Segmentation of Dashboard Screen Images:

Preparation of Inputs for Object-based Metrics of UI Quality

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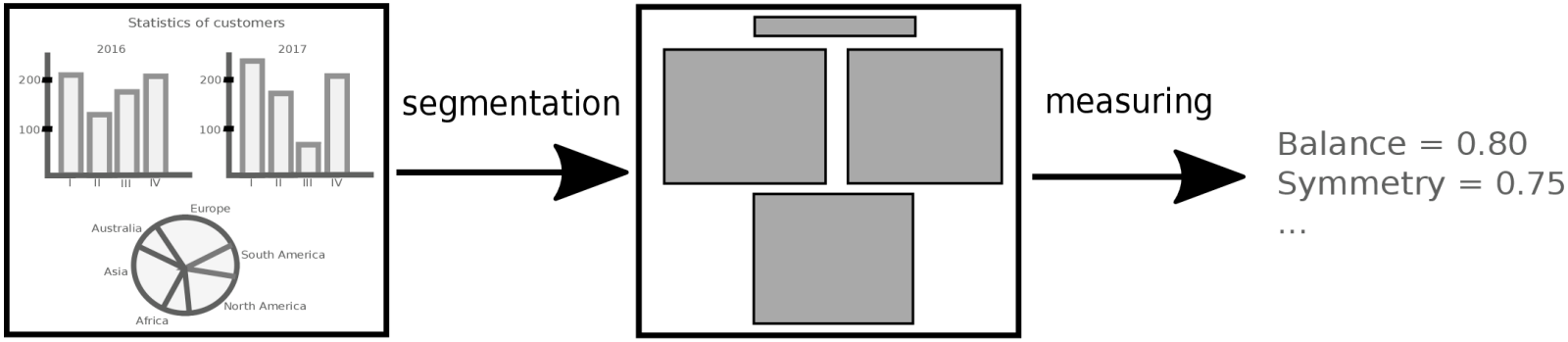
Goal of the Research

Design a method for automatic segmentation of dashboards



Input = bitmap (UI screenshot)

Output = regions

- rectangle boundaries of visually dominant objects
- used for analysis of UI (quality, usability, ...)

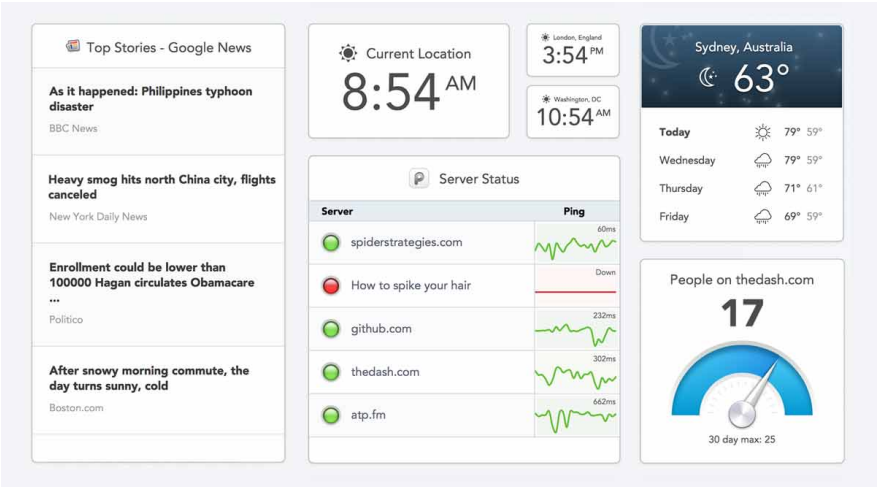
Background

- tool for a **single screen** data visualization
- presents **the most important information**
- user can monitor the information **at a glance**
- helps to **achieve goals**

S. Few, 2006

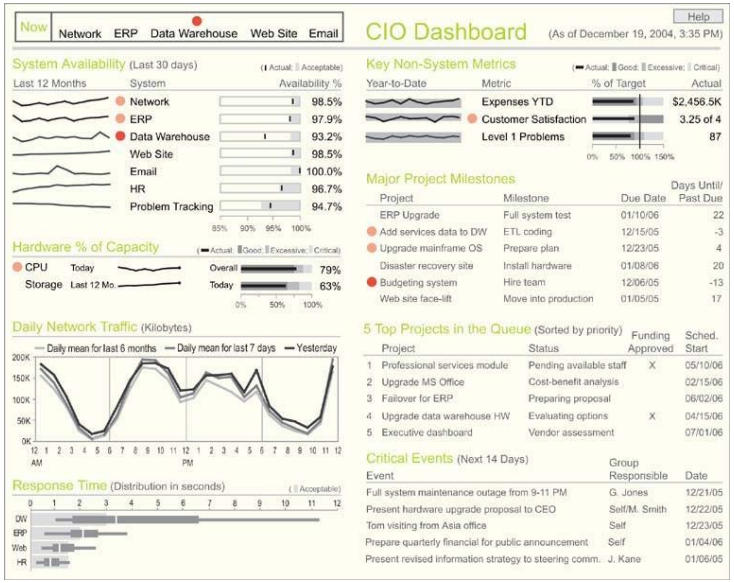
- Malik S. (2005): Enterprise Dashboards, Wiley
- Few S. (2006): Information Dashboard Design, O'Reilly
- Eckerson W. (2006): Performance Dashboards, Wiley
- Wexler S., Shaffer J., Cotgreave A. (2017): The Big Book of Dashboards, Wiley.

Dashboards



Klipfolio.com

TheDash.com



S. Few

Further services:

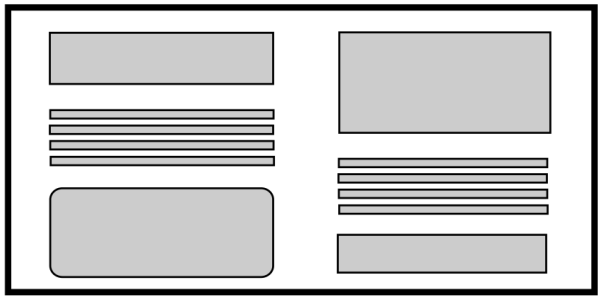
Sisense.com, Datapine.com,

ClicData.com, Plot.ly, ...

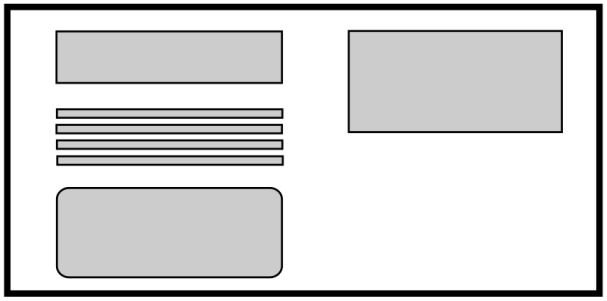
- quantitative measuring of UI characteristics
- avoid design problems during early design phase
- decrease “some” time and resources of user testing

Object-based metrics: **Balance**
by D. C. L. Ngo, L. S. Teo , and J. G. Byrne (2003)

A:



B:



$$\mathrm{BM} = 1 - \frac{|\mathrm{BM}_{\mathrm{vertical}}| + |\mathrm{BM}_{\mathrm{horizontal}}|}{2} \in [0, 1]$$

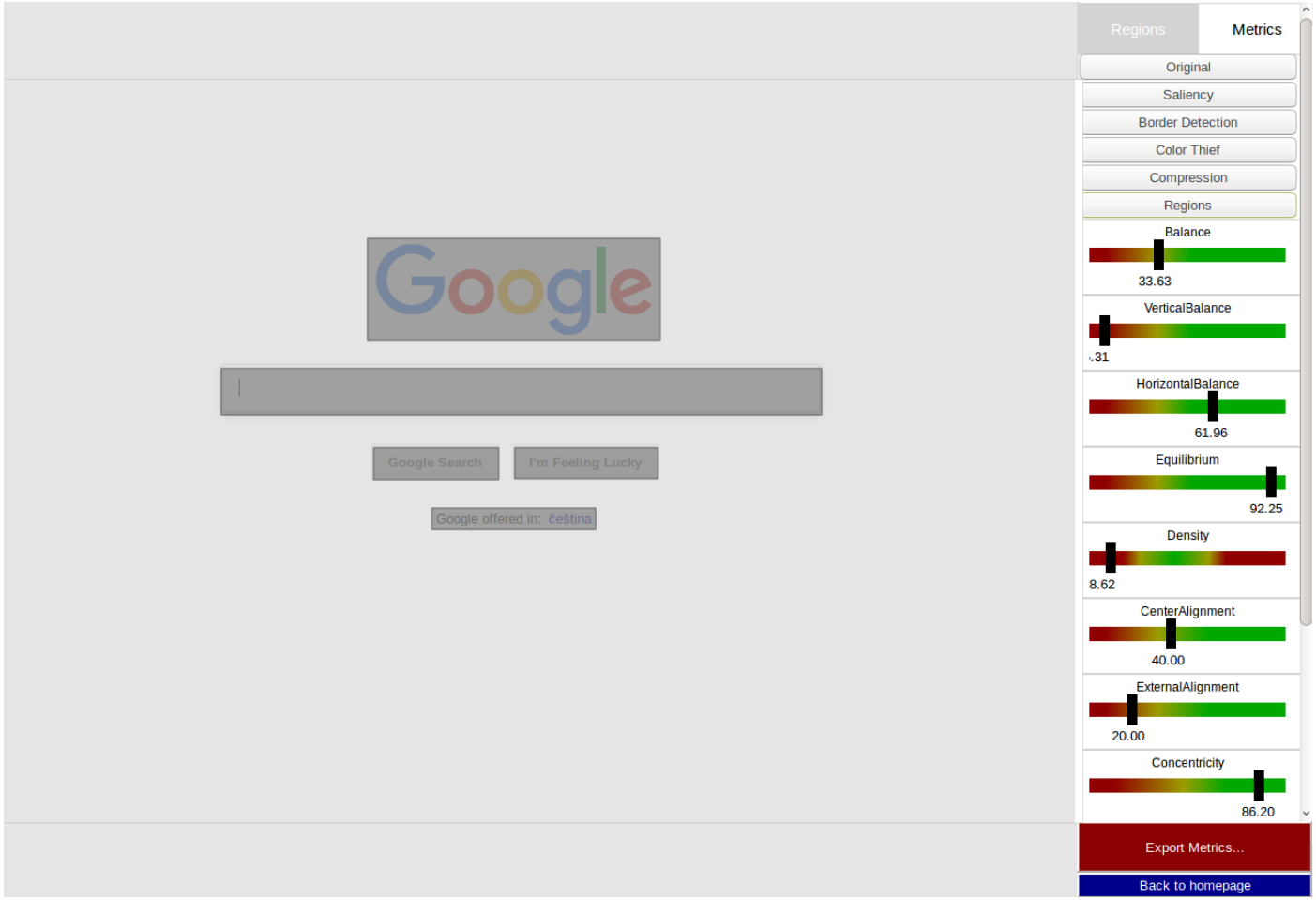
$$\mathrm{BM}_{\mathrm{vertical}} = \frac{w_{\mathrm{L}} - w_{\mathrm{R}}}{\max(|w_{\mathrm{L}}|, |w_{\mathrm{R}}|)}$$

