Chameleon: A Color-Adaptive Web Browser for Mobile OLED Displays

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Display

is a major power consumer in a smartphone

A. Carroll, "A analysis of power consumption in a smartphone," 2010


Organic
Light-
Emitting
Diode

2009 2010 2011


OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!

Power = 2.0W


20.0

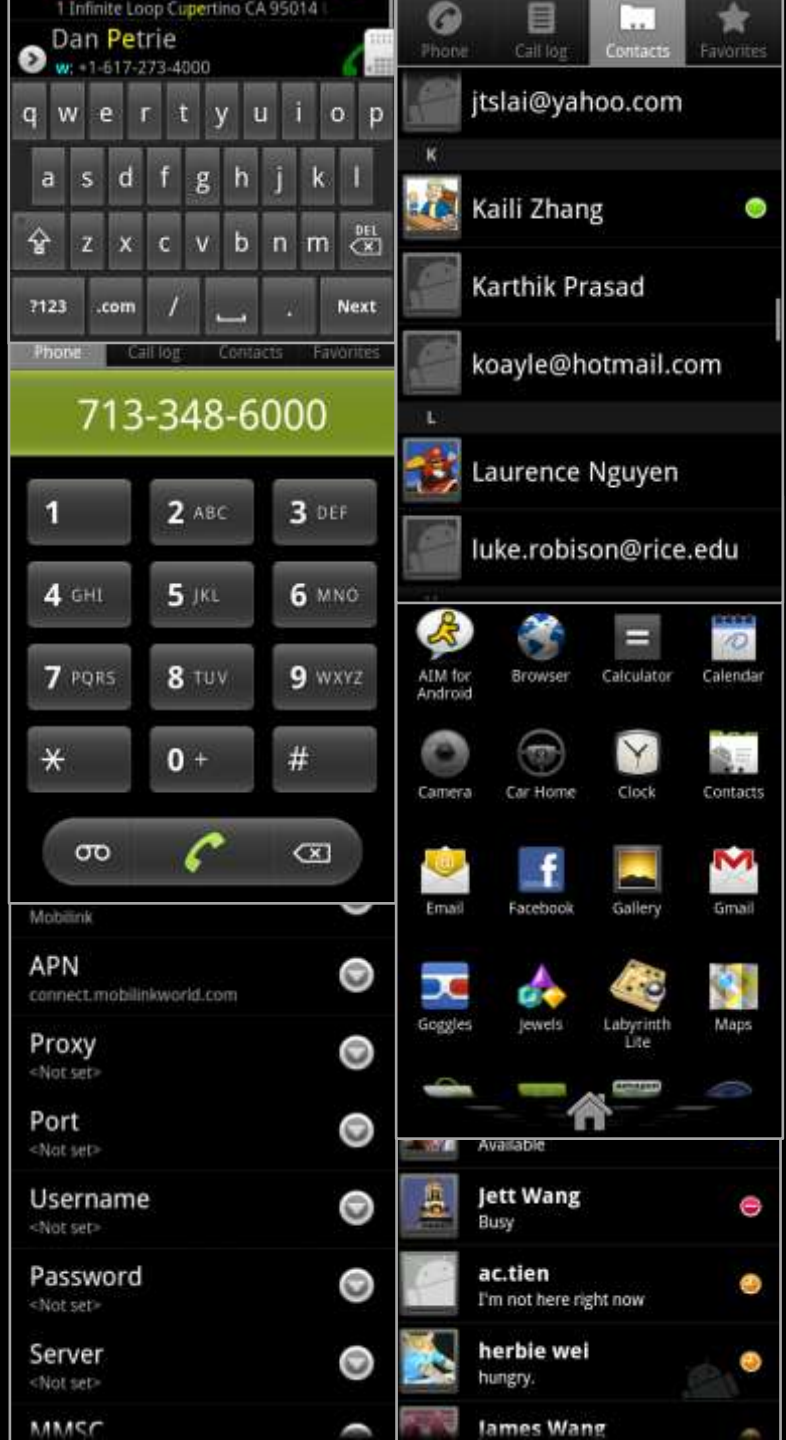

OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!

