Algorithms on a variable-size rectangular interface

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13 April 2022

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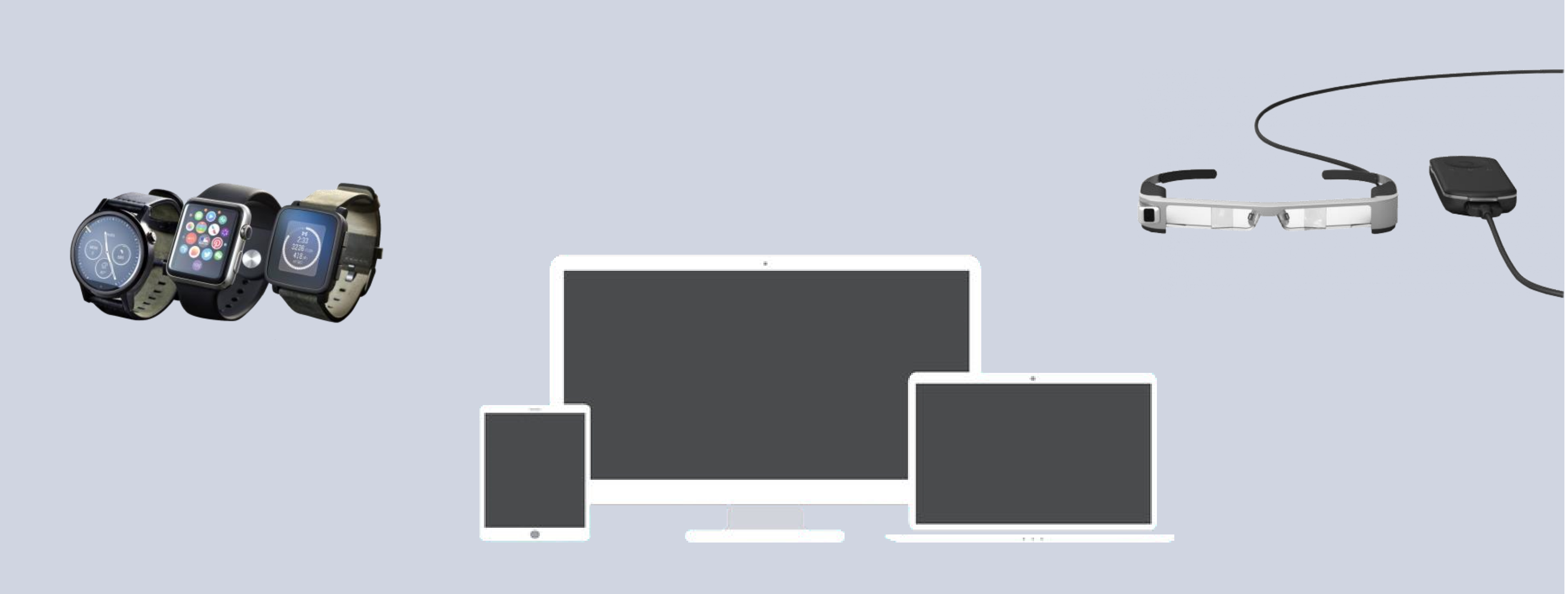
Outline

- Introduction
- Problem Description
- Human-Computer Interaction Approach
- Combinatorial Optimization Approach
- Tests and Results
- Conclusion and Perspectives

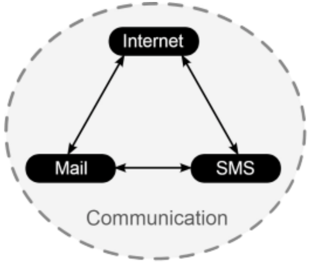
Introduction



Introduction: Tile based interface

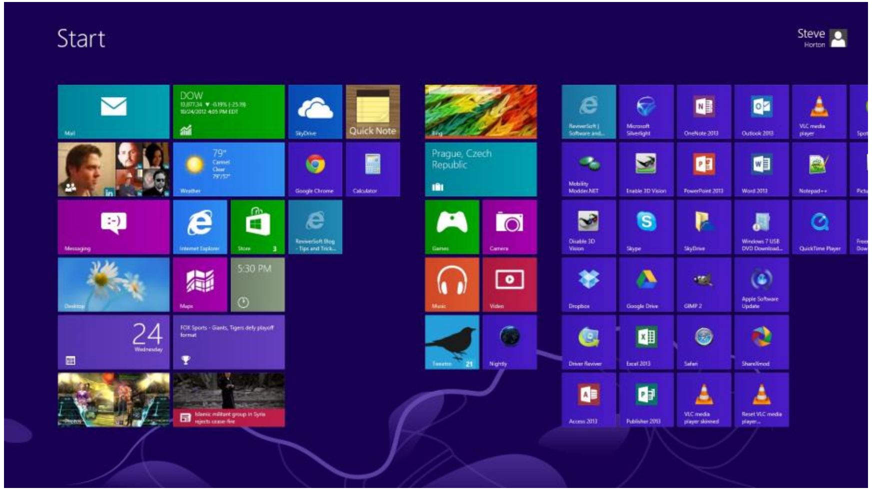
Tiles:

- Are represented by a rectangle.
- Have different sizes.
- Can contain text, image, video, shortcut, ...
- Give access to services usually organized into categories.