$$\mathrm{BM}_{\mathrm{horizontal}} = \frac{w_{\mathrm{T}} - w_{\mathrm{B}}}{\max(|w_{\mathrm{T}}|, |w_{\mathrm{B}}|)}$$

$$w_j = \sum_{i}^{n_j} a_{ij} d_{ij} \quad j = \mathrm{L}, \mathrm{R}, \mathrm{T}, \mathrm{B}$$

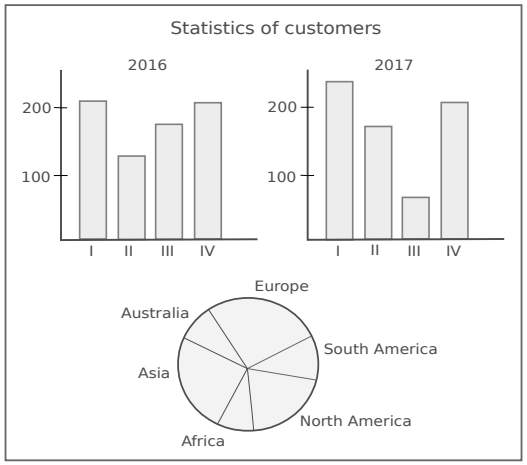
Existing tools

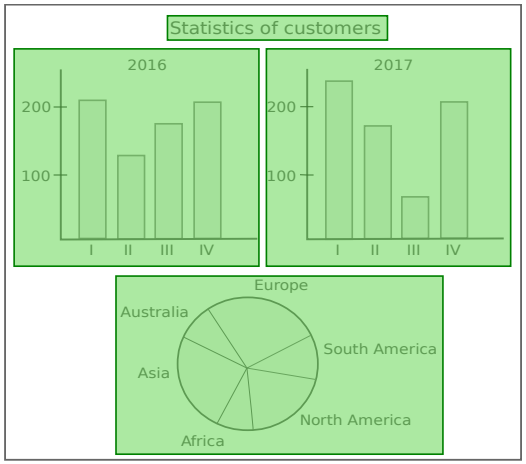
- **QUESTIM: Quality Estimator Tool using Metrics** by **M. Zen and J. Vanderdonckt** (2014). http://questimapp.appspot.com

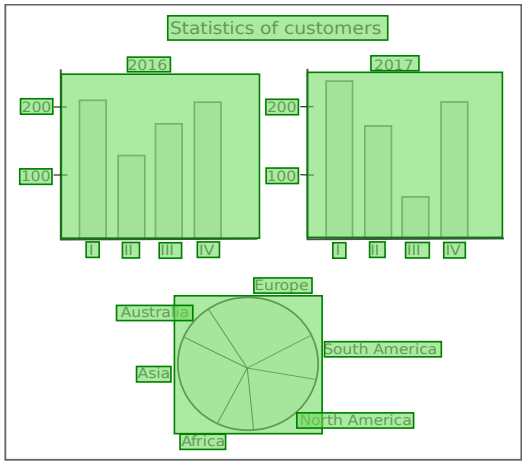


Ambiguity of Object Regions

What are the object regions?







1) manual selection by users

2) parsing the UI source code (HTML+CSS+Javasrcipt, … ?)

