CO3091 - Computational Intelligence and Software Engineering

Lecture 13

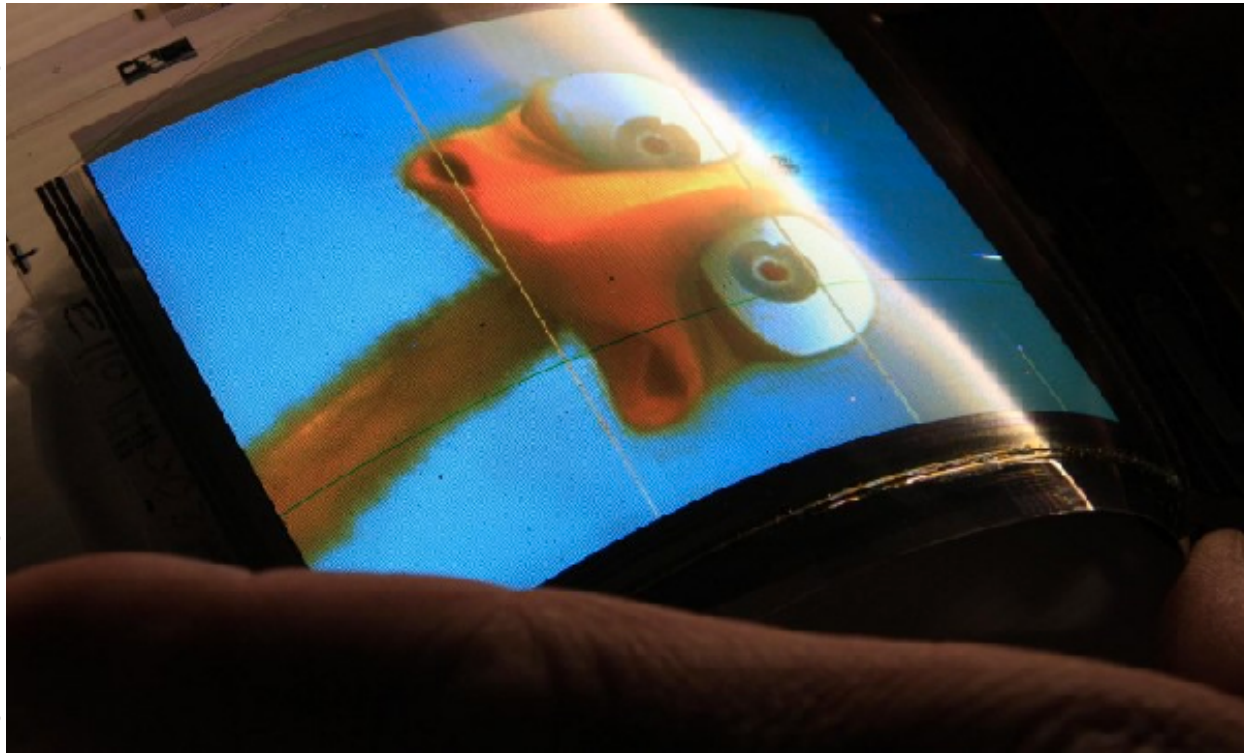

Image from: http://cdn.slashgear.com/wp-content/uploads/2013/04/flexible_oled-820x420.jpg

Energy Consumption Optimisation

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Overview

- Mobile apps and OLED screens
- Energy consumption of OLED screens as an optimisation problem
- A multi-objective evolutionary algorithm for this problem

Mobile Apps

- Mobile apps have widespread use.
- Mobile apps consume energy (battery).
- Studies show that battery consumption is one of the key factors considered by users when choosing a mobile app.
- In order to reduce energy consumption, one can concentrate on how mobile apps use energy-greedy hardware components, e.g., GPS, Wi-Fi, or the screen.

Screens…

Old-Style Cathode-Ray Tubes (CRTs) TVs

Image from: http://robonwriting.com/wp-content/uploads/2013/04/OldTV.jpg

The biggest ones were about 30–60cm (1–2ft) deep and almost too heavy to lift by yourself.

1940s TVs

Image from: http://3.bp.blogspot.com/-vkaOVPMiqk8/VPcydzeDtEI/AAAAAAAABeg/hUutzQmatK8/s1600/TVeurope_TV_Baird_T-18_1938.JPG

Liquid Crystal Display (LCD) TVs

Image from: http://web.tradekorea.com/upload_file2/product/000/P00241000/cbe9caa5_b5a7181c_5fd3_42aa_bee2_1e29eb232e1a.jpg

LED-backlit LCD TV (LED TVs)

Image from: http://cdn.ndtv.com/tech/intex_led_tv_4300_fhd.jpg

Organic LED (OLED) TVs

Image from: http://icdn2.digitaltrends.com/image/lg-65ec9700-lined-up-970x647-c.jpg