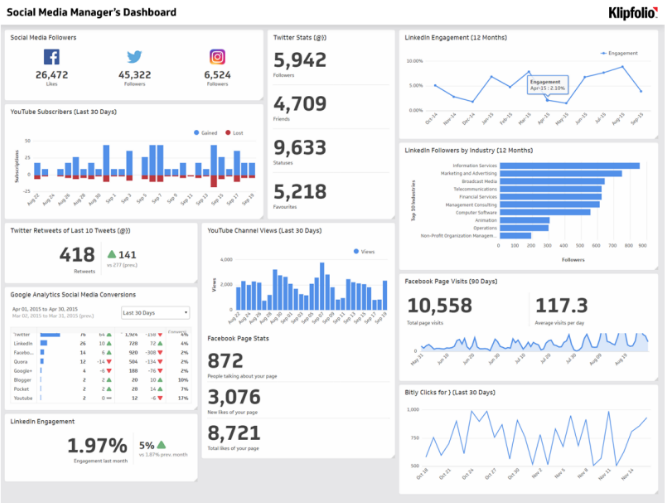


Introduction

Windows tile based interface



Example of dashboard (A. Sarikaya *et al.* 2018)

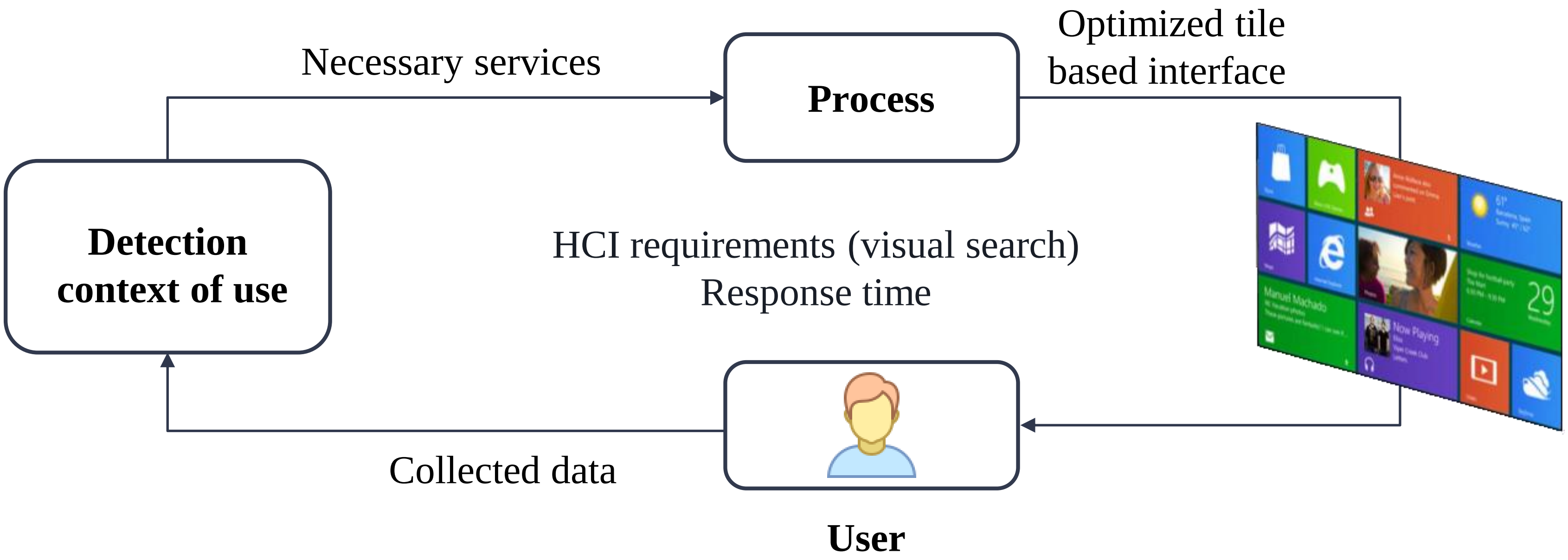


Problem Description

- More tiles => More difficulty to access.
- Usual solution: user customizes the positions and the sizes of the tiles.
- One layout cannot be the best in all situations of use.
- The interface should be sensitive to the context of use.

Problem Description

Our proposal: a module to generate a layout according to the context of use



Human-Computer Interaction Approach

Context of use = importance

Value that can represent the frequency of use, the degree of interest, etc.

Human-Computer Interaction Approach

The proposed approach:

- The Gestalt laws.
- The eye tracking studies.

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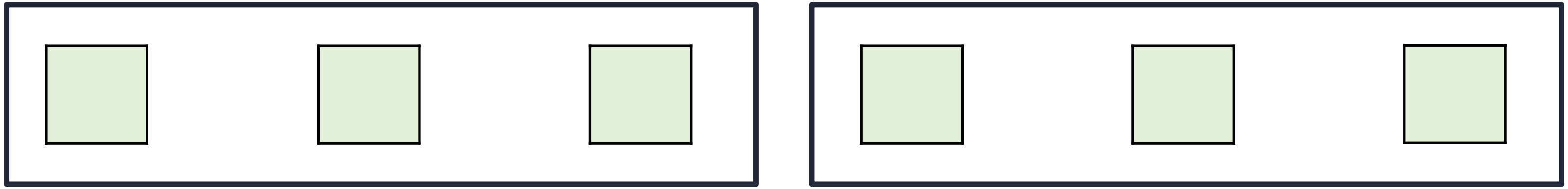
The Gestalt laws:

- Gestalt theory is a group of psychological theories that are usually expressed as laws.
- Describe how humans group similar elements, recognize patterns and simplify complex images when we perceive objects.
- There are many variations of the laws of Gestalt theory (Common Region, Continuity, Proximity, Similarity, …).

Common Region:

“ The proposed principle of common region states that, all else being equal, elements will be perceived as grouped together if they are located within a common region of space, …” E. Palmer 1992



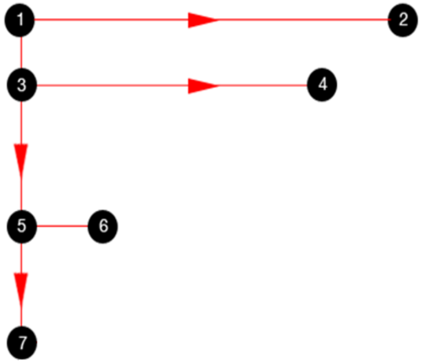
Human-Computer Interaction Approach

- Eye tracking studies where and how long the user looks.