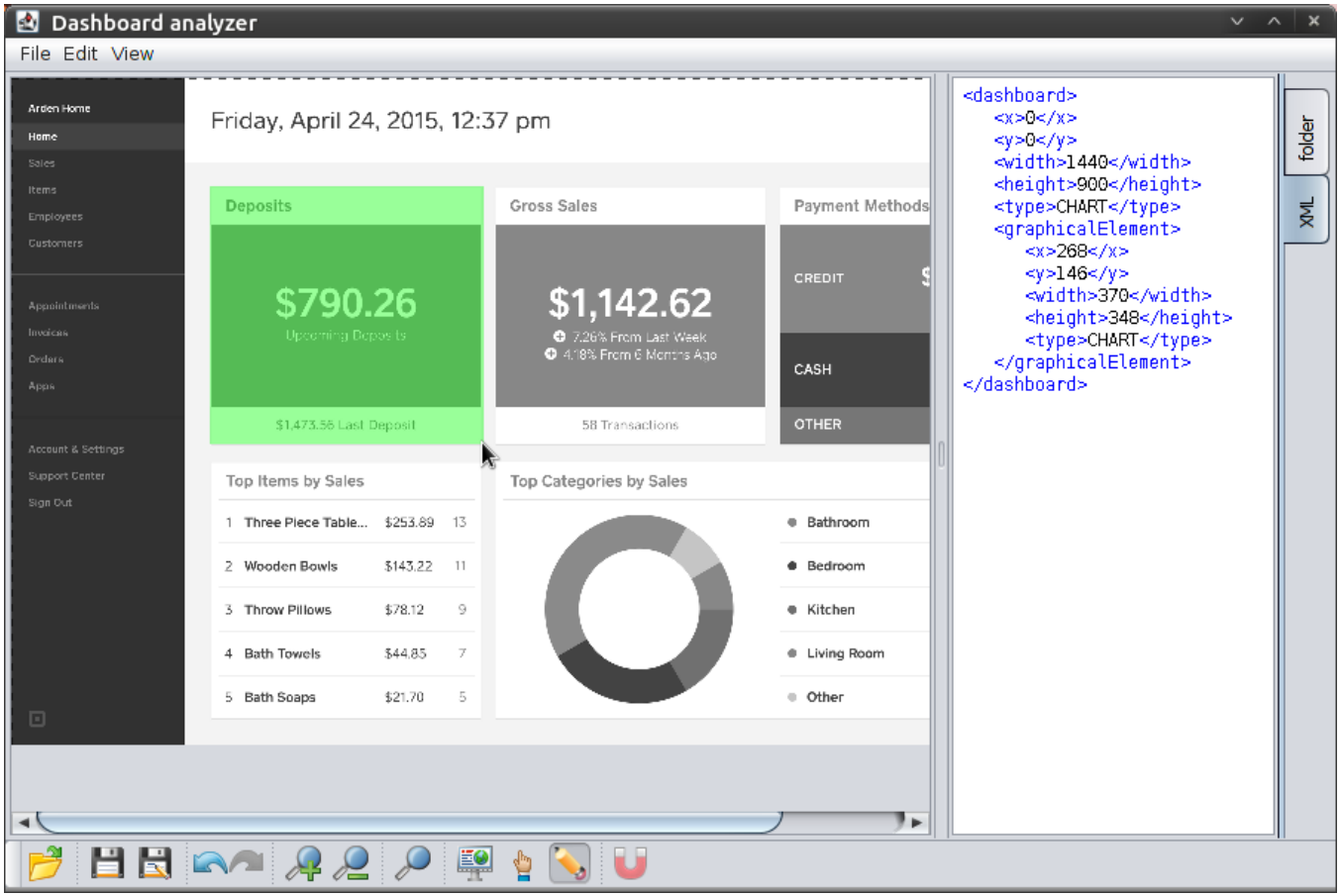
3) segmentation of UI screenshot

Gestalt laws, subjective perception of users,

Study of Visual Perception

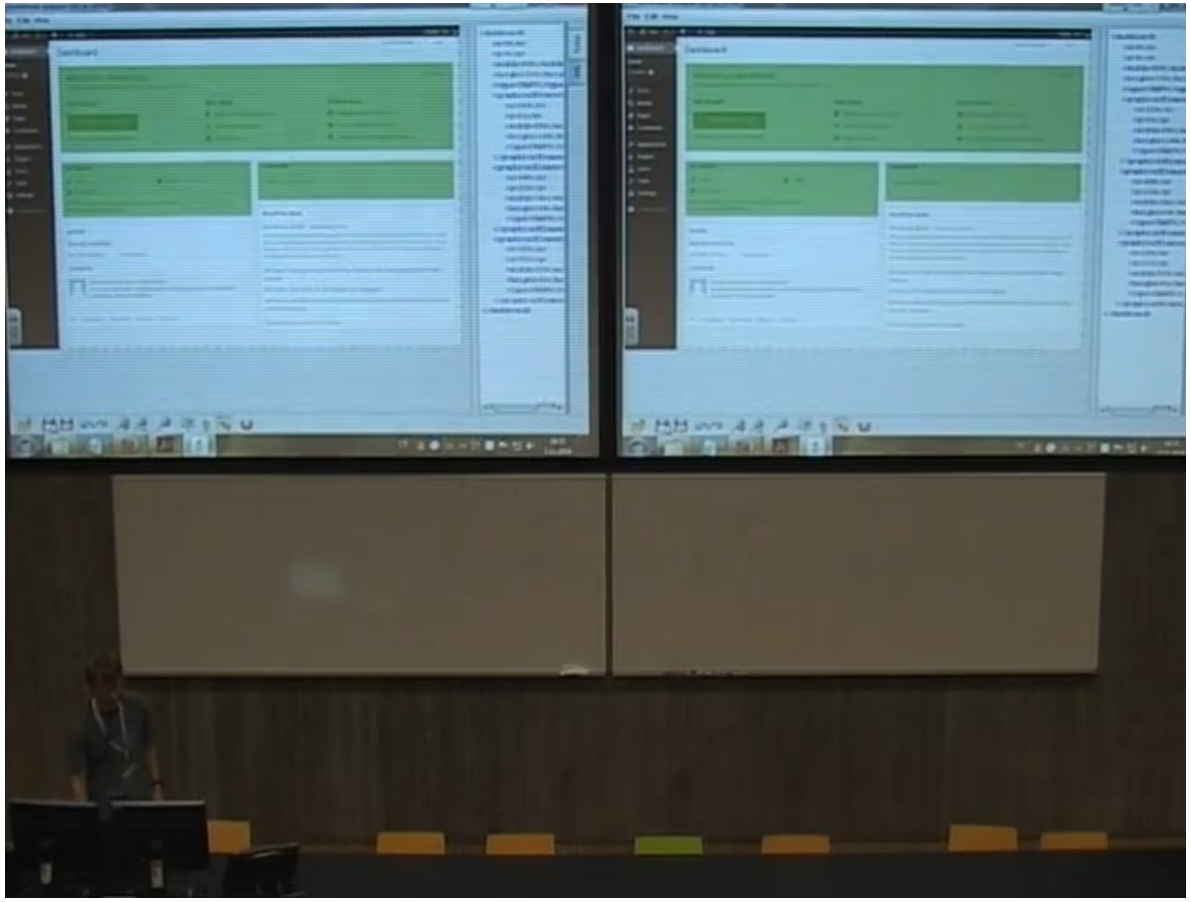
Procedure

- **251** users, **130** dashboards
- every user **20** samples (every dashboard ~ **39** users)
- Java application for selection visually dominant regions



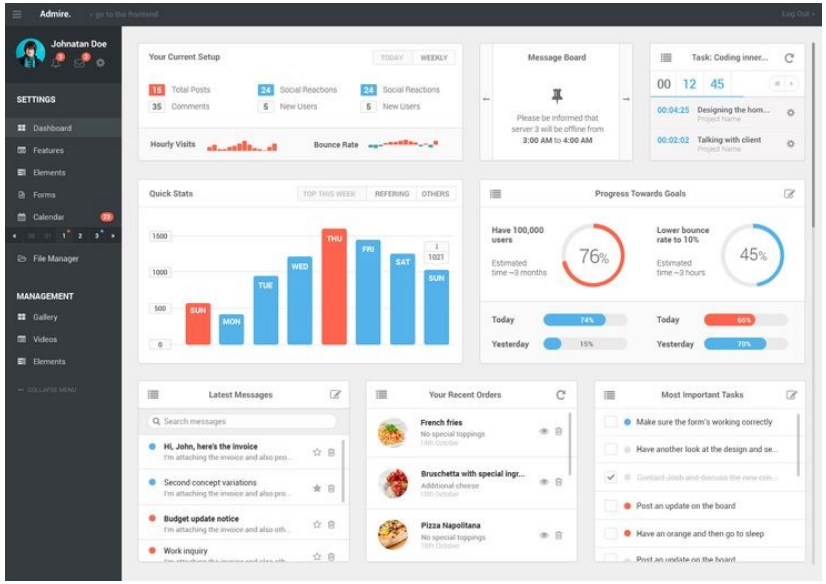
Procedure

- IT students at Brno University of Technology (~20 years old)
- familiarized with the software, dashboards, Gestalt laws and the task (2 hours lecture)



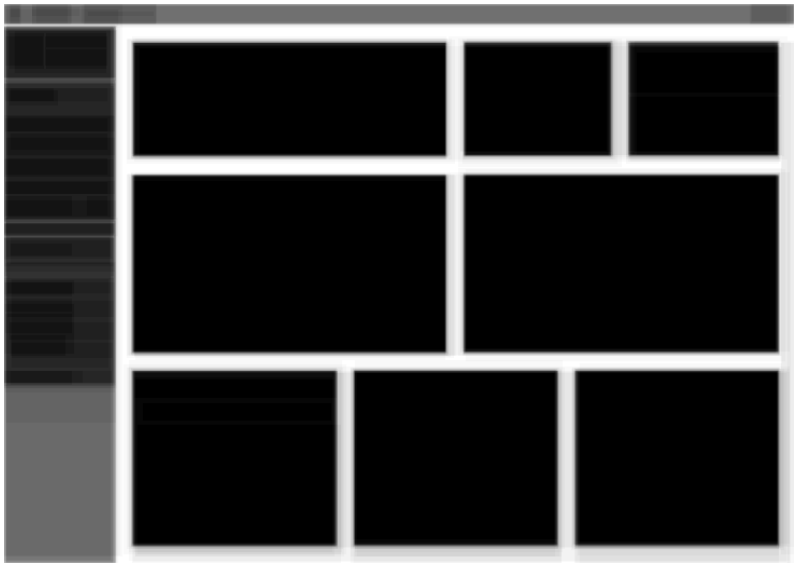
1.

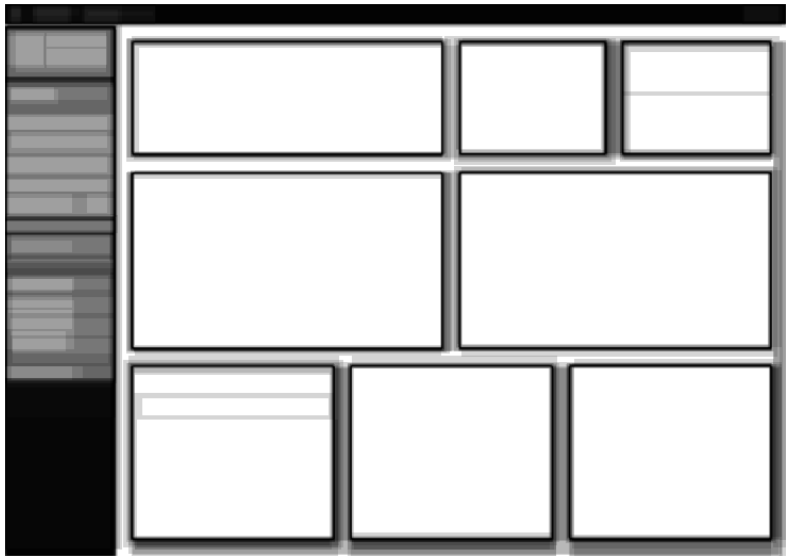
n users



2. Average description of regions

(Heatmap)

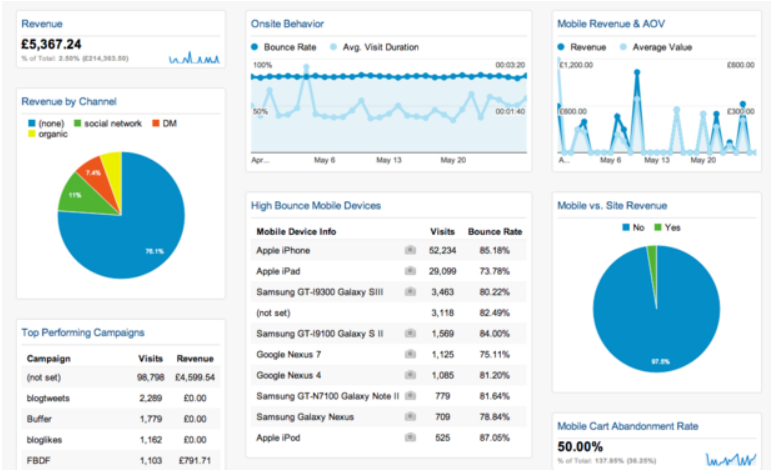




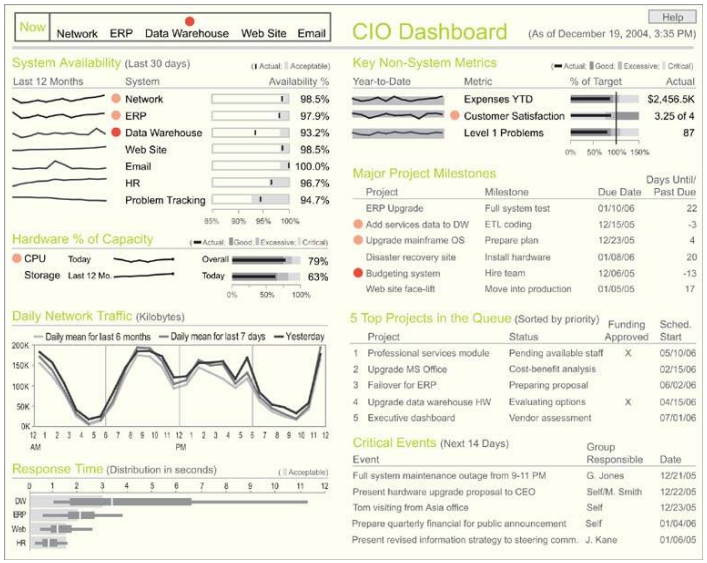
3. Perception ambiguity

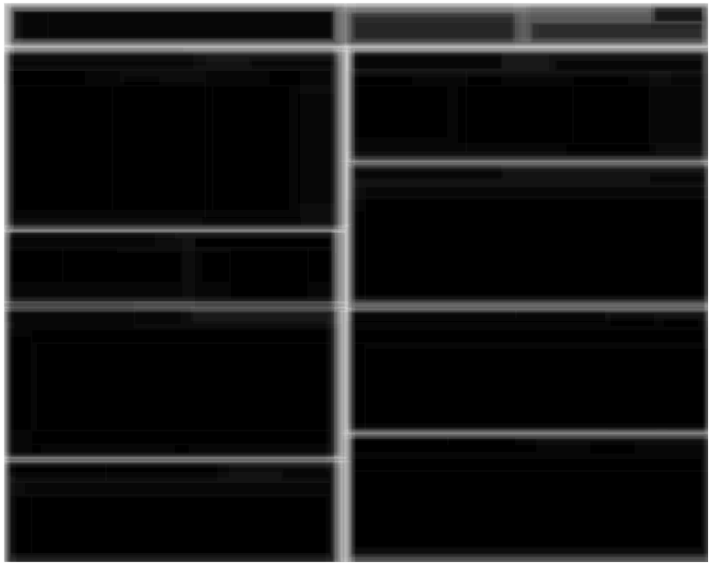
(Binary Entropy)