OLED Mobiles

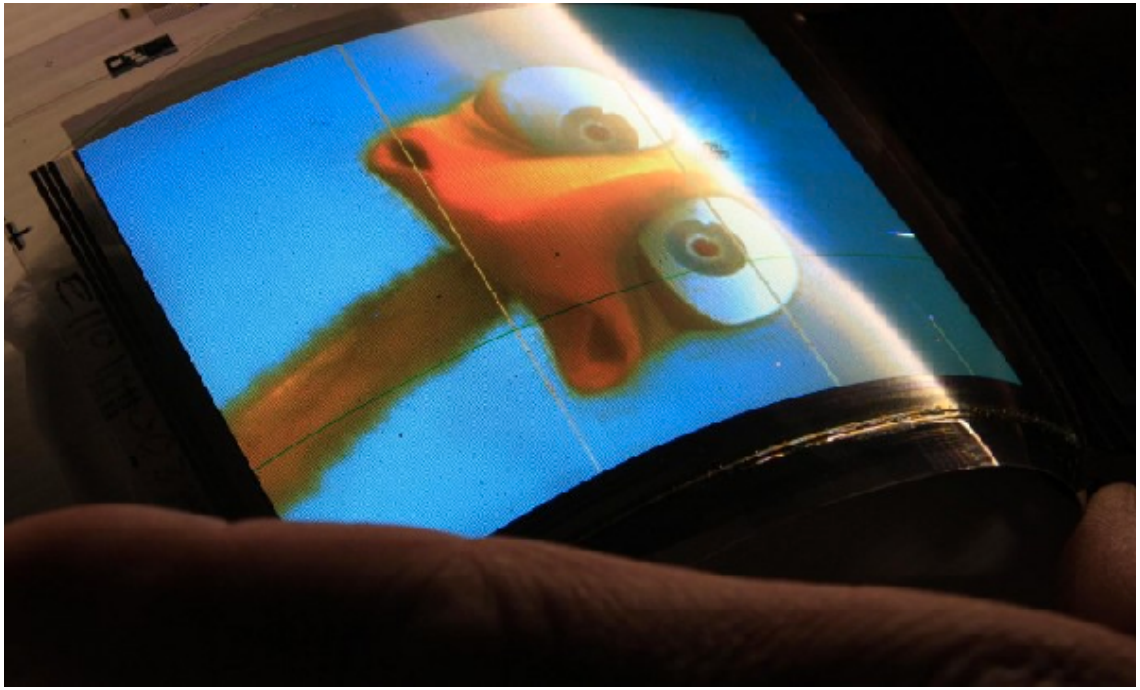

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Image from: http://www.oled-info.com/files/Samsung-Galaxy-Round-img_assist-401x226.jpg

LCD vs OLED

- LCD displays: energy consumption is constant independent of the colours being displayed.
- OLED displays: energy consumption depends on the colours being displayed.

LCD vs OLED

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- OLED displays: energy consumption depends on the colours being displayed.

We can reduce energy consumption by choosing an appropriate GUI colour composition!

OLED Energy Consumption Optimisation Problem

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Optimisation Algorithm

- NSGA-II has been used for this problem.
- The design for the algorithm will be explained at the same time as more details on the problem formulation are given.

Problem Formulation

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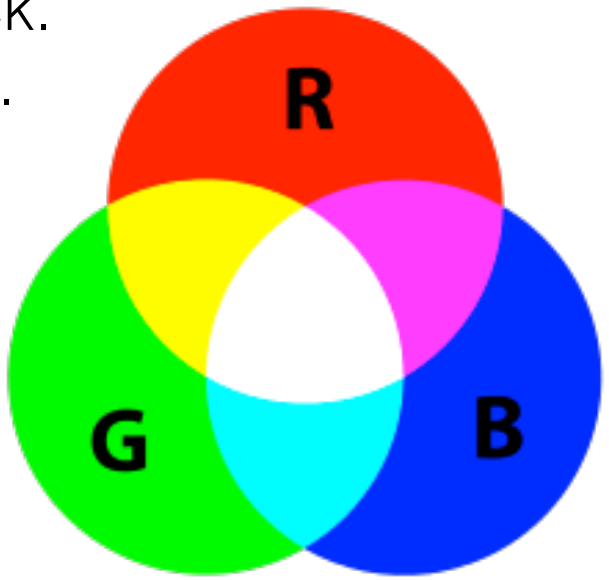
RGB Colour Scheme

- Produces colours by combining the primary (component) colours red, green and blue.
- Used to represent and display images in electronic systems.
- Each of the primary colours has a level of intensity.
  - Zero intensity for all colours gives black.
  - Full intensity for all colours gives white.
- Different numeric representations, e.g.:
  - Digital 8-bit per channel
    $(\{0,1\}^8,\{0,1\}^8,\{0,1\}^8)$
    (0-255, 0-255, 0-255)



http://www.rapidtables.com/web/color/RGB_Color.htm

Image from: https://upload.wikimedia.org/wikipedia/commons/thumb/c/c2/AdditiveColor.svg/220px-AdditiveColor.svg.png

Bag-Of-Colour-Pixels (BOCP)

Image from: http://paper-and-string.co.uk/category/43796-15-cm-single-colour-bags.aspx

Bag-Of-Colour-Pixels (BOCP)

- When optimising power consumption, we can restrict the colours of the pixels.
  - Pixels with the same colour in the original GUI design should have the same colour in the optimised GUI design.

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  - Pixels with the same colour in the original GUI design should have the same colour in the optimised GUI design.
- Bag-of-colour-pixels (BOCP): collection of pixels with the same colour.
  - We have one BOCP for each different colour in the GUI.
  - Android View Server can be used to collect this information.

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  - We have one BOCP for each different colour in the GUI.
  - Android View Server can be used to collect this information.
- We can exclude pixels from images to avoid changing the colours of these.

Representation

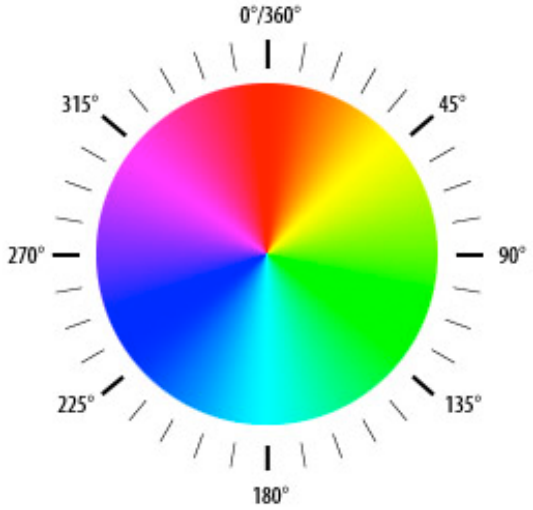
- Vector of genes, where each gene defines the colour of a BOCP.
- If we have N different colours in the original design, we will have N genes.