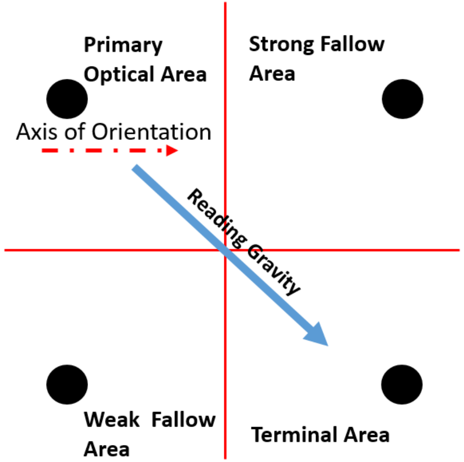
F-shaped heat map obtained from the Nielsen's Norman Group eye tracking research

Human-Computer Interaction Approach

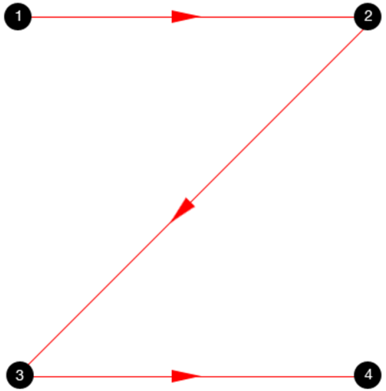
- User’s scanning patterns



F-pattern

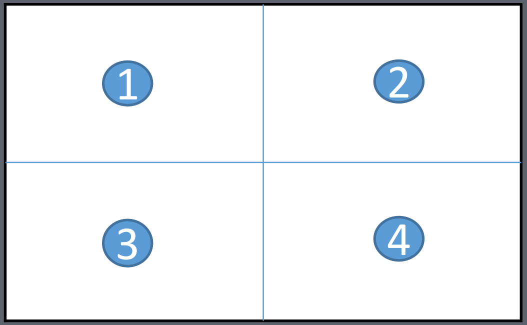


Gutenberg diagram



Z-pattern

Common Regions

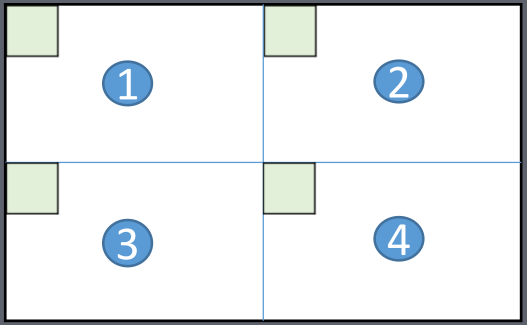


Common Regions

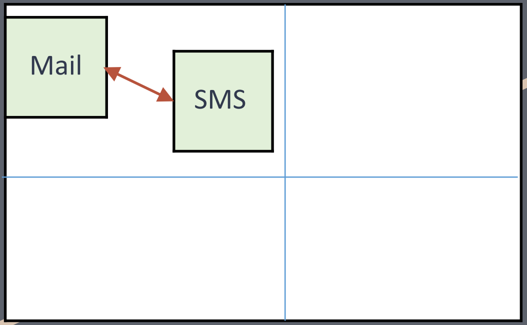
The tiles are dispatched into four « Common regions ».

The tiles are divided into four groups following their importance.

The most important tiles are placed in one comon region at the top left of the screen.



Top left corner



Proximity

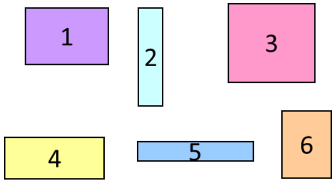
One Common Region

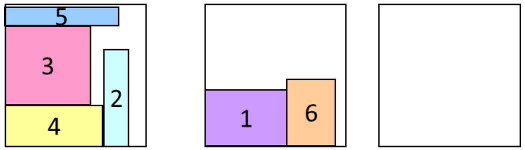
- The most important tile of each group is placed at the top left corner of its region.

- The distance between tiles that propose the same category of services is reduced as much as possible.

Combinatorial Optimization Approach

- The mathematical formulation of this problem is quite similar to the one used for the standard two-dimensional bin packing problem.





- This problem is NP-hard.

- Three methods: Mathematical (Exact), Heuristic, Memetic.

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Combinatorial Optimization Approach

Data:

- A set of tiles T where each tile T_i represents a service $T = \{T_1, T_2, .., T_N\}$.
- For each tile T_i we denote its height h_i and its width w_i.
- A degree of importance f_i is attributed to each tile such that $\sum_{i=1}^{N} f_i = 1$.

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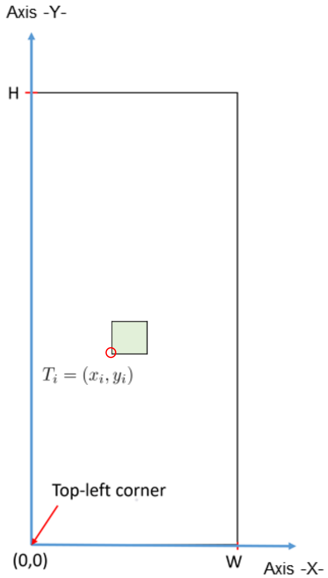
Combinatorial Optimization Approach

Data:

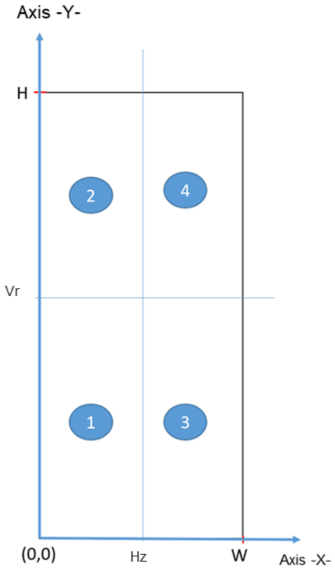
- A set of m categories of service where the tiles are grouped following their proposed services $C = \{C_1, C_2, .., C_m\}$.
- Four sets containing tiles following their importance $\delta = \{\delta_1, \delta_2, .., \delta_4\}$.
- A set of four zones $Z = \{Z_1, Z_2, .., Z_4\}$ where we will attribute each set of importance.

