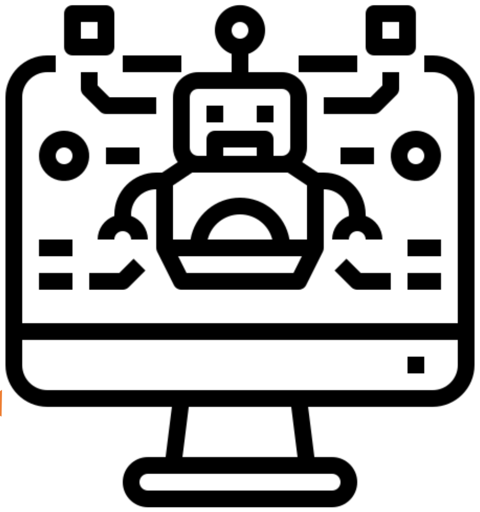


No convincing difference

The second-stage model



	Required Area	Max Aspect ratio
1	2400	1.25
2	1600	1.33
3	3600	1.85
4	800	3.33
5	2100	1.18
6	1750	2
7	360	3.33
8	1540	1.67



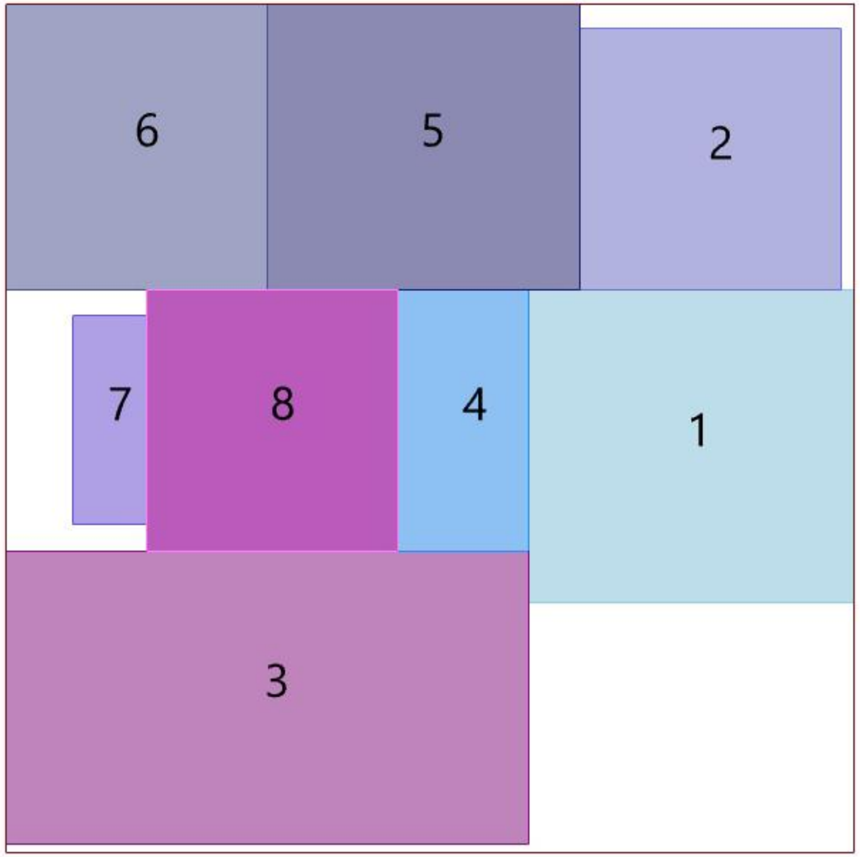
Other constraints:

No overlap with each other

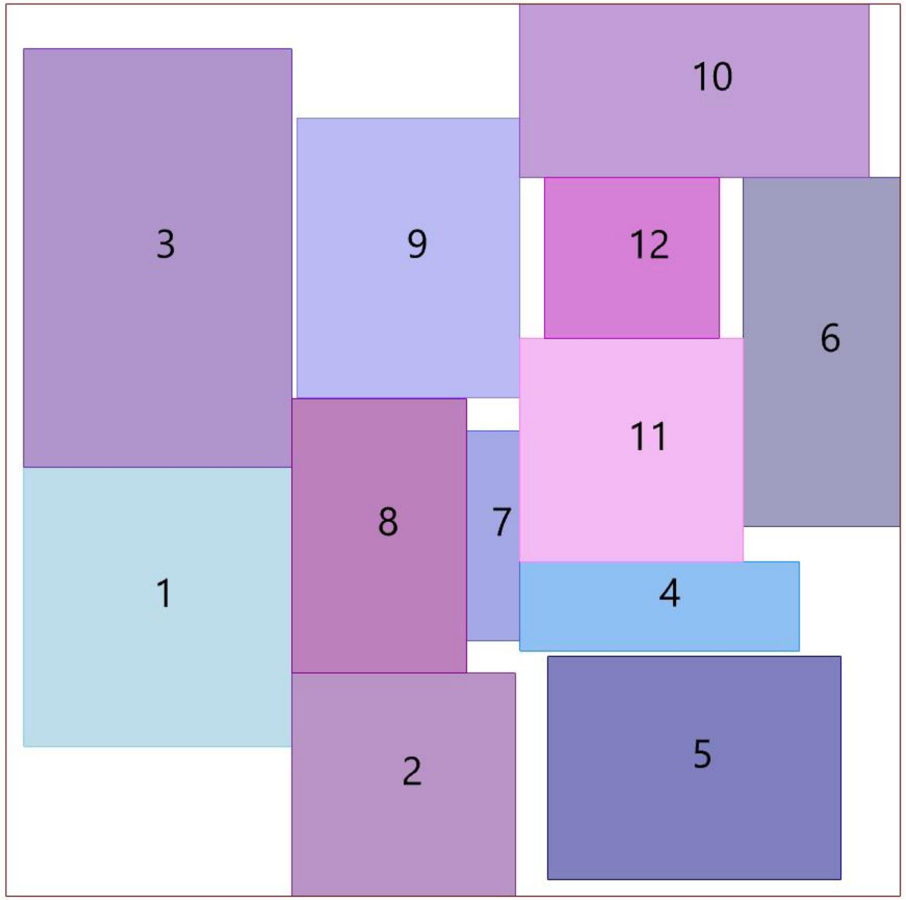
No overlap with outside facility

What else to feed the model?