Power = 0.5W


20.0

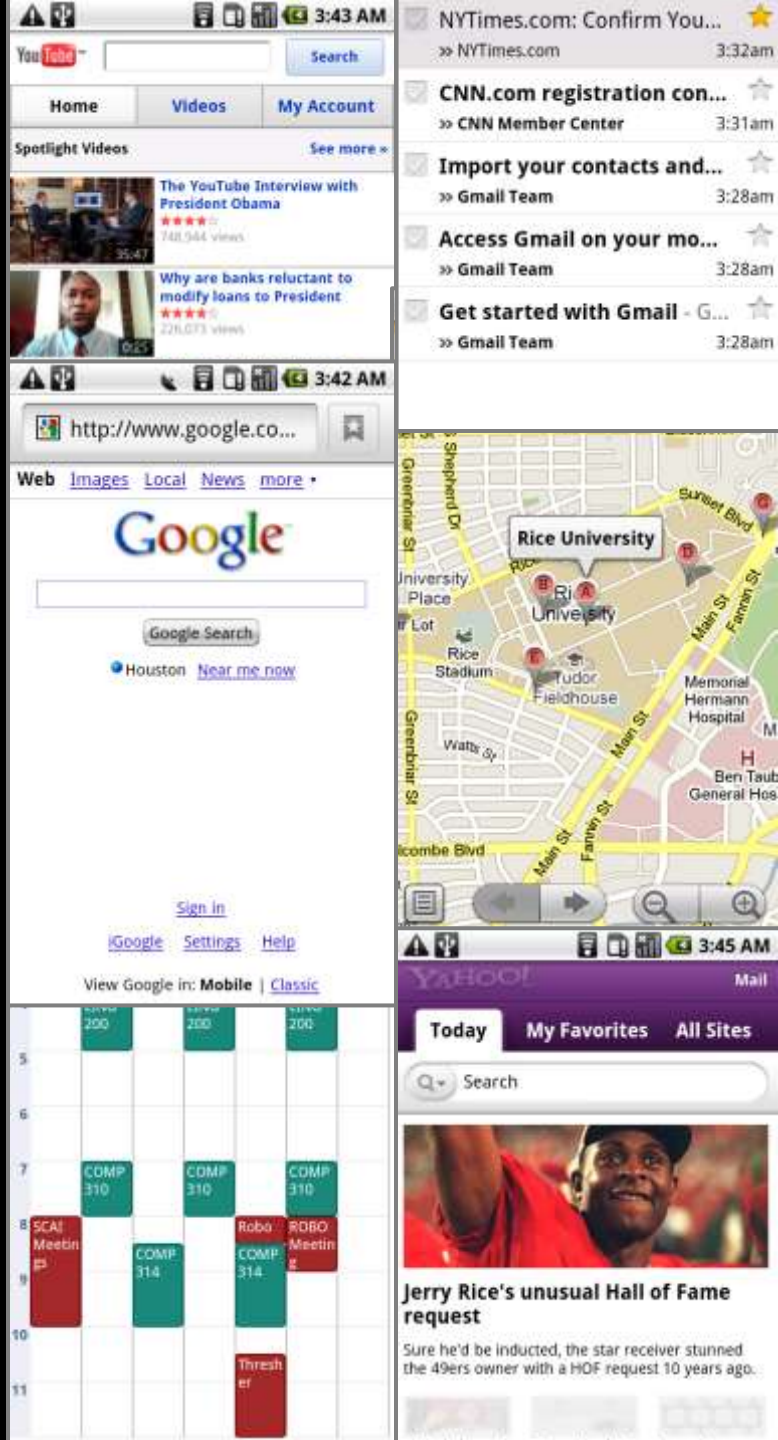
An OLED-friendly theme works for

GUIs



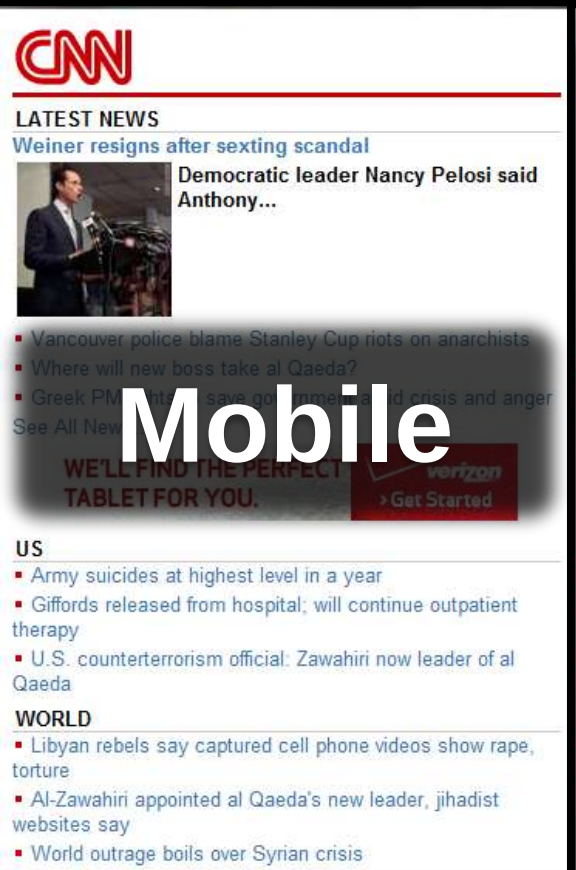
but not for

Contents



65% of the contents in the web are **White**

LiveLab: A field study (25 users; 12 months)



Web Design

solves the problem?