1. Gestalt law of Enclosure



2. Gestalt law of Proximity and Closure

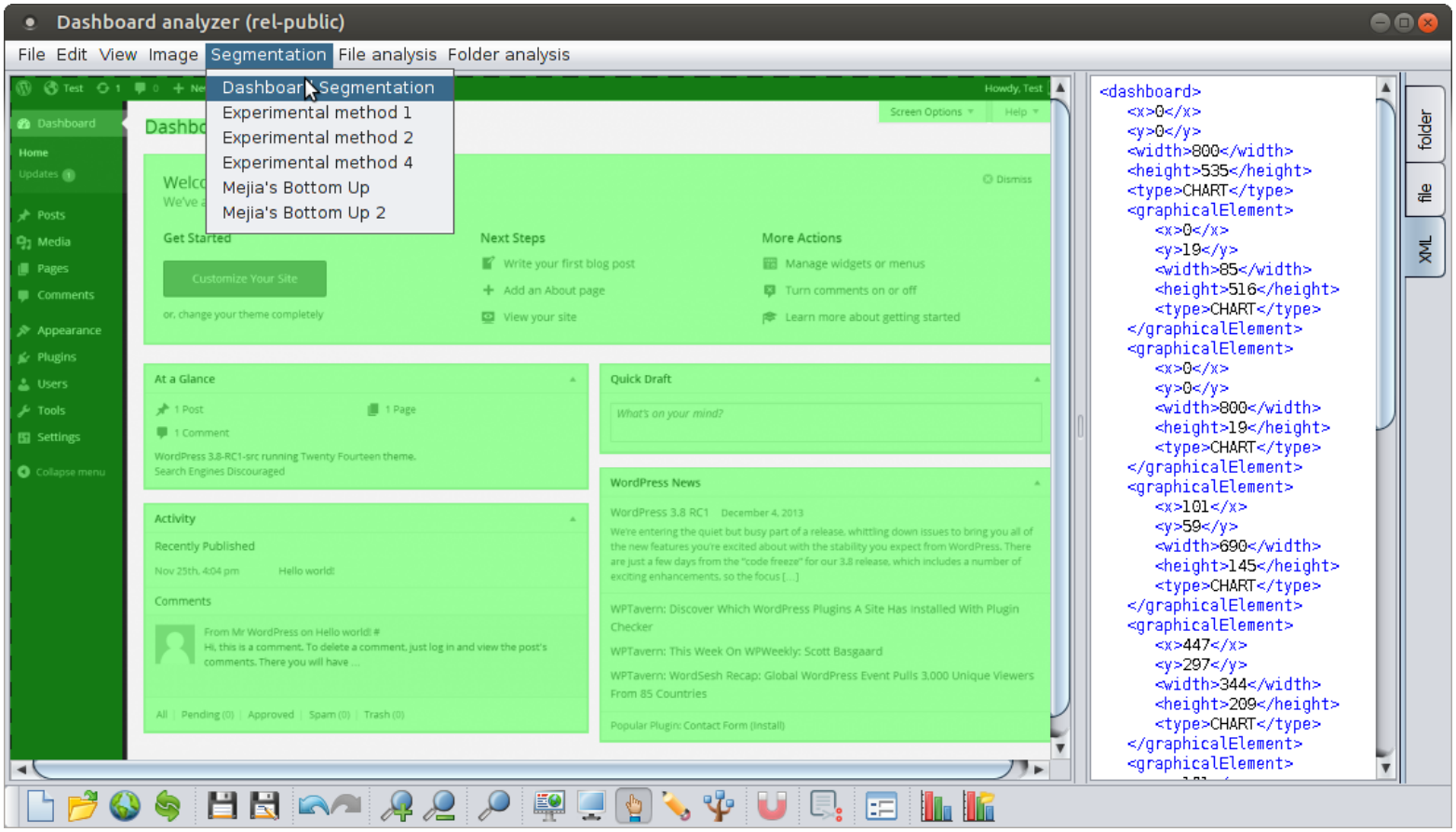




Method
for Segmentation of Dashboards

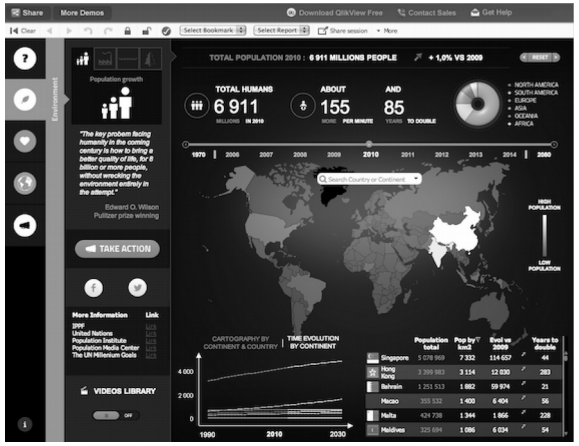
Dashboard Analyzer

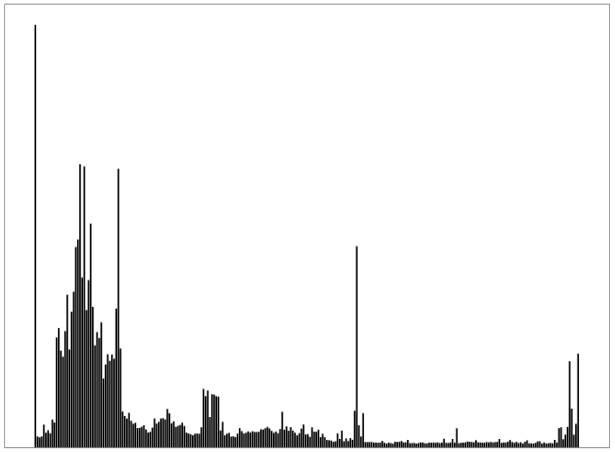
- Method integrated in **Dashboard Analyzer**
- fit.vut.cz/~ihynek/dashboards/visigrapp-2019
- **github.com/Jirka/dash**



Phase 1/7: Image Preprocessing

1) 24-bit RGB → 8-bit Grayscale color space (256 colors)

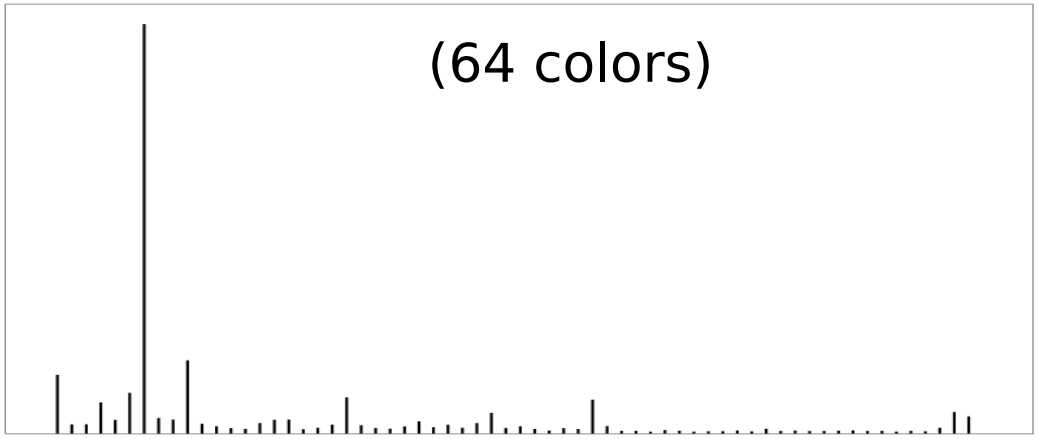




2) Remove color gradients

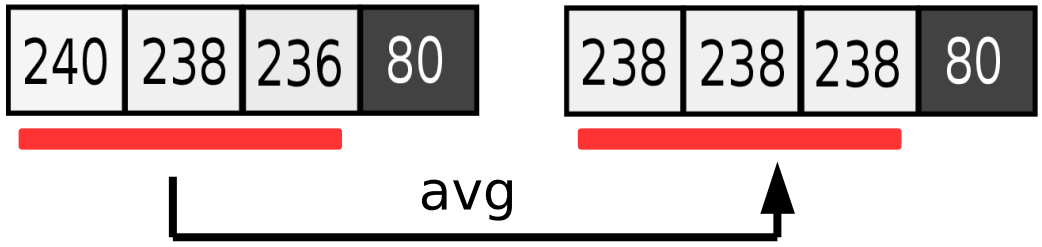
3) Posterization to [4-6]-bit Grayscale color space

(64 colors)