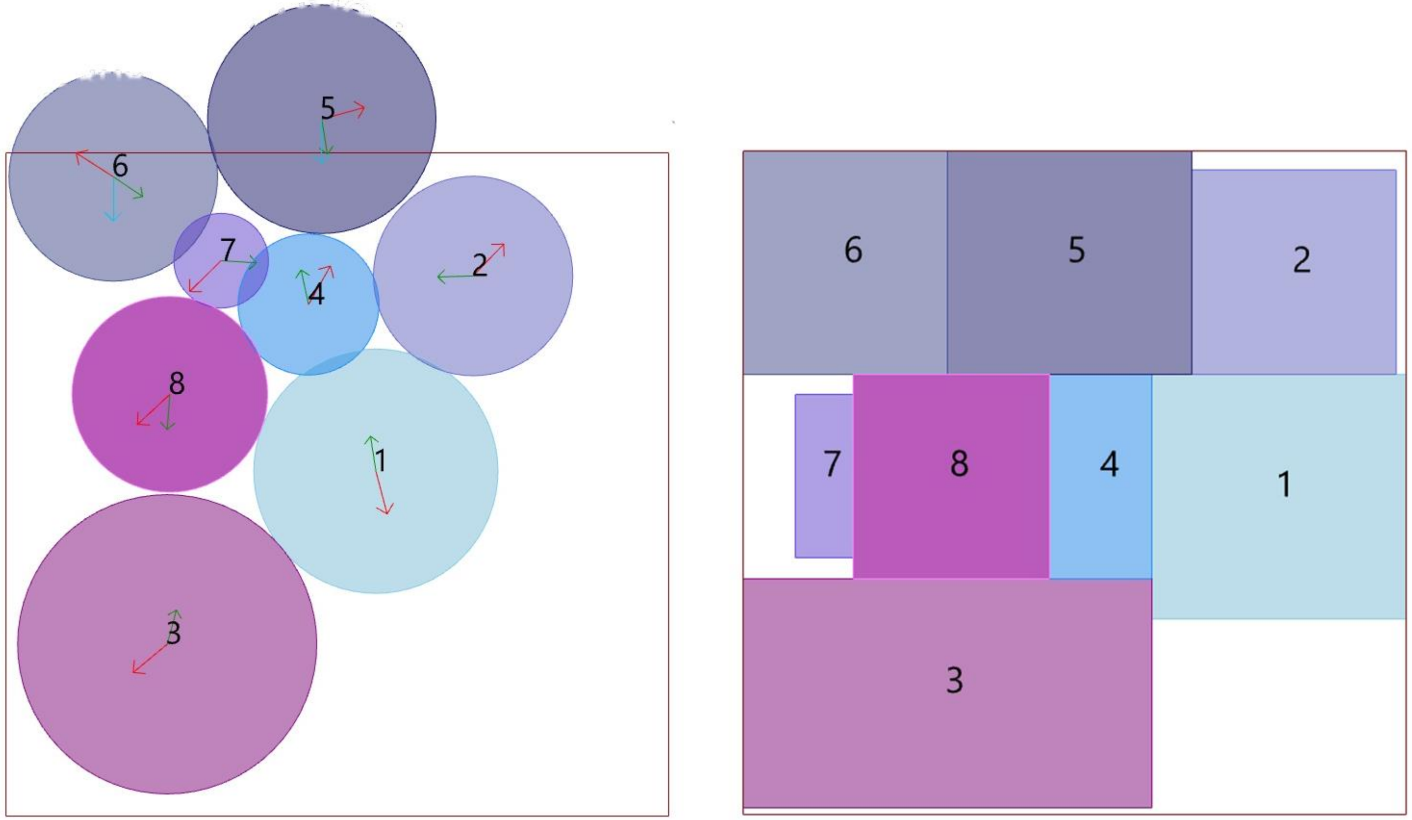
Final result: 8 departments



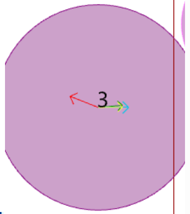
Final result: 12 departments

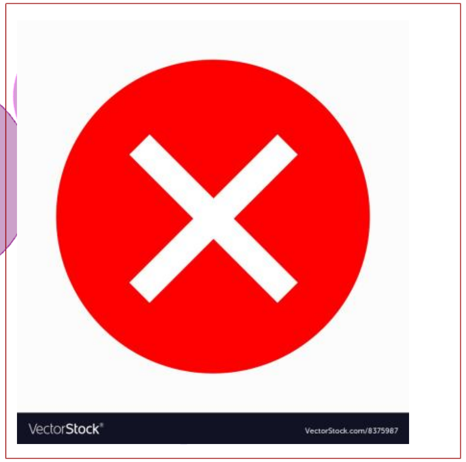


Final result: 12 departments first stage compared to the second stage

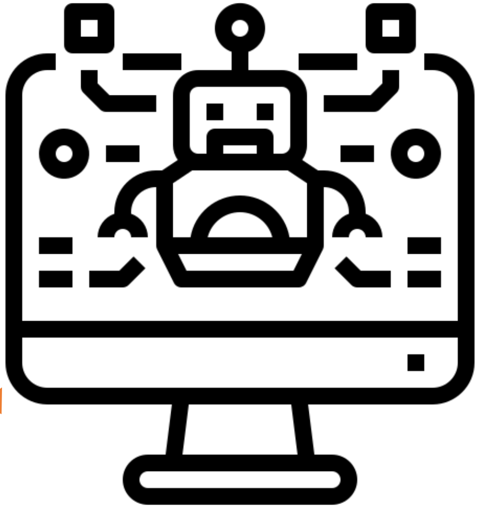


What if we take out the first-stage models constraints?