50% of the webpages visited by iPhone users are

Non-Mobile

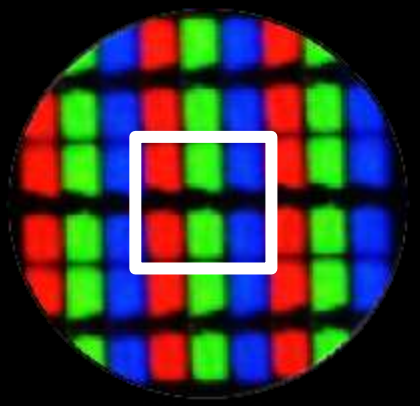
Max:	70%
Min:	20%
Median:	50%

LiveLab: A field study
(25 users; 12 months)

1 Generate Device Specific OLED Power Model

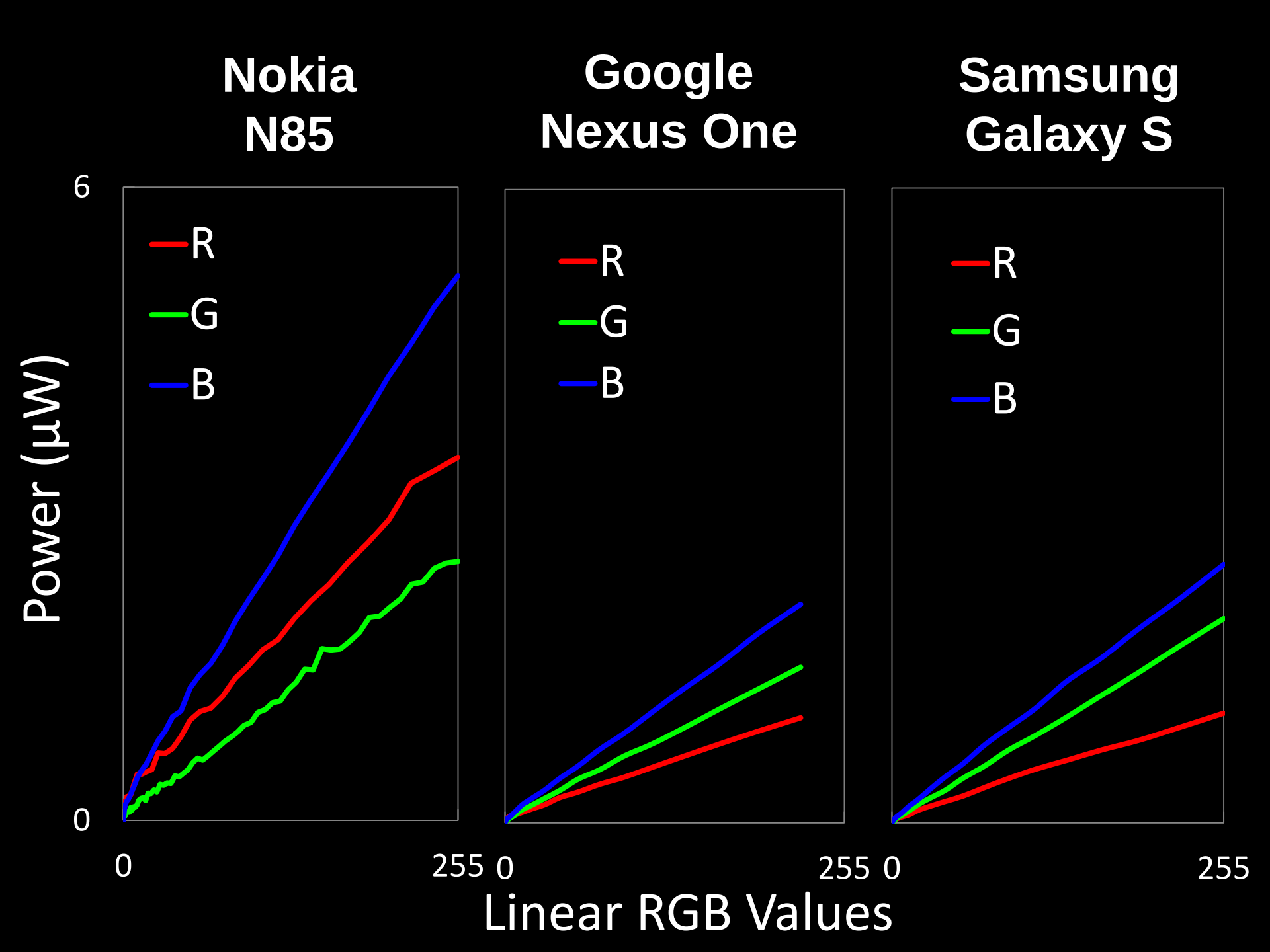
Single pixel i

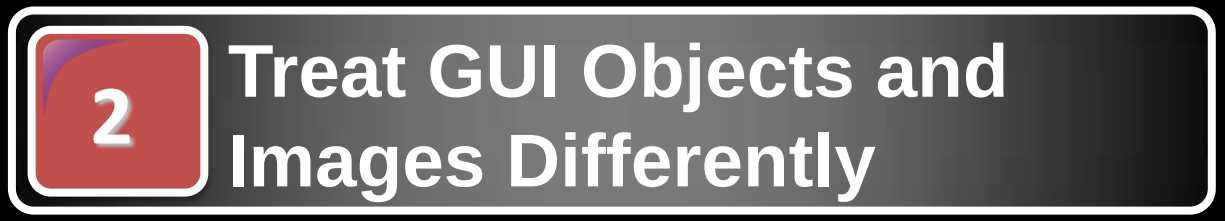
$$P_i = a \cdot R_i + b \cdot G_i + c \cdot B_i$$