Combinatorial Optimization Approach

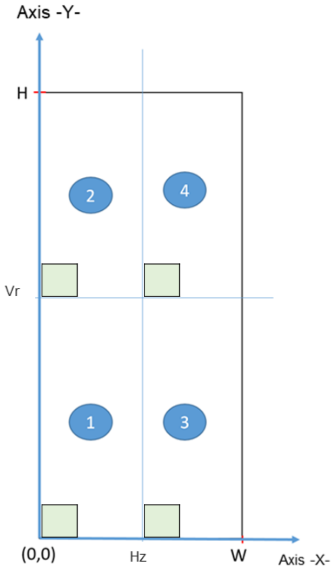
Mathematical Model



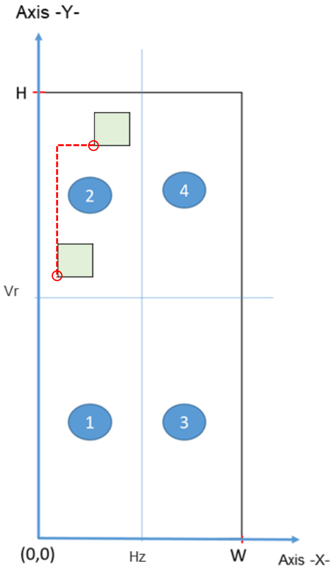
The screen as a container



Common Regions (zones)



Top-left corner

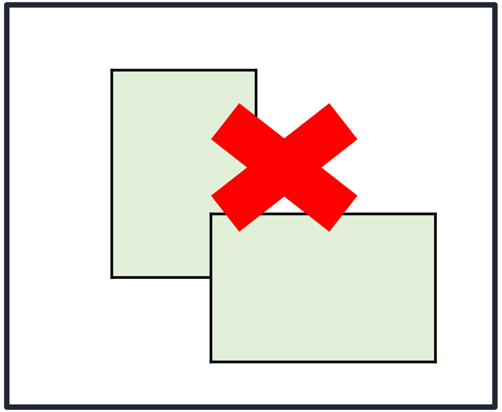


Proximity

Distance

Norm one (Manhattan)

Mathematical Model



Non-overlapping

Ratio aspect

Combinatorial Optimization Approach

Mathematical Model

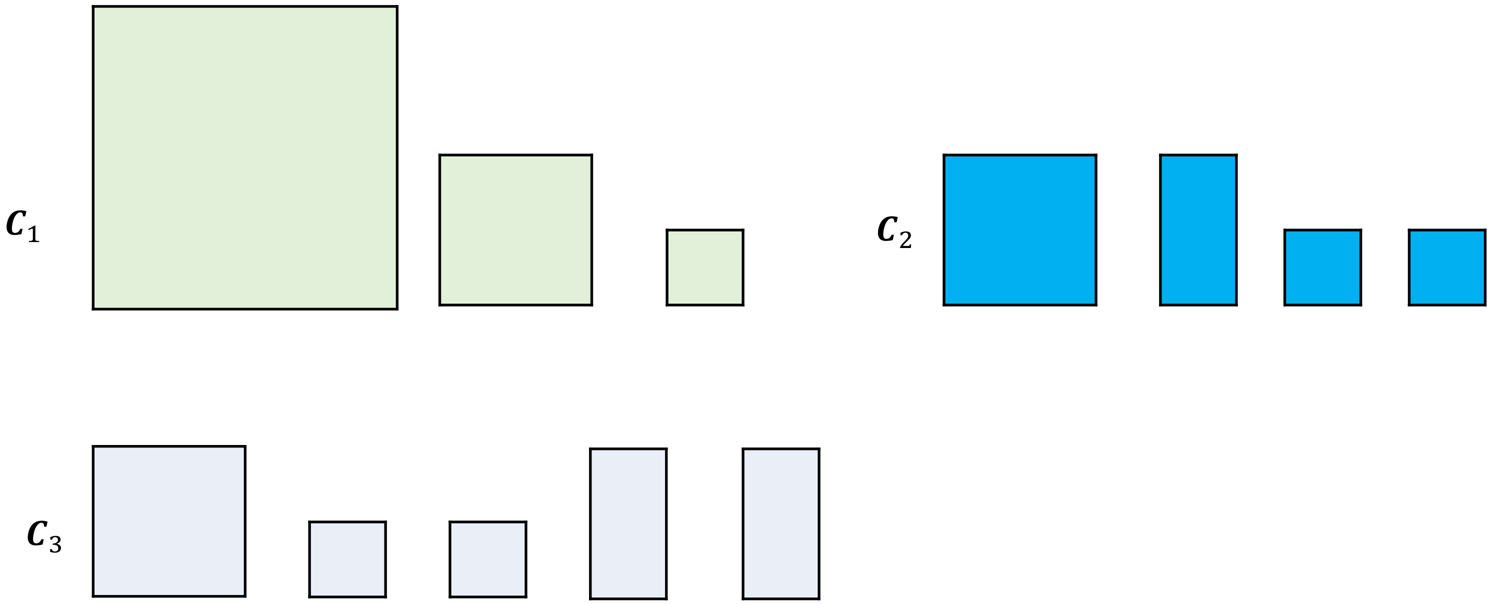
- Minimize the unused space in the interface