So, pixels with the same colour in the original design will have the same colour in the optimised design.

Initial Population

- Colour palette is used to create initial population to help creating appealing colour combinations.
  - The colour of each BOCP from the original design.
  - White.
  - Black.
  - Equidistant colour harmonies.
  - Equidistant monochromatic colours.

Hue Saturation Brightness Value (HSB/HLS) colour model



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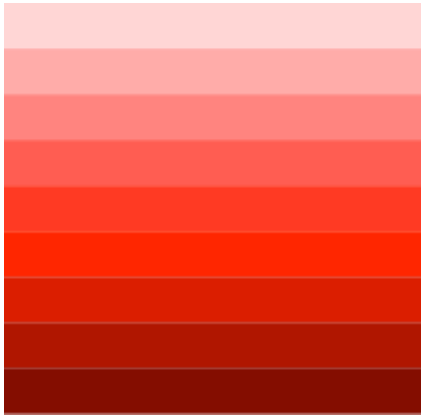

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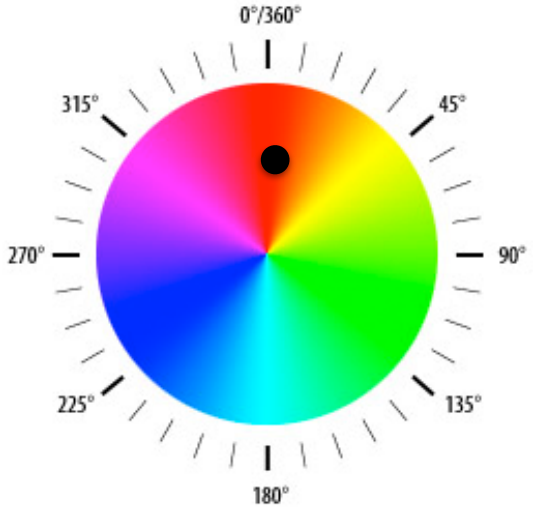

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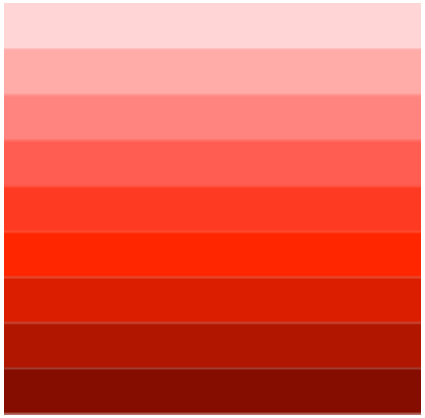

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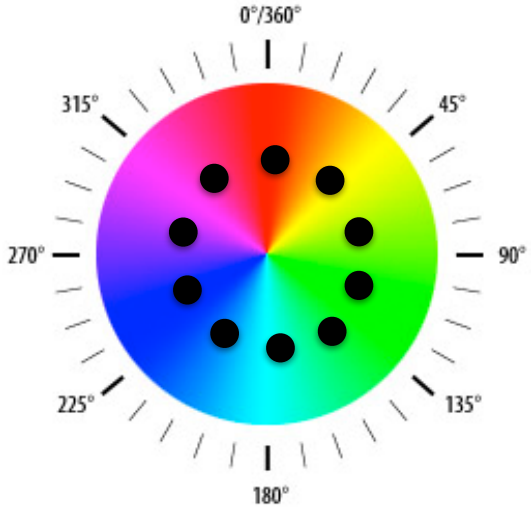

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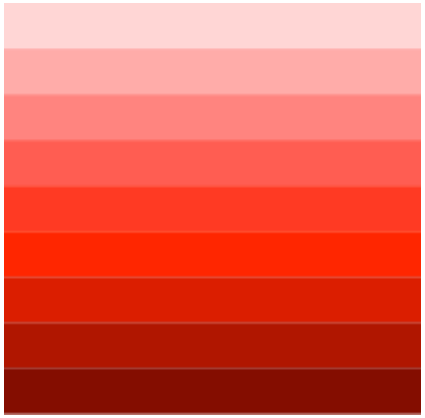

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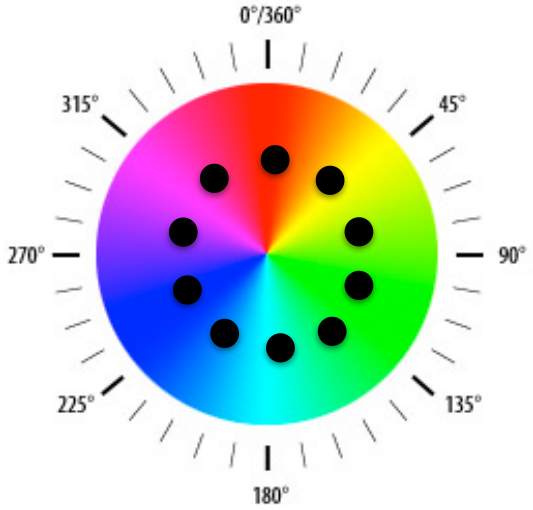

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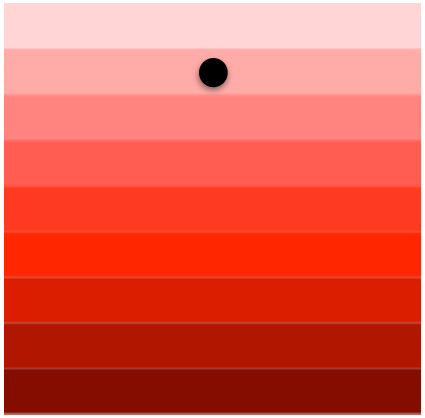