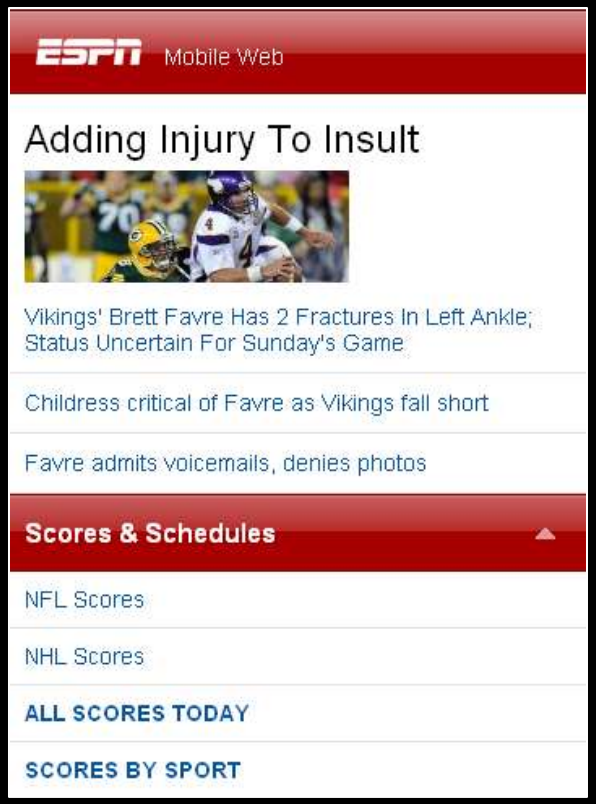
A display with N pixels

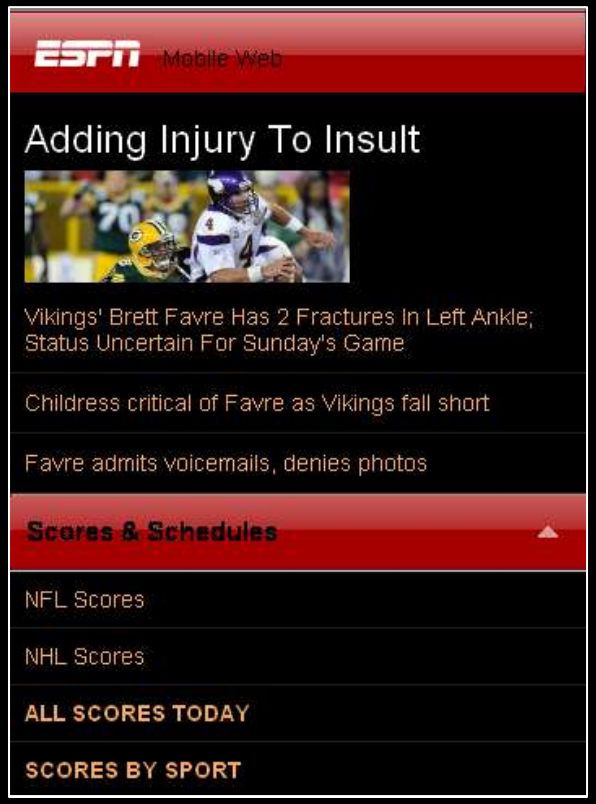
$$P = \sum_{i=1}^{N} P_i = \sum_{i=1}^{N} (a \cdot R_i + b \cdot G_i + c \cdot B_i)$$


Nokia
N85
Google
Nexus One
Samsung
Galaxy S
6
0
Power (µW)
R
G
B
0
255
Linear RGB Values