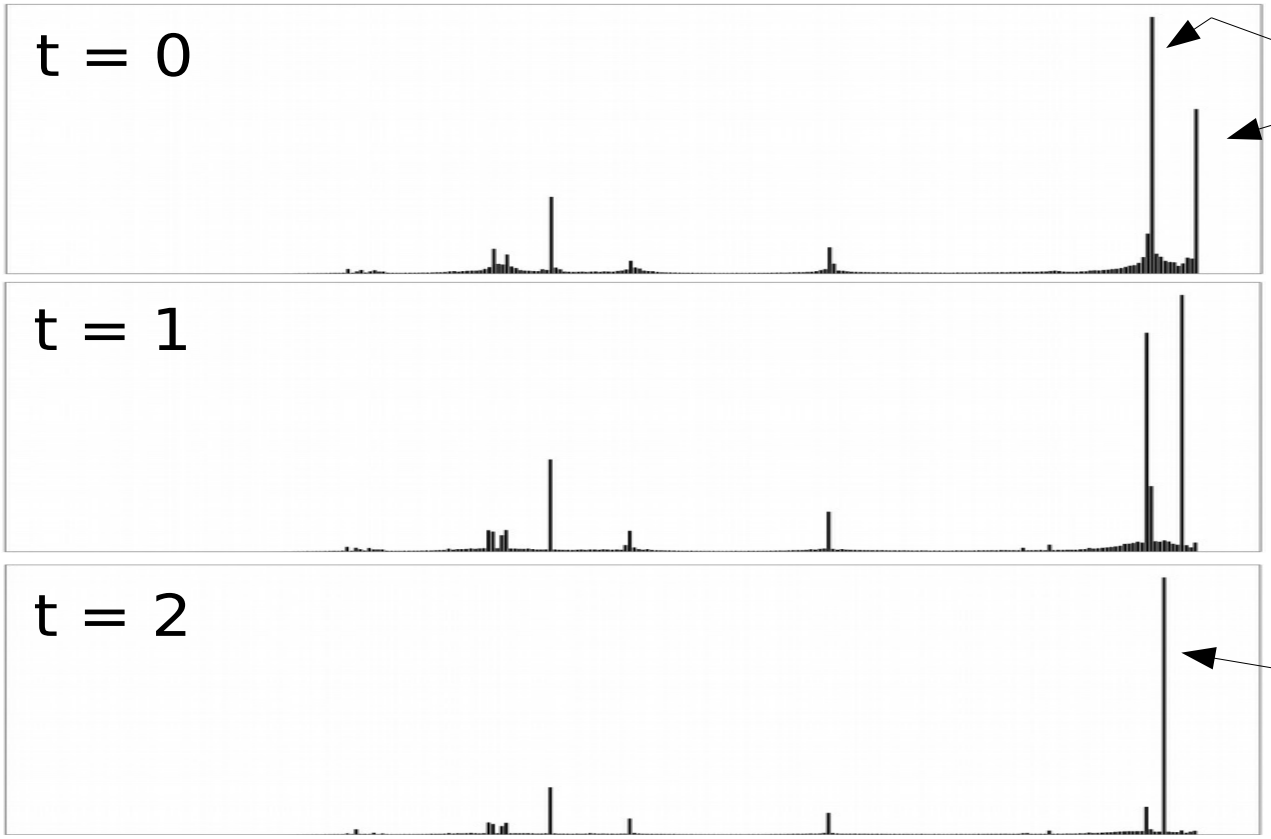


Phase 1/7: Image Preprocessing

Searching clr. gradients:
flood-fill-based algorithm



Selecting threshold:

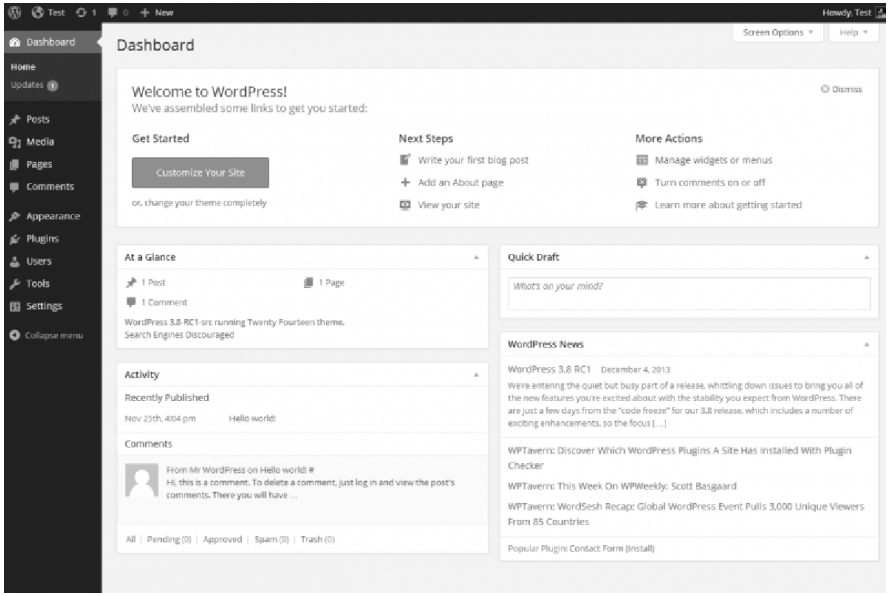


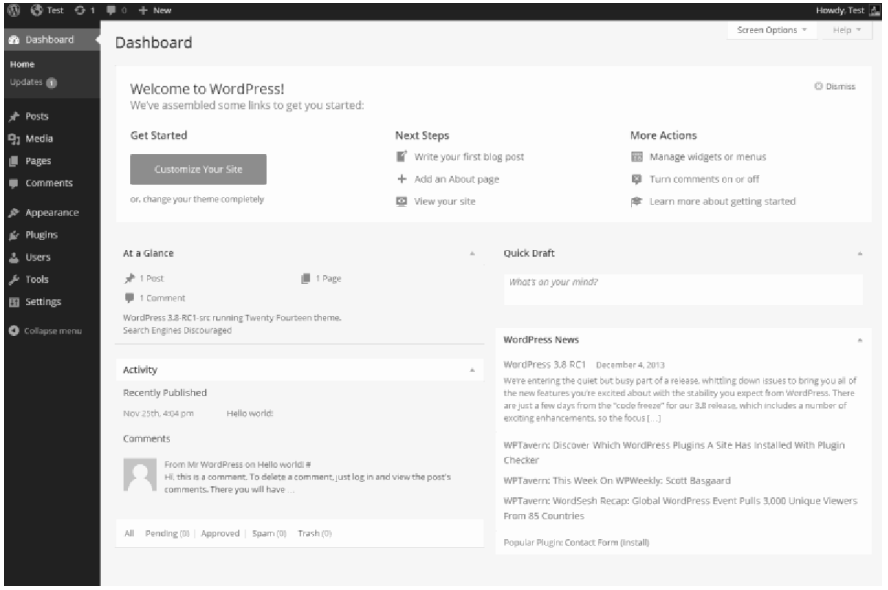
2 dominant colors

2 dominant colors

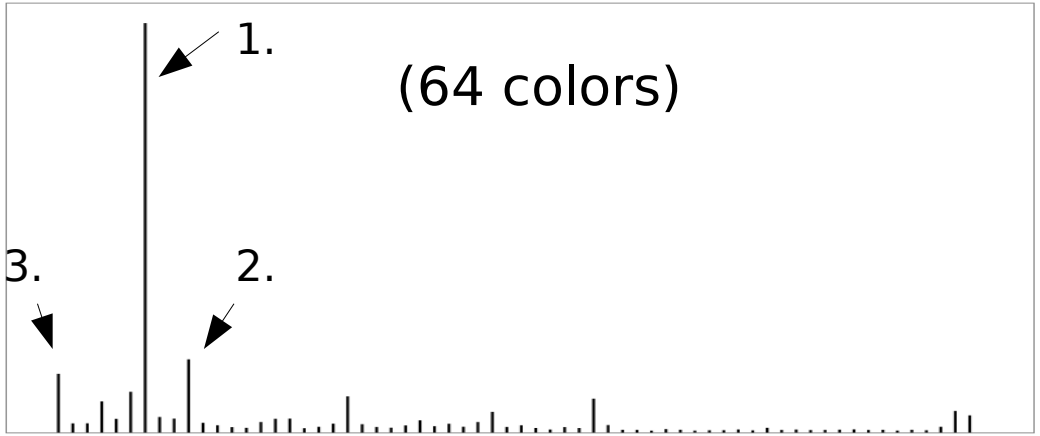
1 dominant colors**!!!**

Phase 1/7: Image Preprocessing

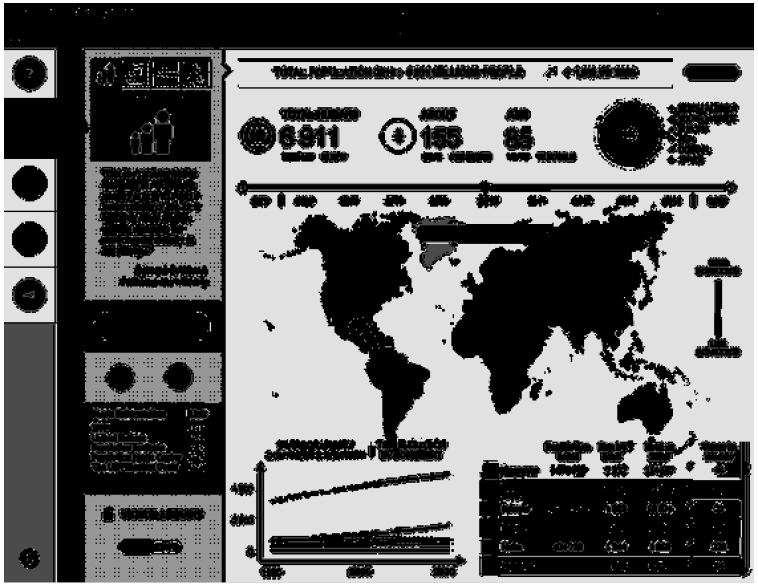




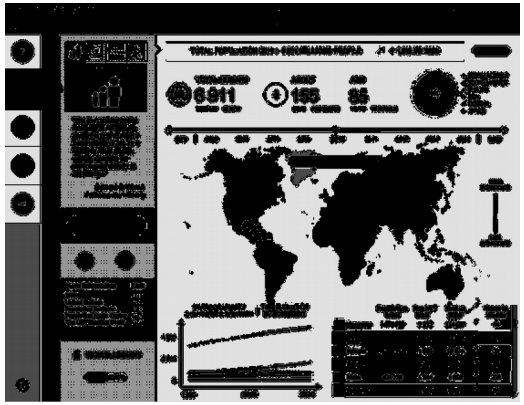
Phase 2/7: Selection of Color Layers



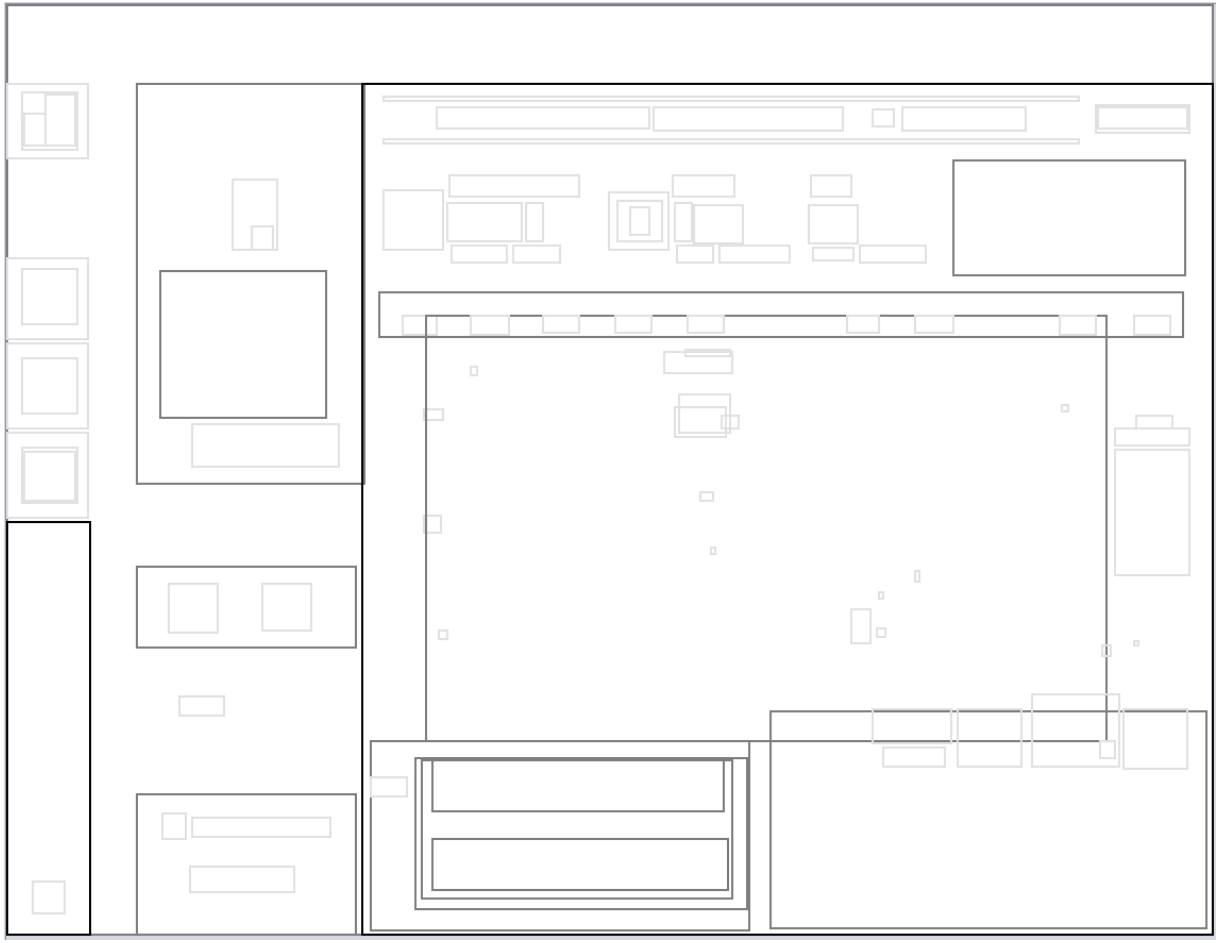
Select [2-10] dominant colors:



Phase 3/7: Detection of Page Primitives



Find boundaries of the “same-color” pixel areas (*Gestalt law of closure*):

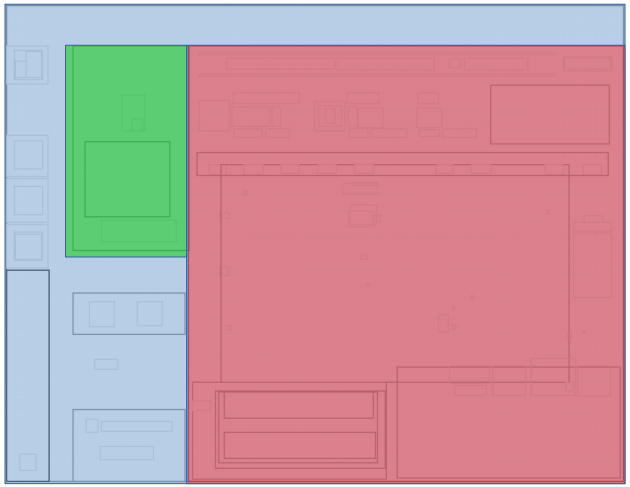


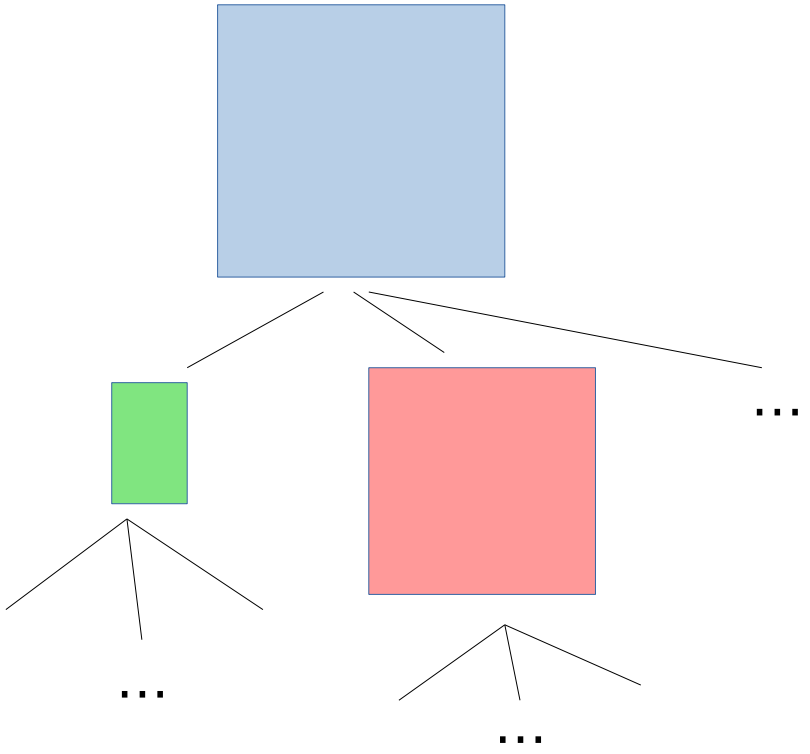
Using
Flood-fill-based
Algorithm

Remember
- color
- share of pixels

in boundary

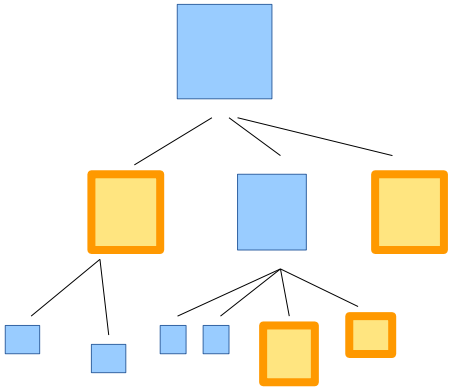
Building the tree of regions:






```
Process r1:
    if r1 is in r2:
        attach r1 to r2
    if r2 is in r1:
        attach r1 to r2.parent
        reattach r2 to r1
    if r1 intersects r2 or:
        attach r1 to r2. parent
```

Phase 5/7: Top-down Layout Analysis



Searching dominant regions

Gestalt law of enclosure

1. sidebars
2. size of regions
   - ~0.3–0.7 of area
   - has tiny children
   - ...
3. type of regions
   - background color
   - ...

Phase 6/7: Analysis of Overlapping Regions

Regions within regions

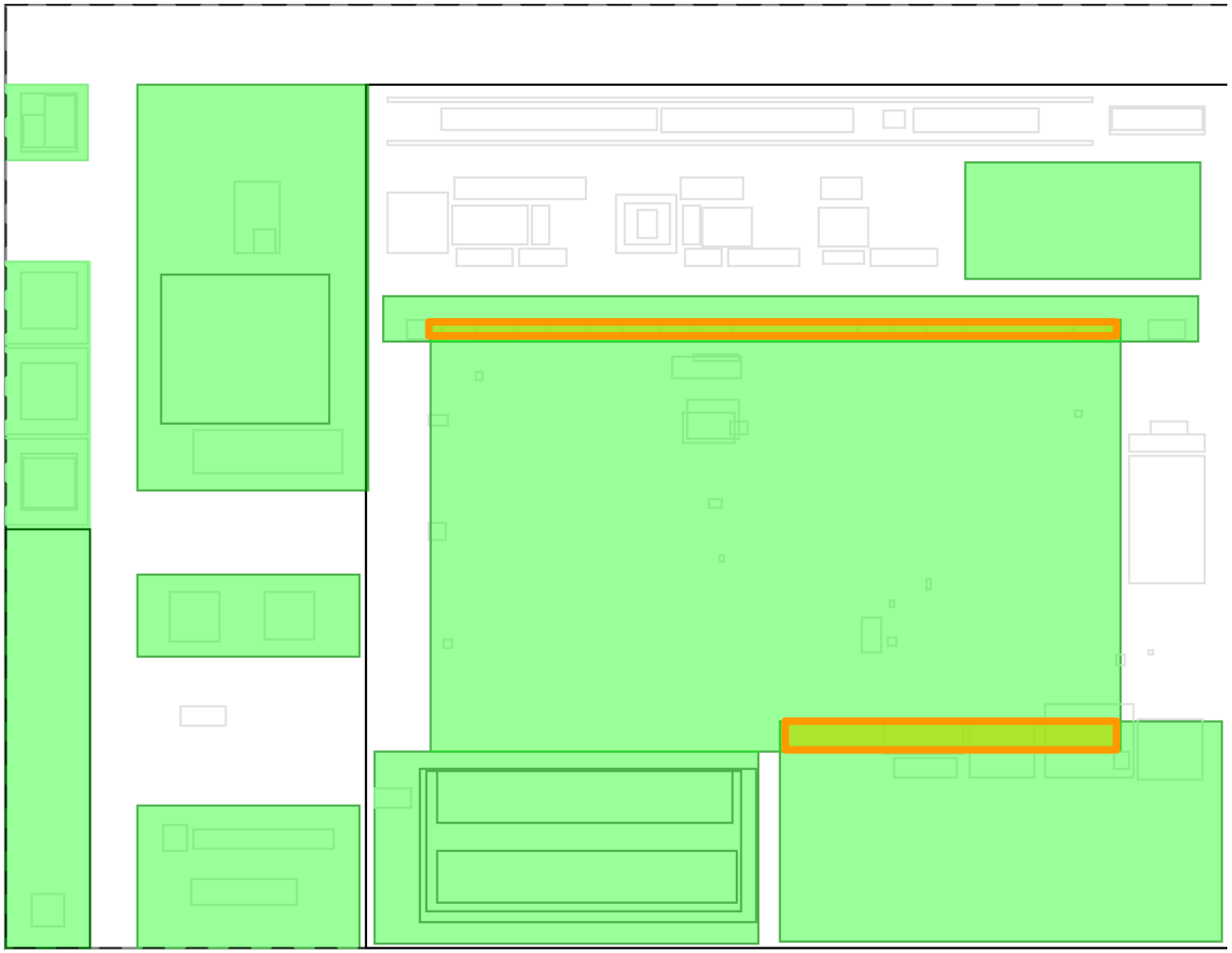
→ remove smaller

>0.33 of regions area, ...