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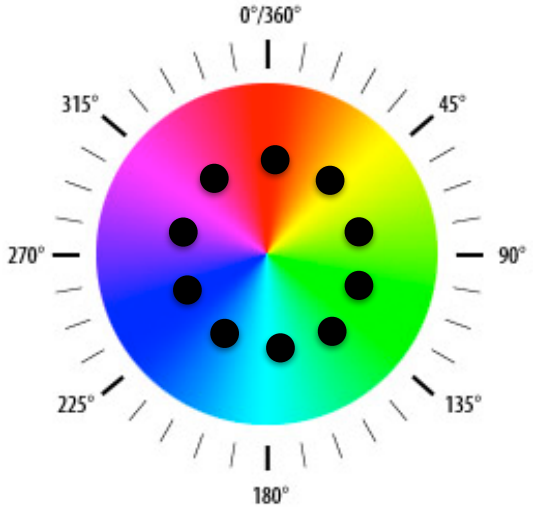

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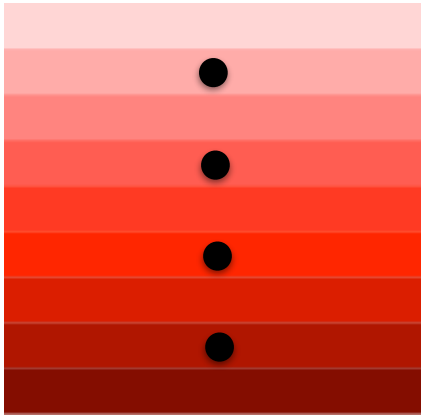

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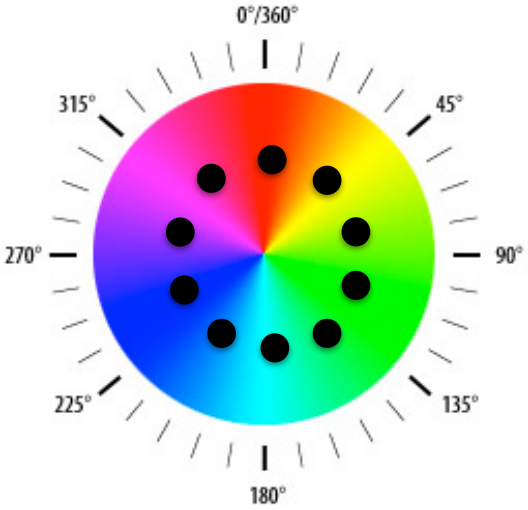
Hue **Saturation** **Brightness** Value (HSB/HLS) colour model



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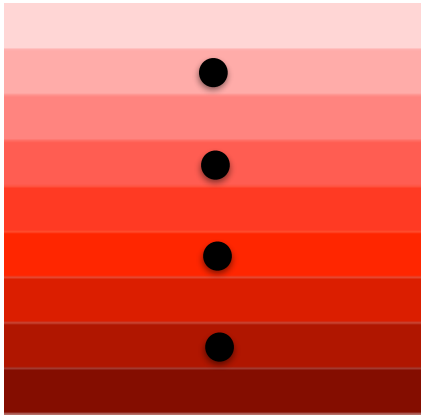

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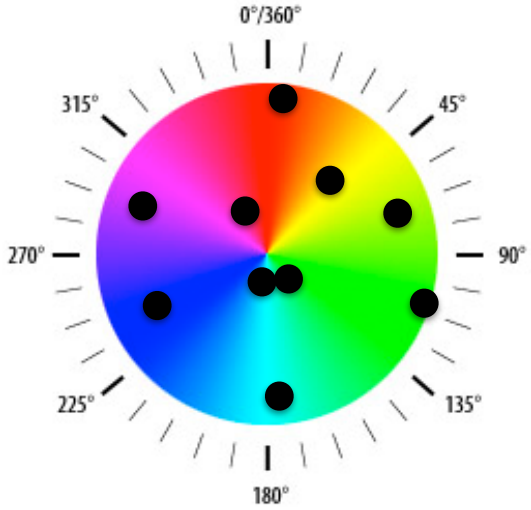

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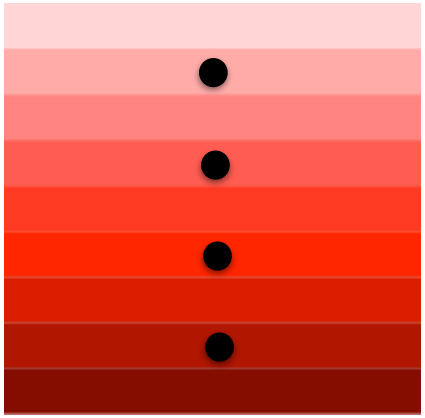

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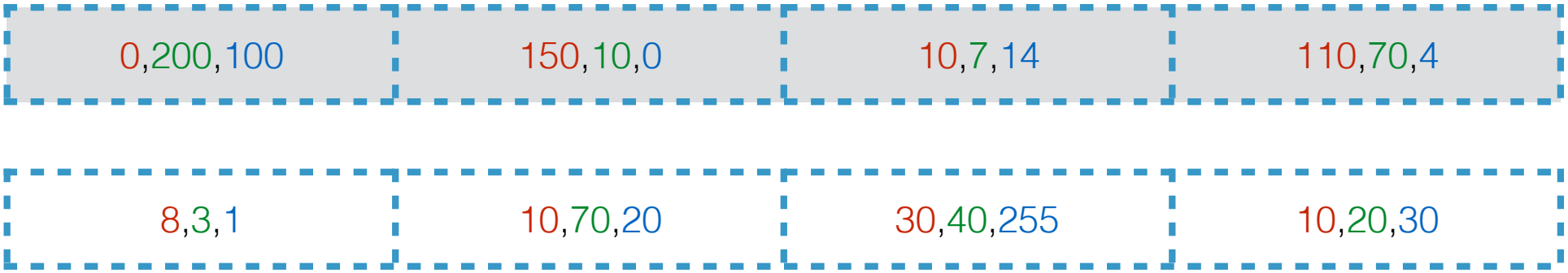
Crossover

- One-point crossover with probability *Pc*.