$$F_1 = min\{H\}$$

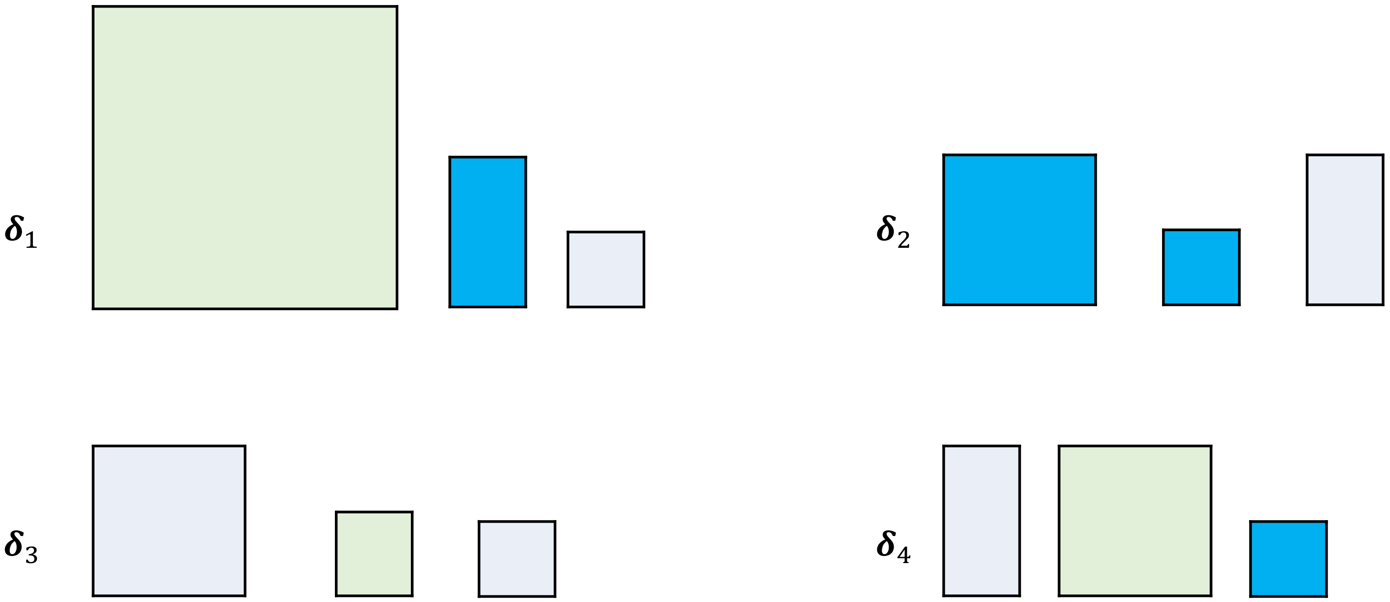
- Optimize the placement of tiles

$$F_2 = min\{\sum_{i=1}^{N}(x_i + y_i)f_i - \sum_{i=1}^{N}\sum_{j=1}^{N} V_{i,j}(f_i + f_j)\}$$

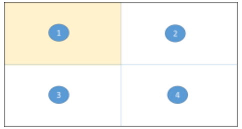
Heuristic



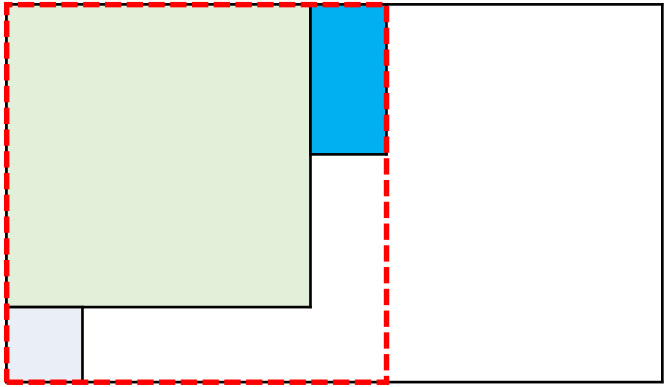
Heuristic



Heuristic



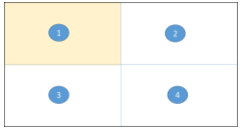
Step 1: Place the tiles of the first class of importance $\boldsymbol{\delta}_1$ following to SFF algorithm [1].



H=8.88
W=5
Hz=5
Vr=5

[1] I.Kacem *et al.* Codit19

Heuristic



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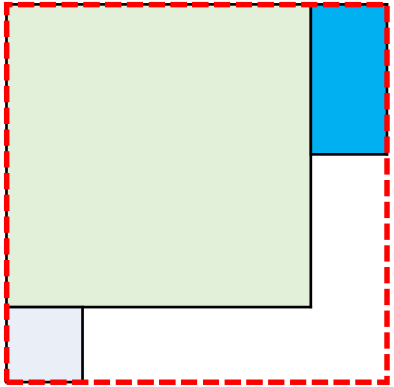

W=5
Hz=5
Vr=5

Step 2: define the vertical and horizontal separators (Hz and Ver)

[1] I.Kacem *et al*. Codit19

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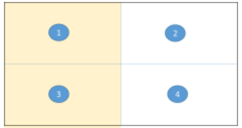
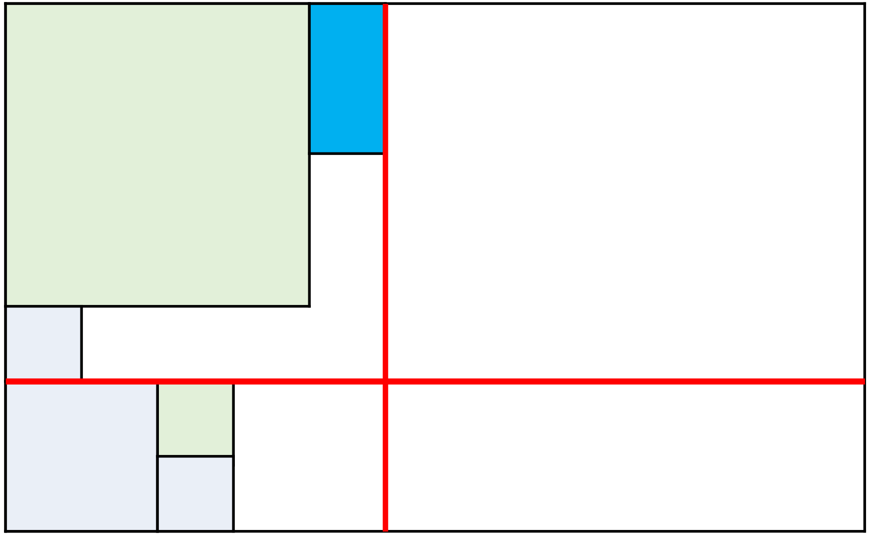
Heuristic