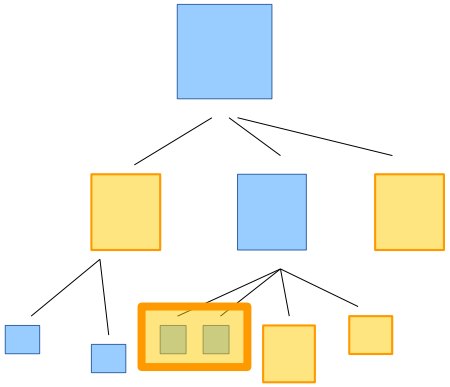
→ join regions

Else ignore

Analysis of regions intersections

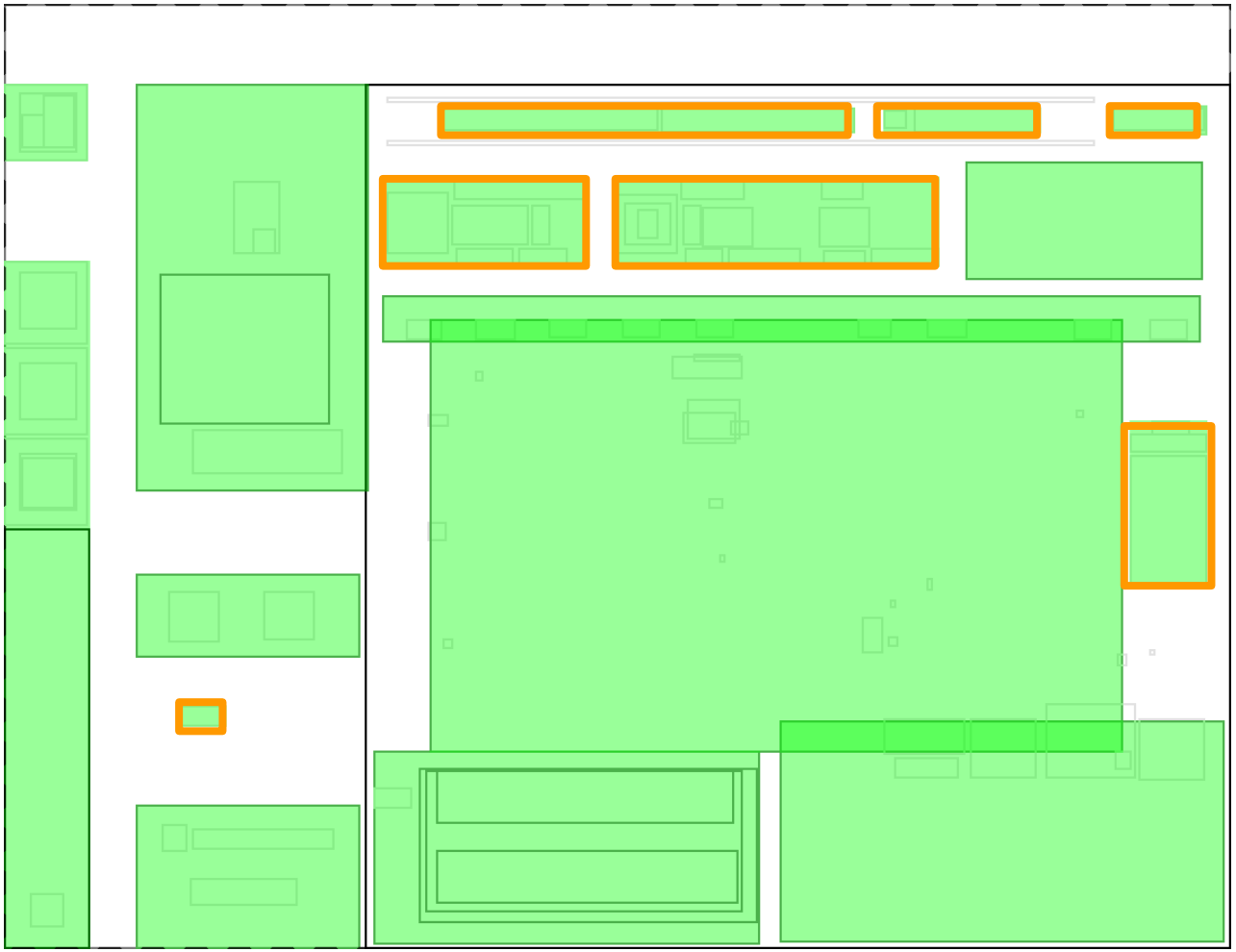


Phase 7/7: Bottom-Up Layout Analysis



Analysis of remaining area

Gestalt law of proximity



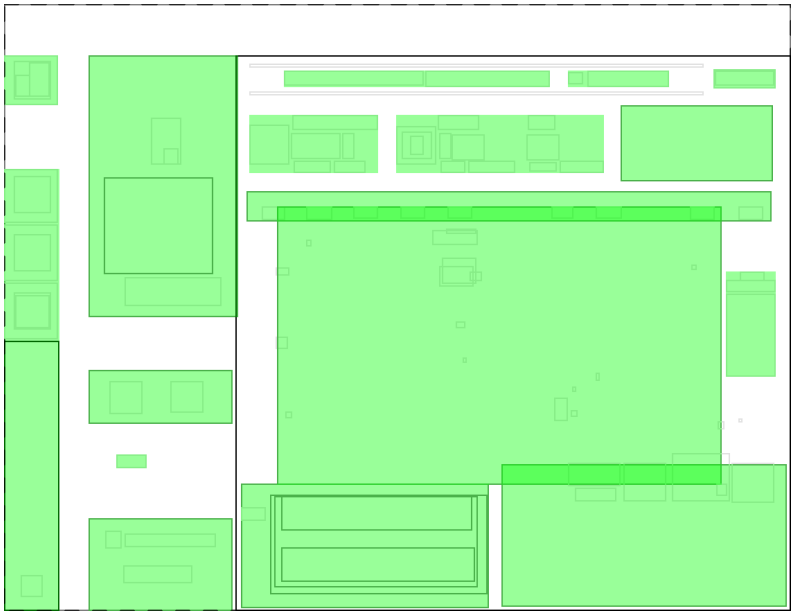
- grouping of remaining regions
- avoid new intersections

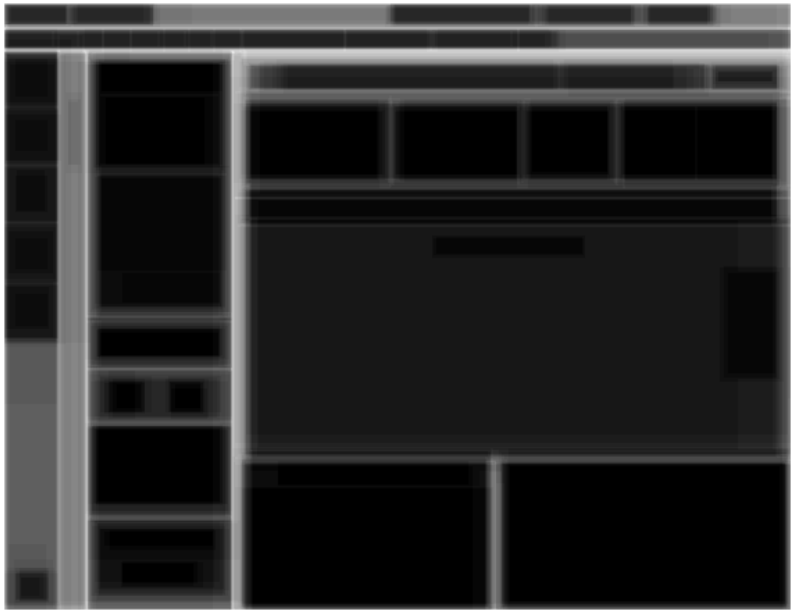
Evaluation

Visual Analysis

alg.

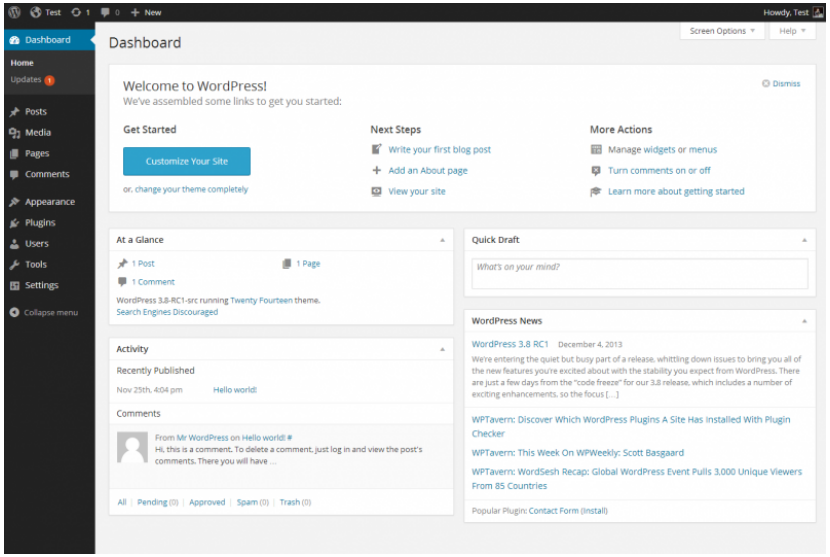
avg.