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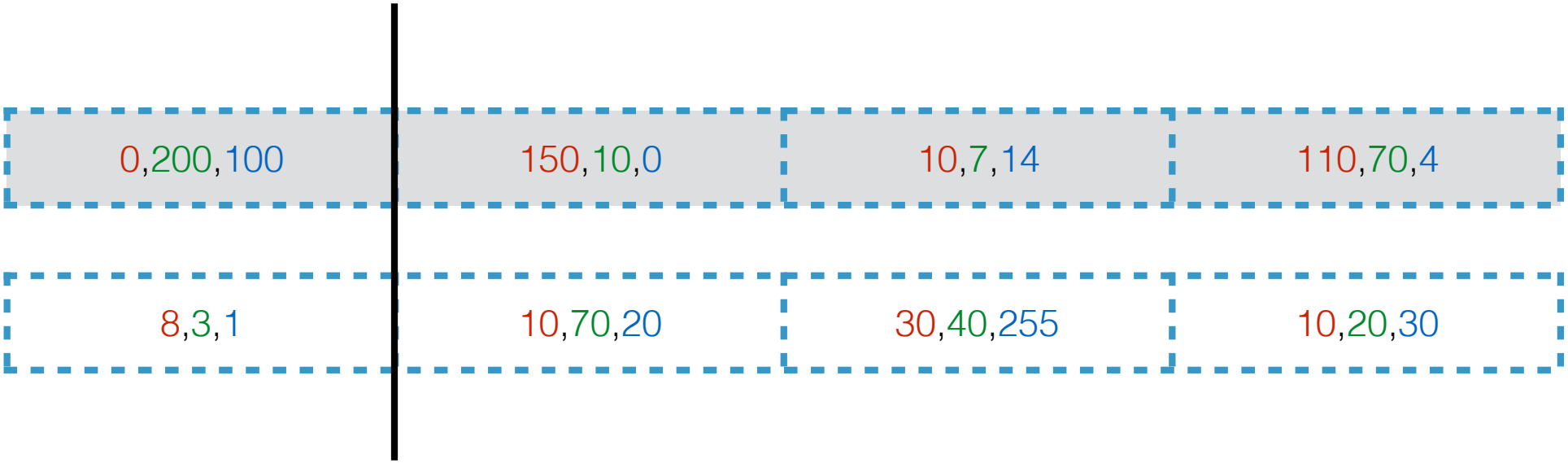

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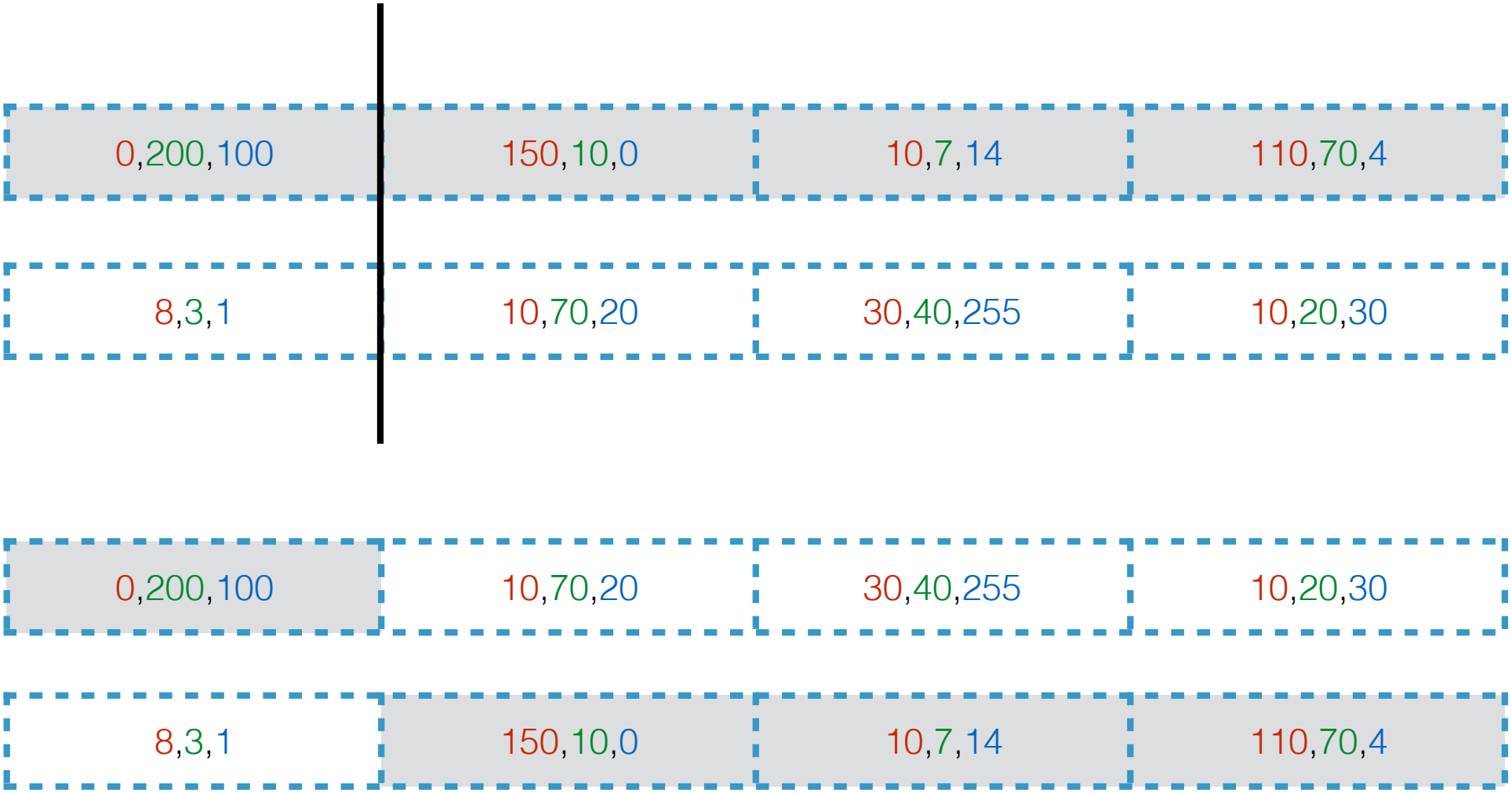
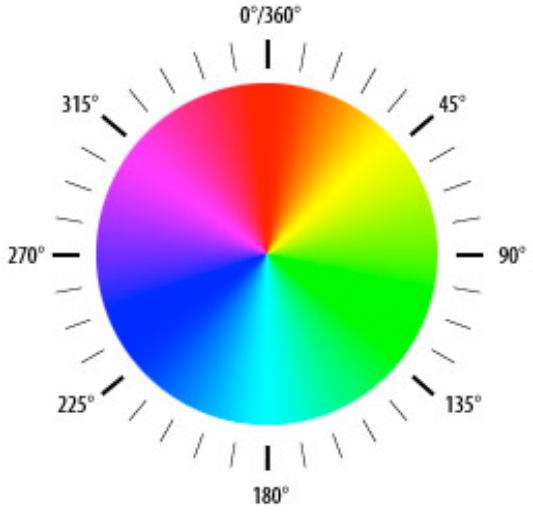