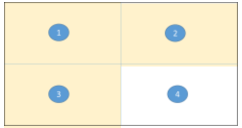


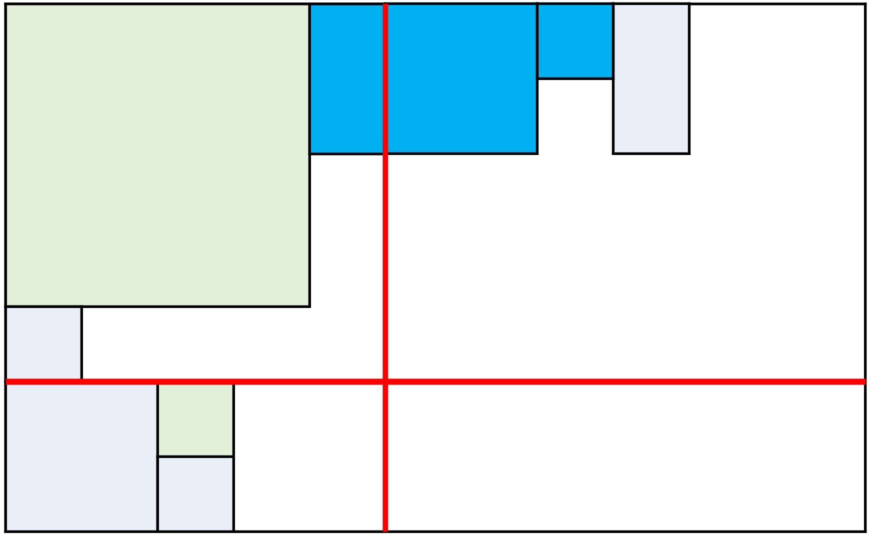


H=12,44
W=7
Hz=5
Vr=max(5,3)=5

Step 3: Update the solution

Heuristic

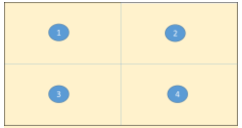


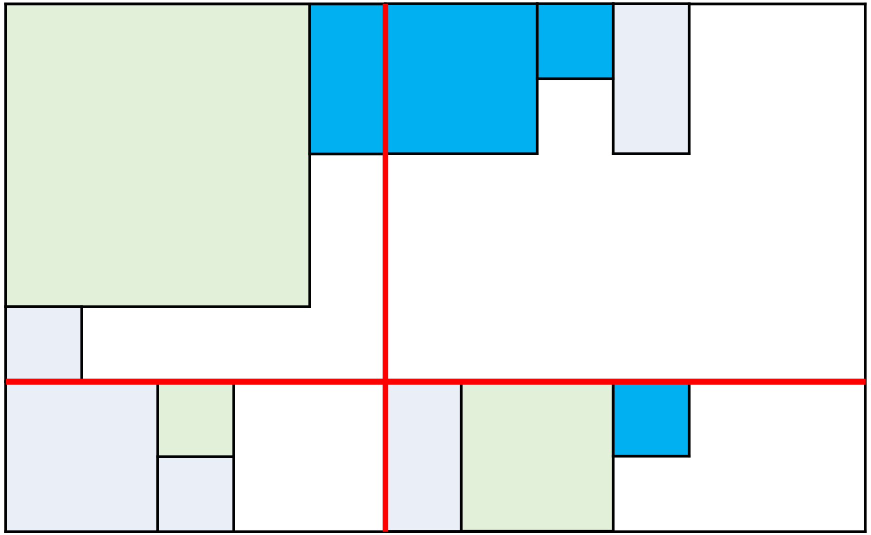


H=12,44
W=7
Hz=5
Ver=5

Step 3: Update the solution

Heuristic





H=12,44
W=7
Hz=max(5,2)
Vr=5

Step 3: Update the solution

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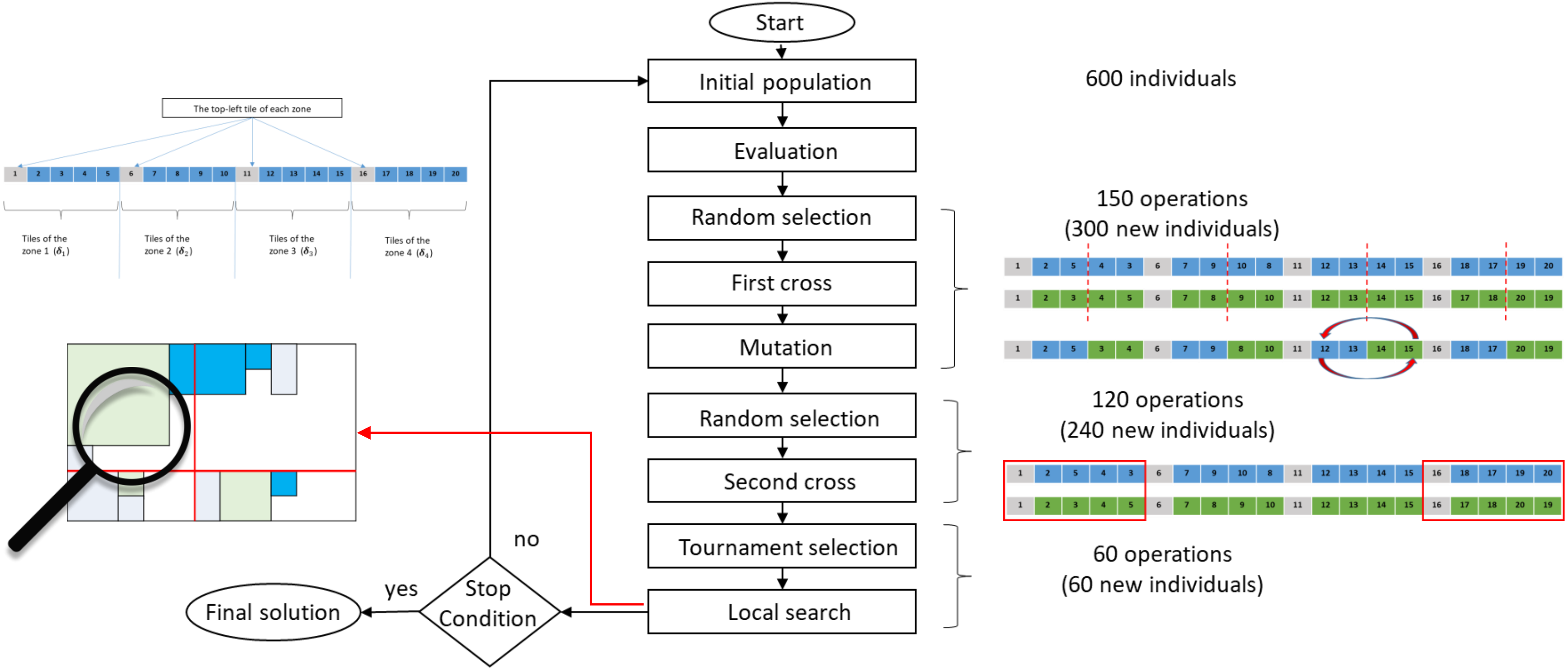
Memetic



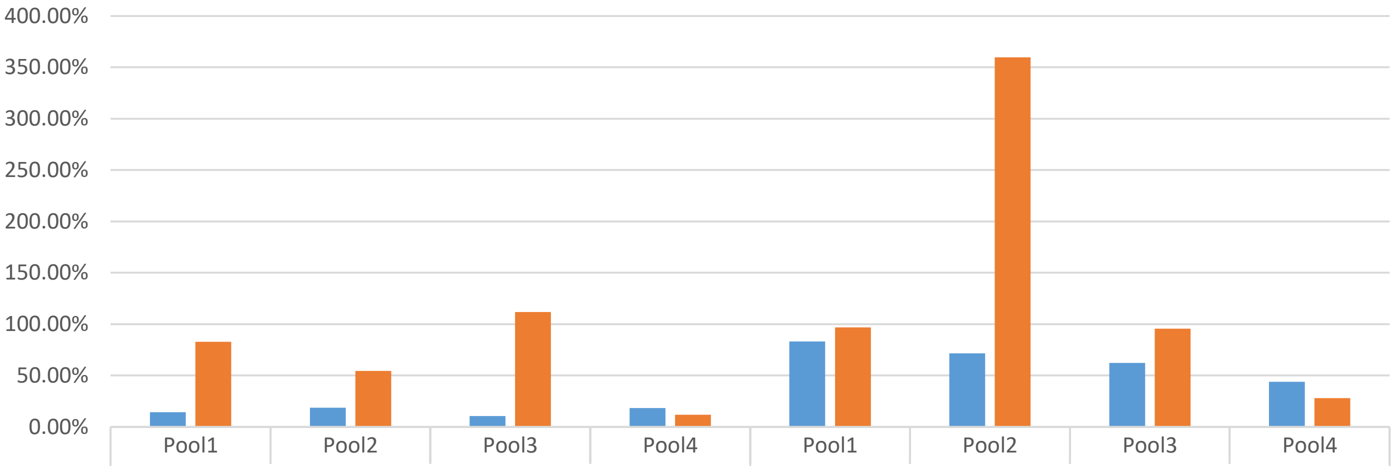
The top-left tile of each zone
Tiles of the zone 1 (δ1)
Tiles of the zone 2 (δ2)
Tiles of the zone 3 (δ3)
Tiles of the zone 4 (δ4)
Start
Initial population
Evaluation
Random selection
First cross
Mutation
Random selection
Second cross
Tournament selection
Local search
Stop Condition
no
yes
Final solution
600 individuals
150 operations
(300 new individuals)
120 operations
(240 new individuals)
60 operations
(60 new individuals)

Tests and Results

- A mathematical model solved by using CPLEX.
- The set of instances that we used is composed of 1161 interfaces (from 5 tiles to 33).
- Four pools where the distribution of importance to the tiles is according to their size.
- The best solution obtained after solving lexicographically the two possibilities of orders of the objective functions using the CPLEX solver.
- The Memetic and heuristic solutions are compared to the solution obtained by CPLEX.