2
Treat GUI Objects and
Images Differently

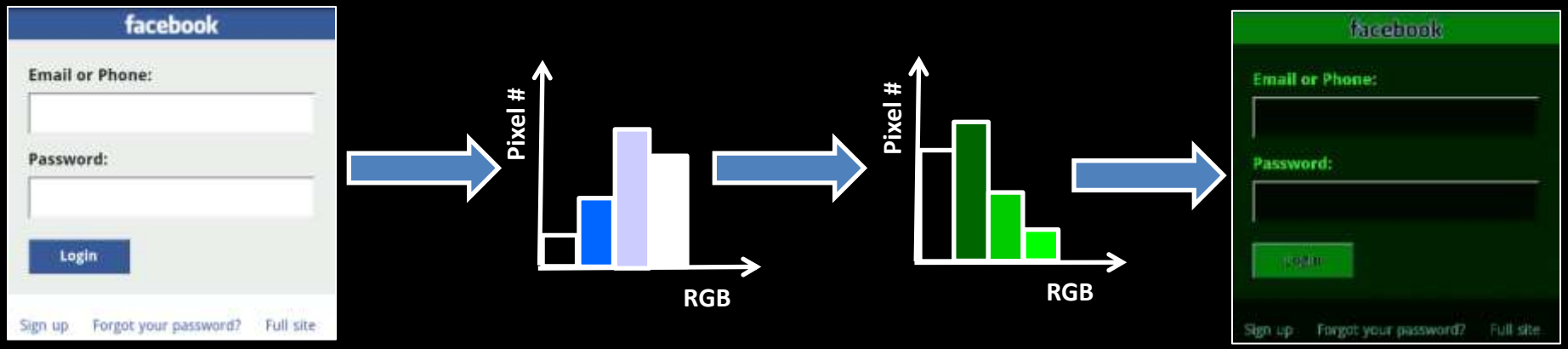
GUI Objects vs. Images





Color Transformation of GUI Objects

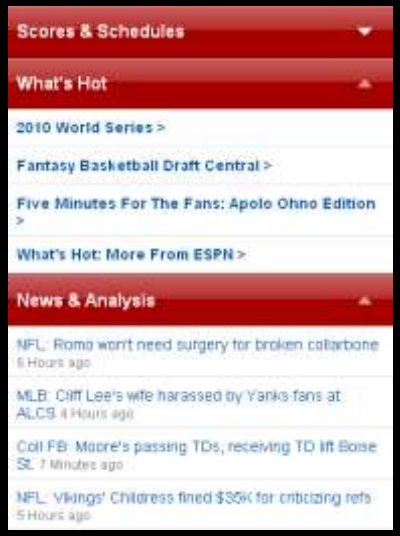
Color Counting **Color Mapping** **Color Painting**

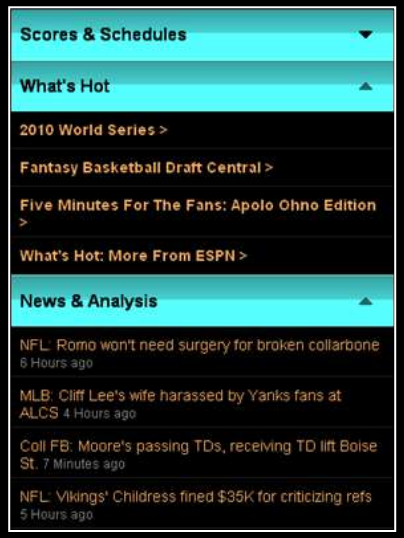


Color Transformation of Images

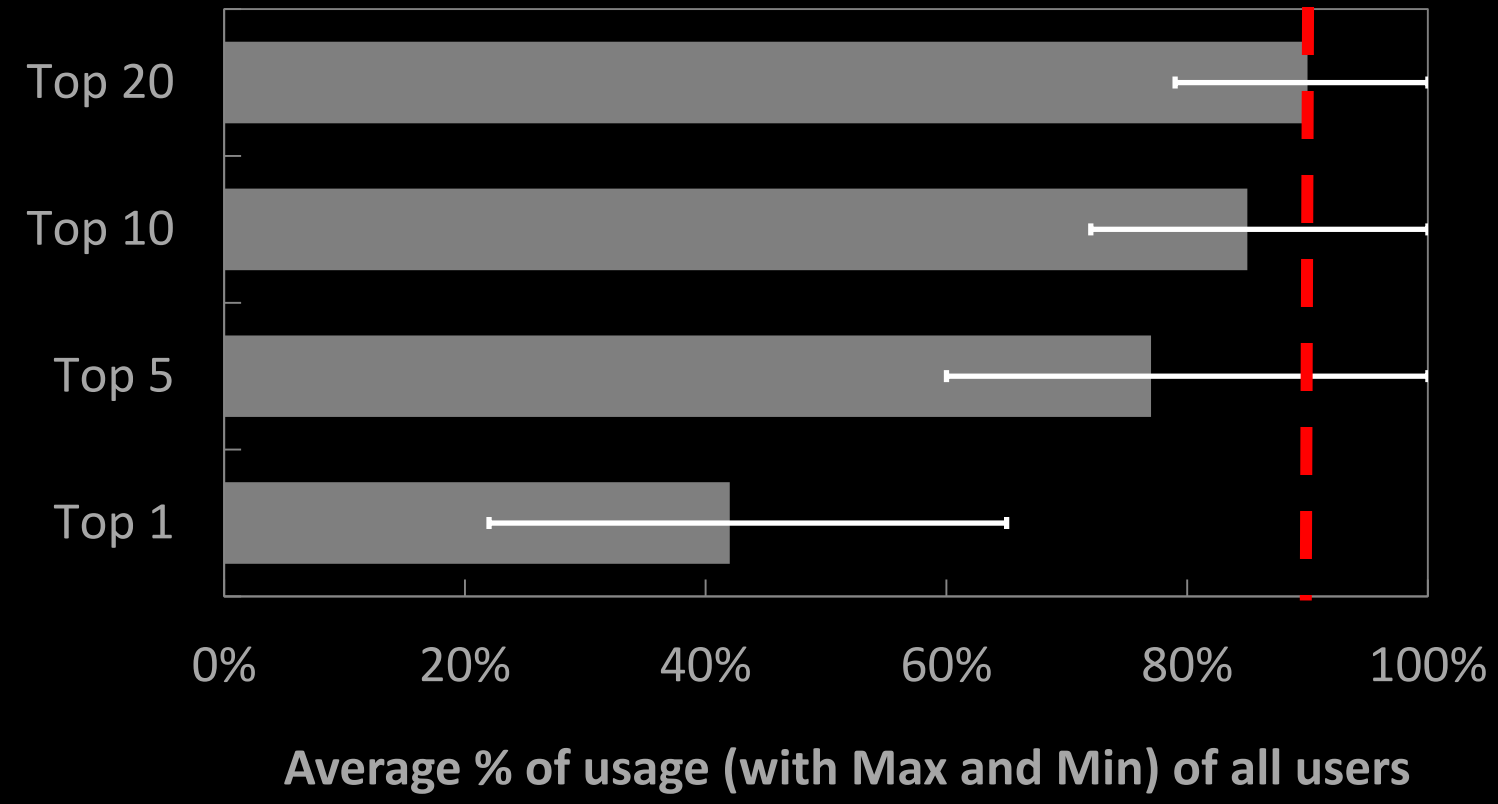
3 Keep Color Consistency for Each Website