Mutation

- With probability *Pm*, change the colour of a gene to a new colour picked uniformly at random.



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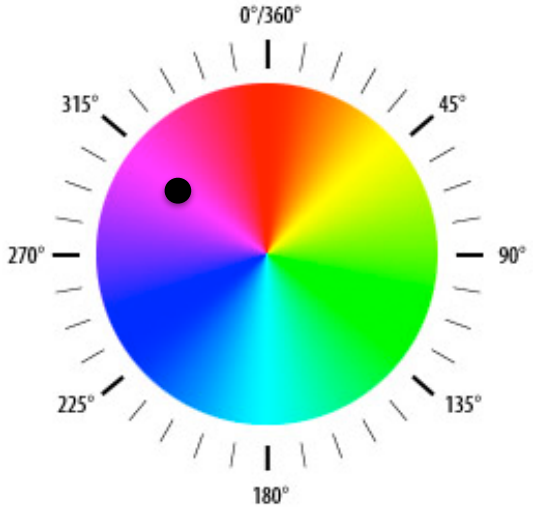

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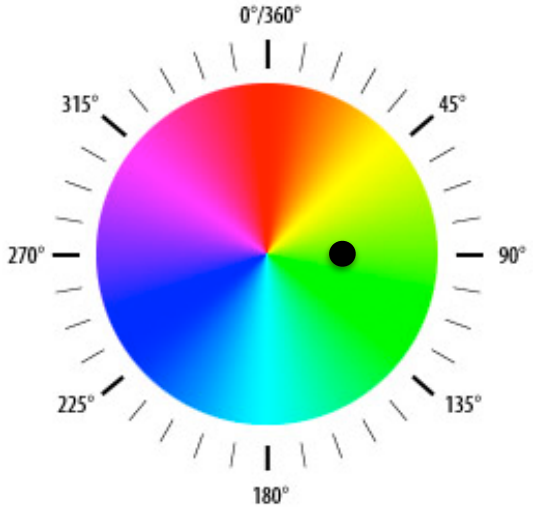

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    Minimise difference with respect to the original GUI design.
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Calculating Power Consumption of a Pixel

- Power consumption of an OLED pixel is a function of the power consumption of its RGB component colours.
- Consider that $colour_{x,y,s}$ is the colour of pixel with coordinates x,y in a given screen s.
- The power consumption of this pixel is the following:

$$P(colour_{x,y,s}) = P_{<R>}(R_{x,y,s}) + P_{<G>}(G_{x,y,s}) + P_{<B>}(B_{x,y,s})$$

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Power consumption of R component

Power consumption of G component

Power consumption of B component

Measuring Power Consumption

- The power of each colour component is screen-specific.
- One can measure the power consumption for each level of each component colour for a given type of screen.

https://www.msoon.com/LabEquipment/PowerMonitor/

Power Consumption Model

Image from Linares-Vasquez et al.

Power Consumption Model

- We can’t measure the power consumption of each pixel during the evolutionary process! We need to get that information beforehand.

Image from Linares-Vasquez et al.