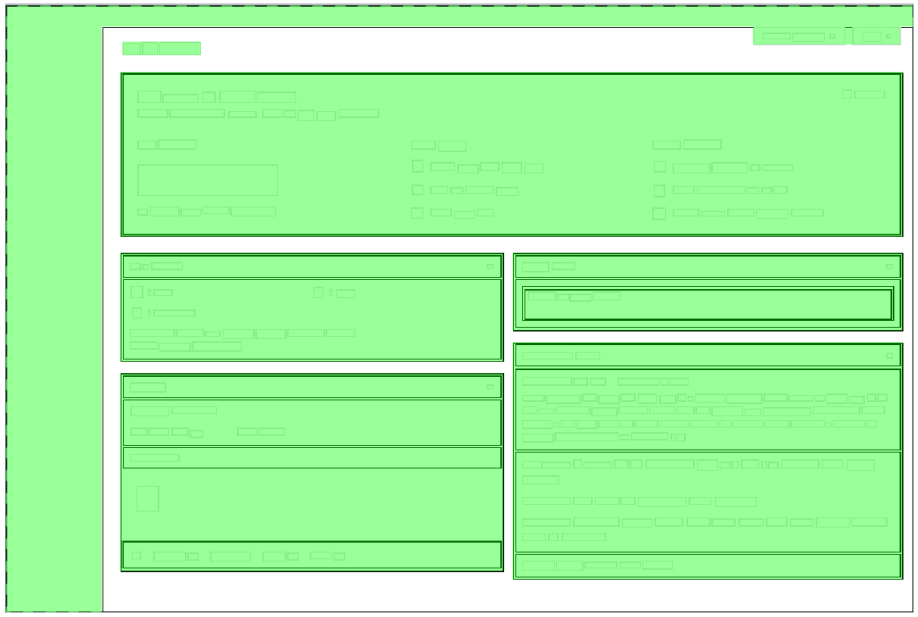


Visual Analysis

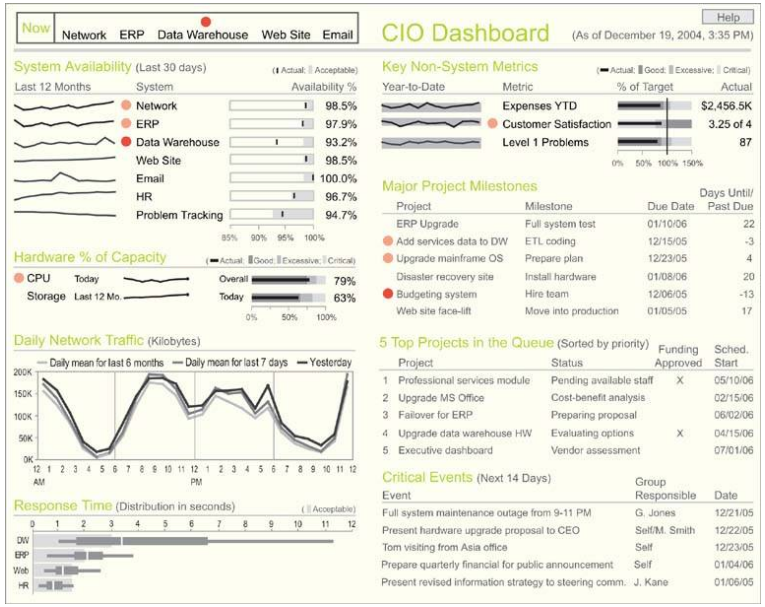
alg.



avg.

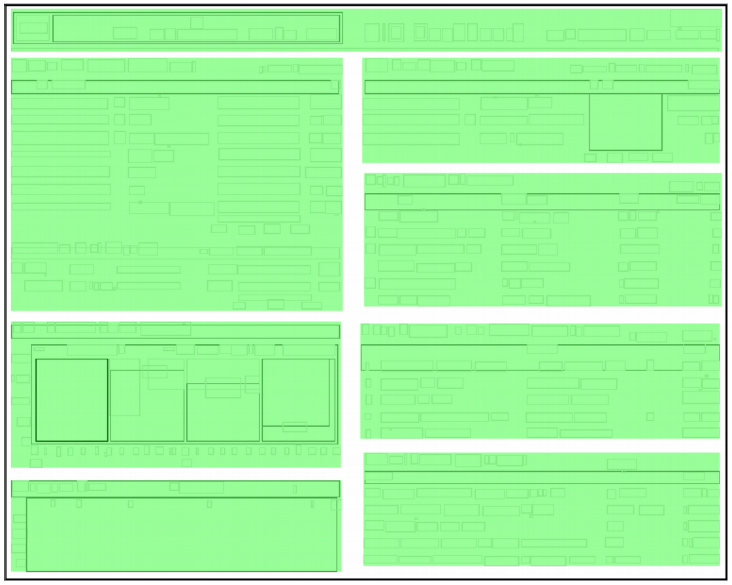


Visual Analysis



alg.

avg.



Comparison with the Users' Perception

| avg. - **user** *u* | | avg. - **alg**. |

For one pixel:

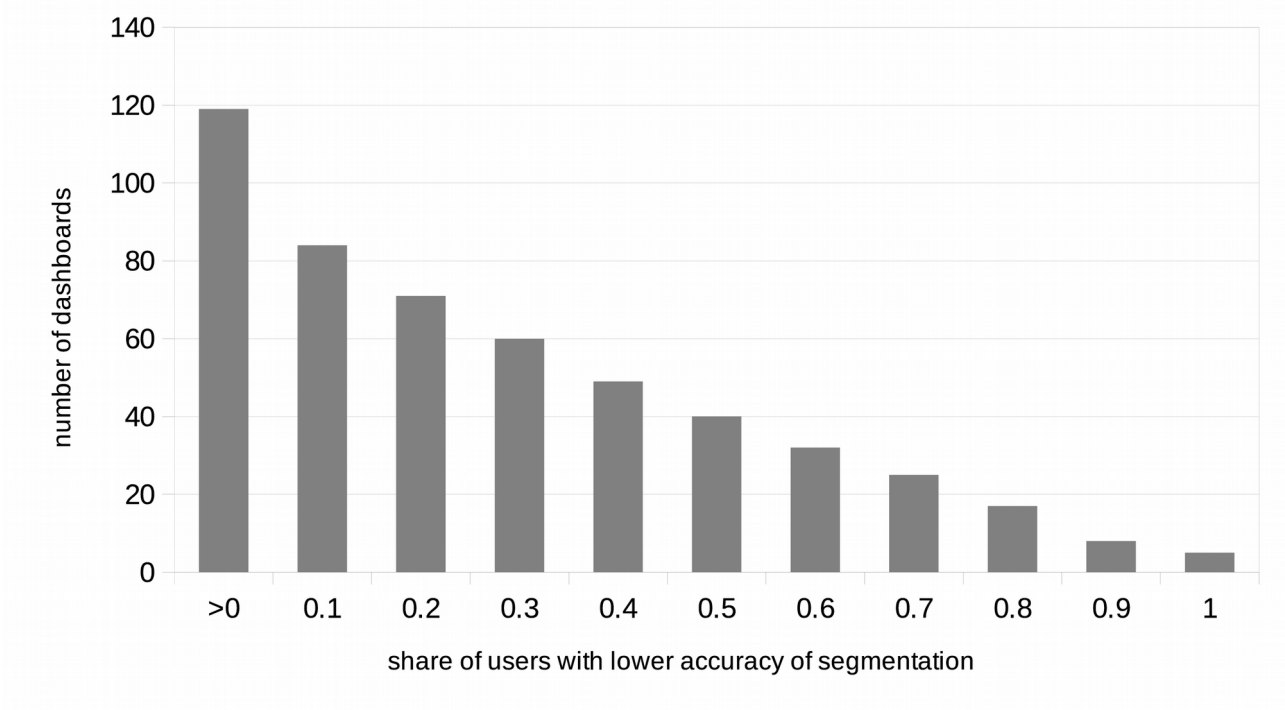
$$\delta_i^{(u)} = | \, p_i - v_i^{(u)} \, |$$

$$\delta_i^{(\mathrm{alg})} = | \, p_i - v_i^{(\mathrm{alg})} \, |$$

For all *n* pixel:

$$\delta_d^{(u)} = \frac{\sum_{i=0}^{n} \delta_i^{(u)}}{n}$$

$$\delta_d^{(\mathrm{alg})} = \frac{\sum_{i=0}^{n} \delta_i^{(\mathrm{alg})}}{n}$$



119 of 130 dashboards segmented *"better"* ($\delta_d^{(\mathrm{alg})} \leq \delta_d^{(u)}$) than at least one user

We measured values BM $\in$ <0,1> for:

Users (on average)	**alg.**	**| Users – alg. |**
$\mu(BM_{d1}^{(u)})$ $\sigma(BM_{d1}^{(u)})$	$BM_{d1}^{(alg)}$	$\delta_{d1}^{(alg,users)}$
$\mu(BM_{d2}^{(u)})$ $\sigma(BM_{d2}^{(u)})$	$BM_{d2}^{(alg)}$	$\delta_{d2}^{(alg,users)}$
...	...	...
$\mu(BM_{d130}^{(u)})$ $\sigma(BM_{d1}^{(u)})$	$BM_{d130}^{(alg)}$	$\delta_{d130}^{(alg,users)}$

$\mu(\sigma(BM^{(u)})) = 0.119$

$\mu(\delta^{(alg,users)}) = 0.1$
($\sigma = 0.086$)

Summary

Limitations

- trained for 130 dashboard samples
- based on perception of selected users
- problems with lower resolutions of images

Future work

- further evaluations should be done
- improvement of image preprocessing
- improvements of heuristics

References

- fit.vut.cz/~ihynek/dashboards/visigrapp-2019
- **github.com/Jirka/dash**

- Hynek, J. and Hruška, T. (2018). Application of object-based metrics for recognition of well-designed dashboards. International Journal of Human–Computer Interaction, pages 1–13, Taylor & Francis.

Thank You For Your Attention !