Color Consistency per Website





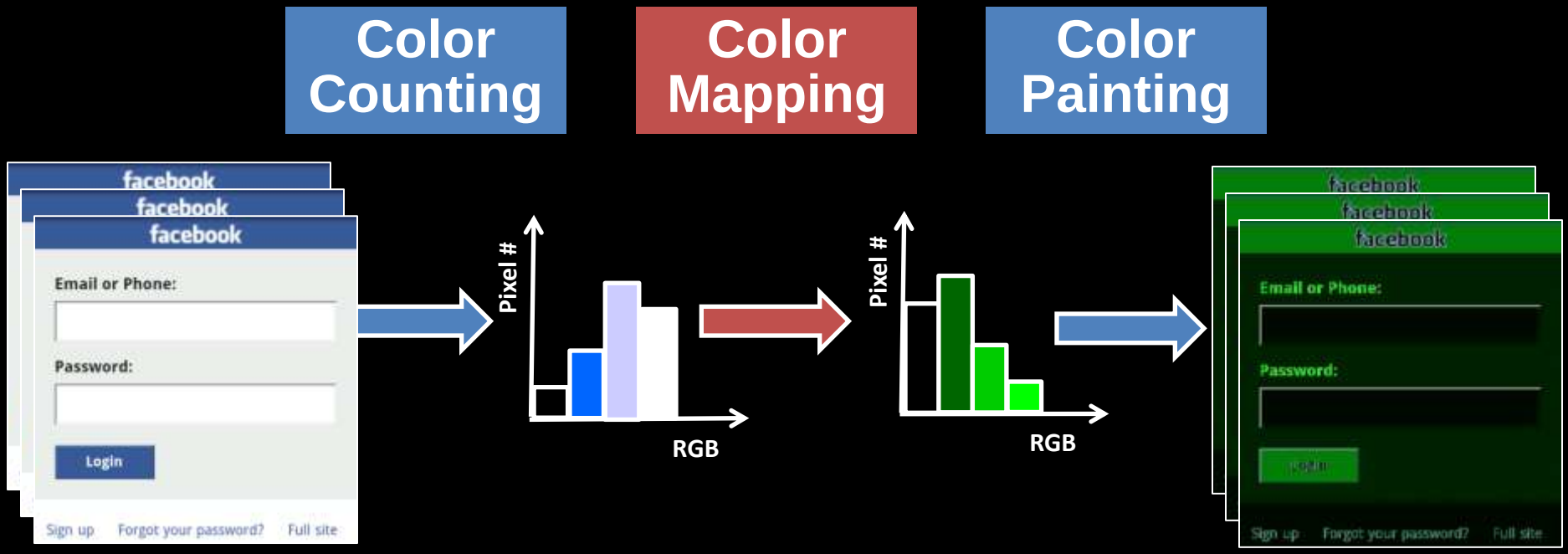
Top 20 websites contribute **90%** of the webpages visited by each user