Power Consumption Model

- We can't measure the power consumption of each pixel during the evolutionary process! We need to get that information beforehand.
- After some transformations, we get the following power consumption model for the screen used by Samsung Galaxy S4:

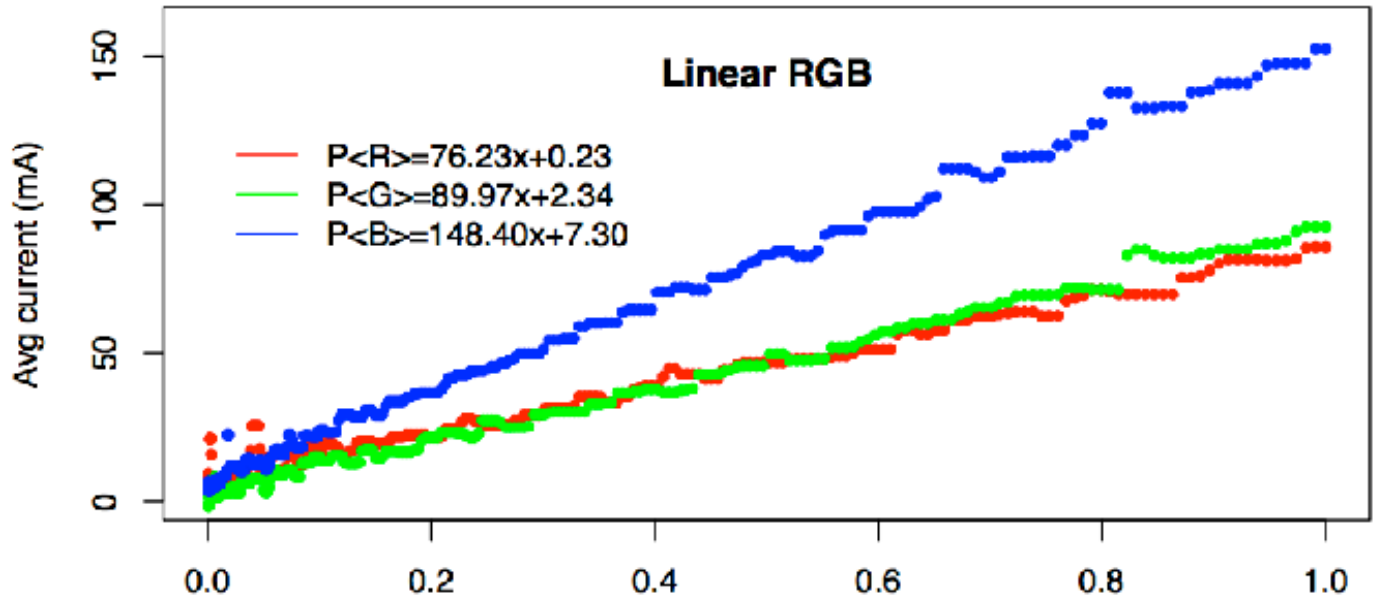

Image from Linares-Vasquez et al.

Calculating Power Consumption of a Screen

- A screen is composed of X * Y pixels, where X is the maximum x coordinate and Y is the maximum y coordinate.
- Power consumption of all pixels in a screen s:

$$\text{TotalPower}(s) = \sum_{x=1}^{X} \sum_{y=1}^{Y} P(\text{colour}_{x,y,s})$$

Calculating Power Consumption of Several Screens

- A GUI is composed of *S* screens.

$$\text{TotalPower(GUI)} = \sum_{s=1}^{S} \text{TotalPower(s)}$$

Calculating Power Consumption of Several Screens

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Calculating Power Consumption of Several Screens

- GUIs are composed of several screens.
- Screens that are used less time are less important.
- We can get information about the percentage of time a user spends on each screen by profiling application usage.

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Percentage of time users spend on screen s

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Finding Adjacent Screen Components

- Android View Server can provide us with the location of each component of a screen and its pixels.
- contrast($C_{c,s}$): sum of the contrasts between a component $C_{c,s}$ and each of its adjacent components.

$$\text{TotalContrast(GUI)} = \sum_{s=1}^{S} \sum_{c=1}^{C_s} \text{contrast}(C_{c,s})$$

where *S* is the number of screens and *Cs* is the number of components of screen s.

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Calculating Distance to Original Design

- Distance between two colours: Euclidean distance between the component colours (RGB).

$$\text{distance}(RGB_1, RGB_2) = \sqrt{(R_1-R_2)^2+(G_1-G_2)^2+(B_1-B_2)^2}$$

Calculating Distance to Original Design

- Distance between two colours: Euclidean distance between the component colours (RGB).

$$\text{distance}(RGB_1, RGB_2) = \sqrt{(R_1-R_2)^2+(G_1-G_2)^2+(B_1-B_2)^2}$$

- Distance between an optimised and the original design:
  - Determine the distances between each colour C in the new design and its closest colour C' in the original design.
  - If a given C and C' are different colours involving the same component, penalise the colour difference by multiplying the corresponding distance by 2.
  - Sum all the [penalised] distances.

Problem Formulation

- Consider an initial GUI design with its colours.
- Design variables: RGB colour of each pixel.
- Objectives:
  - Minimise power consumption on OLED displays.
  - Maximise contrasts between adjacent GUI elements.
  - Minimise difference with respect to the original GUI design.
- **Constraints:**
  - **Adjacent elements of the GUI should not have the same colour or colours with too low contrast between them.**

Constraints

Constraints

- Contrast between the colour of a component $C_{c,s}$ and an adjacent component $C_{c',s}$ should be larger or equal to a given threshold.