	Requi	
1		
2		
3		
4	[illegible]	[illegible]
5	2100	1.18
6	1750	2
7	360	3.33
8	1540	1.67



Other constraints:

No overlap with each other

No overlap with outside facility

What else to feed the model?

What if we take out the first-stage models constraints?

	Relational constraints	No relational constraints	Difference%
25s	477.2	528.1	9.6
100s	427.6	520.3	17.8
300s	410.3	515	20.3

Objective for the 8 department problem

	Relational constraints	No relational constraints	Difference%
25s	1338.9	1678.4	20.2
100s	1302.1	1607.1	19.0
300s	1302.1	1444.0	9.8

Objective for the 12 department problem

How well does the method perform versus other methods?

Departments	OV	Recomputed OV	Tam OV	Chwif OV
8	410.3	967.3	839	-
12	1302.1	3931.4	3162	3684

But..

Our method's layout gives a more compact layout, only 20% empty space versus 37% of Tam and 23% of Chwif

Conclusions

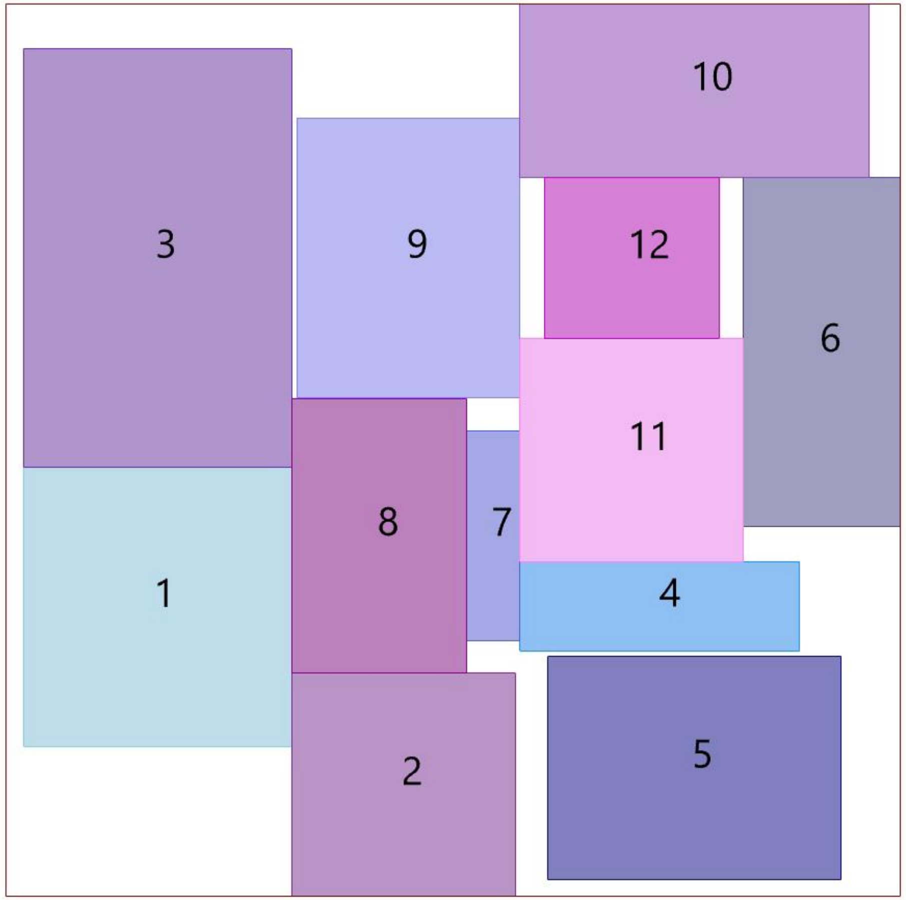
Conclusions

The first-stage model tremendously increases the effectiveness of the second-stage model

The method in total performs slightly less compared to other methods in literature. However, the layout found is more compact.

There is improvements that can be made, but the thesis was a succes as far as I am concerned

Questions?



Figures sources

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