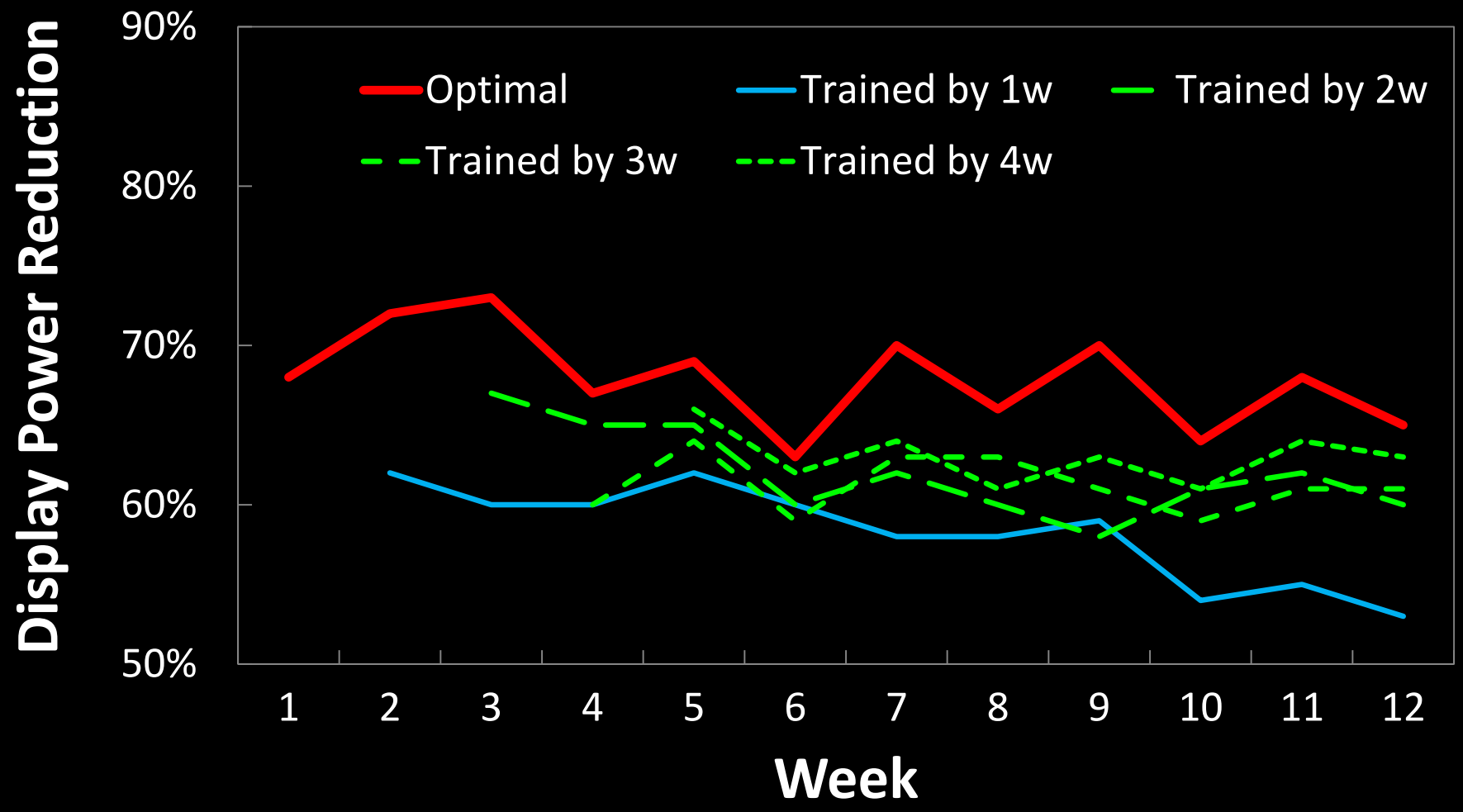
LiveLab: A field study (25 iPhone users; 12 months)

4 Calculate Color Maps Offline

Color Transformation of GUI Objects



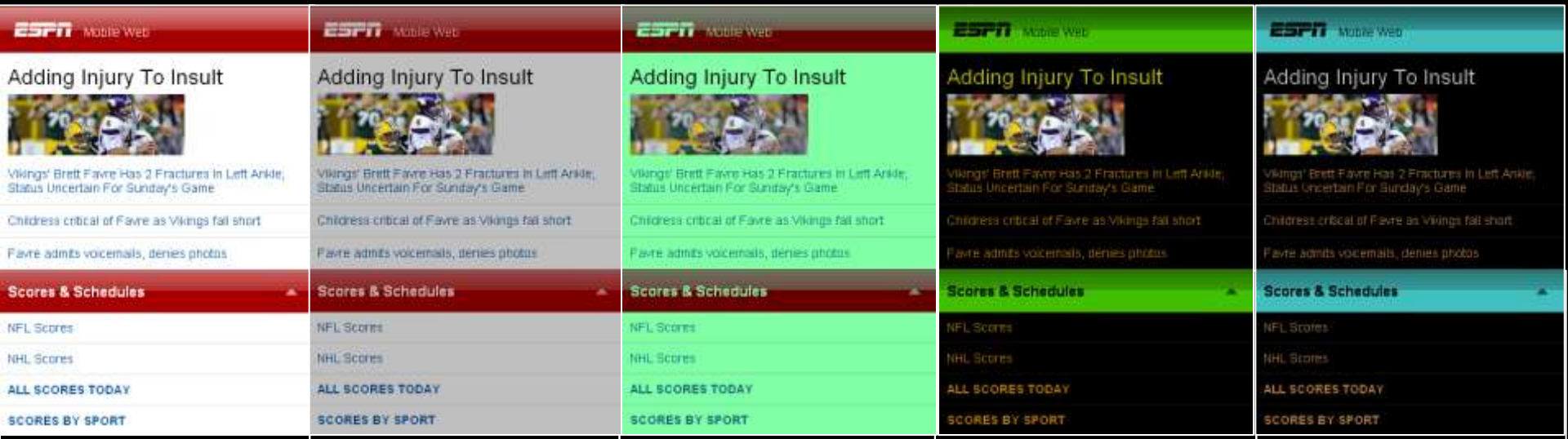
2 Weeks of training work for **3 Months**