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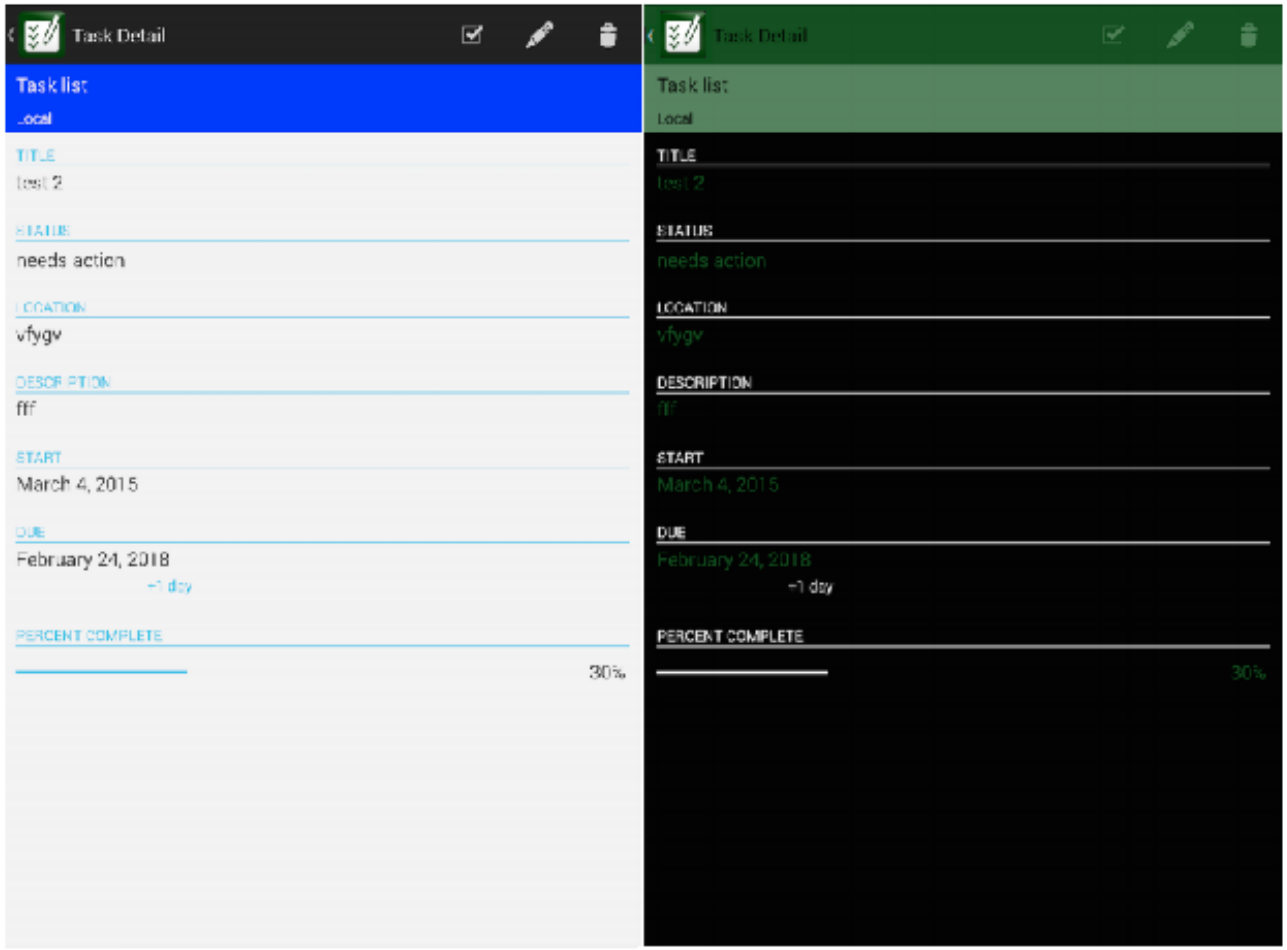
- Contrast between the colour of a component $C_{c,s}$ and an adjacent component $C_{c',s}$ should be larger or equal to a given threshold.

- Number of violations in a given solution = number of times adjacent components have contrast lower than the threshold.

Constraints

- Contrast between the colour of a component $C_{c,s}$ and an adjacent component $C_{c',s}$ should be larger or equal to a given threshold.
- Number of violations in a given solution = number of times adjacent components have contrast lower than the threshold.
- Dealing with constraints (in NSGA-II):
  - An infeasible solution is worse than a feasible solution.
  - When comparing two infeasible solutions, the one with lower number of violations is better.

Examples of Solutions



Images from Linares-Vasquez et al.

Original Design

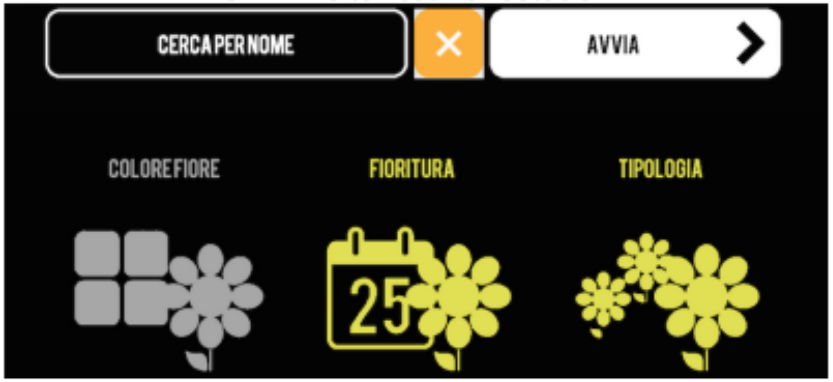
GEMMA's lowest ECF solution

The optimised GUI (right) offers energy consumption savings of up to 53% as well as an increase in terms of contrast ratio by 31%.

Examples of Solutions

Original Design

GEMMA's lowest ECF solution



Images from Linares-Vasquez et al.

Further Reading

Optimizing Energy Consumption of GUIs in Android Apps: A Multi-objective Approach

Mario Linares-Vásquez, Gabriele Bavota, Carlos Bernal-Cárdenas, Rocco Oliveto, Massimiliano Di Penta, Denys Poshyvanyk

Proceedings of the 2015 10th Joint Meeting on Foundations of Software Engineering

Pages 143-154

http://dl.acm.org/citation.cfm?id=2786847&CFID=648846544&CFTOKEN=44813324