Tests and Results

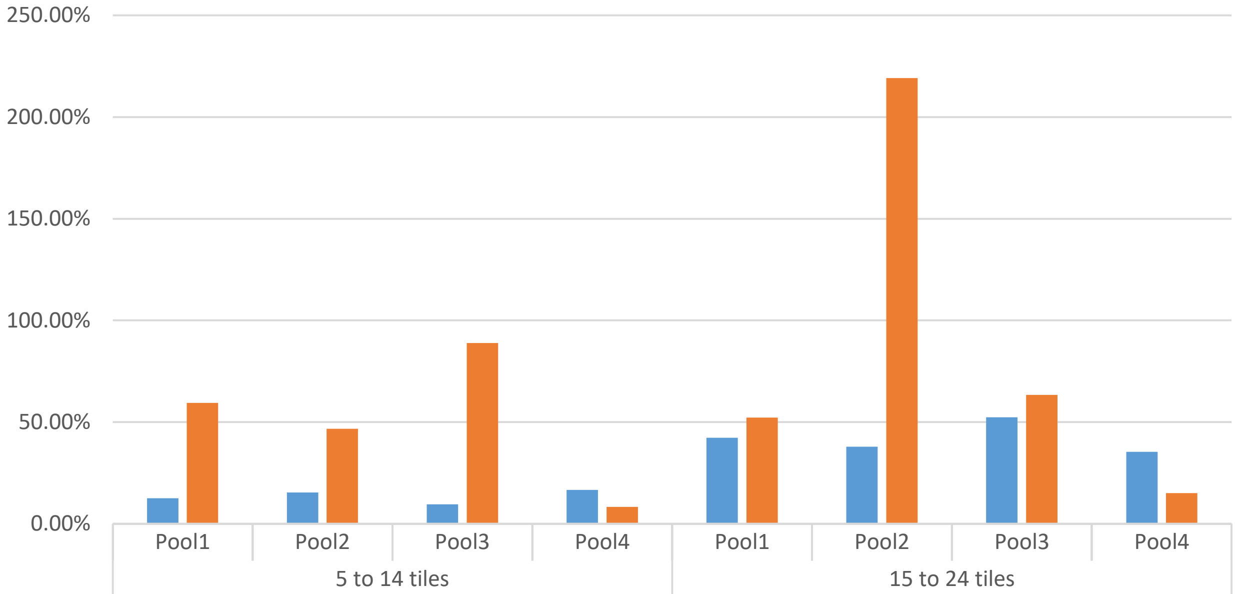
The average gap between Heuristic and CPLEX



	5 to 14				15 to 24			
	Pool1	Pool2	Pool3	Pool4	Pool1	Pool2	Pool3	Pool4
Gap_F1	14.32%	18.73%	10.49%	18.18%	83.19%	71.48%	62.32%	43.87%
Gap_F2	82.66%	54.33%	111.83%	11.90%	96.78%	359.67%	95.73%	27.85%

Tests and Results

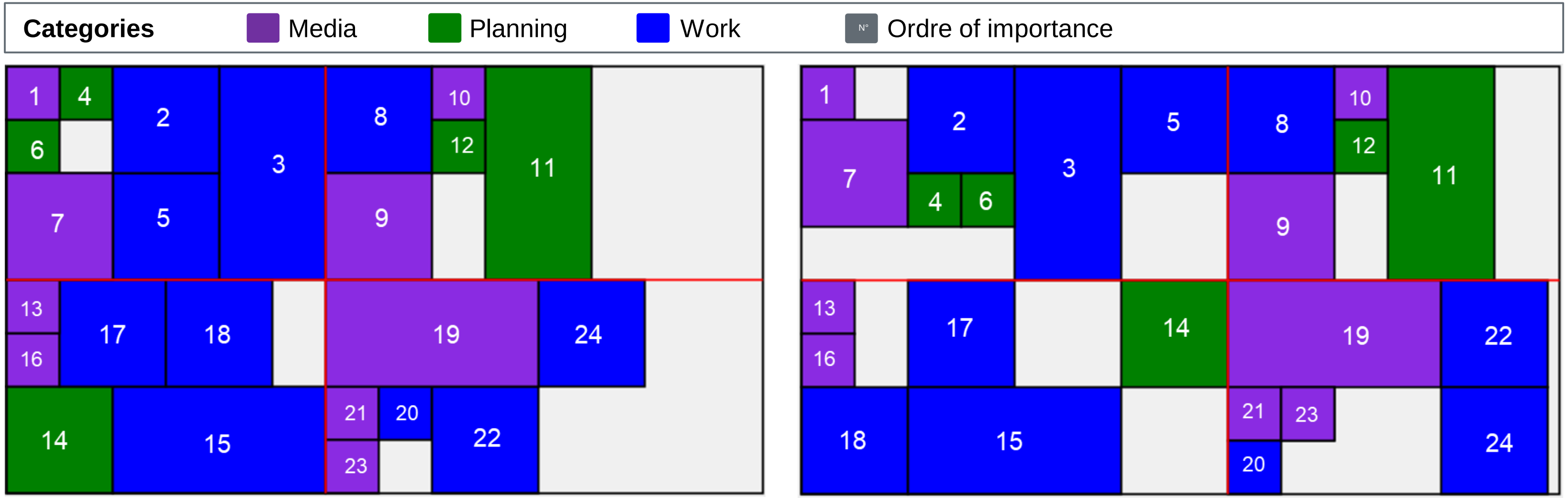
The average gap between Memetic and CPLEX



	Pool1 (5 to 14 tiles)	Pool2 (5 to 14 tiles)	Pool3 (5 to 14 tiles)	Pool4 (5 to 14 tiles)	Pool1 (15 to 24 tiles)	Pool2 (15 to 24 tiles)	Pool3 (15 to 24 tiles)	Pool4 (15 to 24 tiles)
Gap_F1	12.47%	15.33%	9.52%	16.60%	42.22%	37.95%	52.36%	35.36%
Gap_F2	59.51%	46.61%	88.85%	8.23%	52.24%	219.23%	63.43%	15.06%

Gap_F1 Gap_F2

Tests & Results



CPLEX Solution

Memetic solution

The solution provided by the memetic algorithm and the pareto optimal obtained by CPLEX

Tests and Results

Methods\Number of tiles	5 to 14	15 to 24	25 to 33
CPLEX	2 s	280.2 s	-
Memetic	8 s	37.7 s	53.1 s
Heuristic	0.001 s	0.001 s	0.001 s

The average computational times of the proposed algorithms

Conclusion

- We proposed Combinatorial Optimization methods to solve a Human-Computer Interaction problem.

- These algorithms optimize the unused area and the placement of tiles at the same time.

Perspectives

- Investigation of new exact methods to solve this problem in order to obtain pareto optimal solutions.
- Introducing new HCI constraints to balance tile's size following their importance to obtain more compact interfaces.

Thank you for your attention !