Websites remain
Color Consistent
over many years
http://confabulator.blogspot.com/2007/01/how-little-web-sites-have-changed-over.html

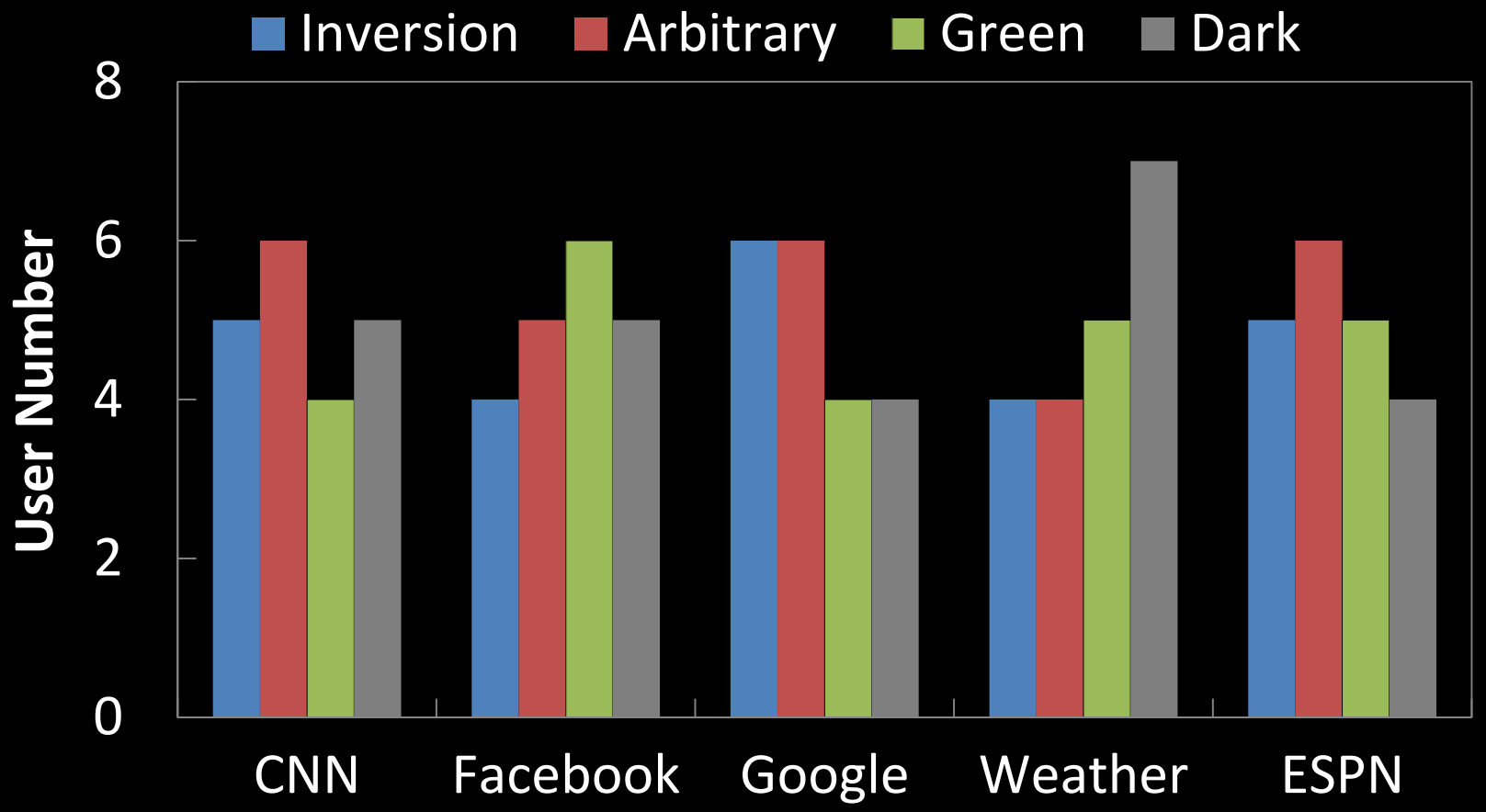
5 Give User Options

20 Participants

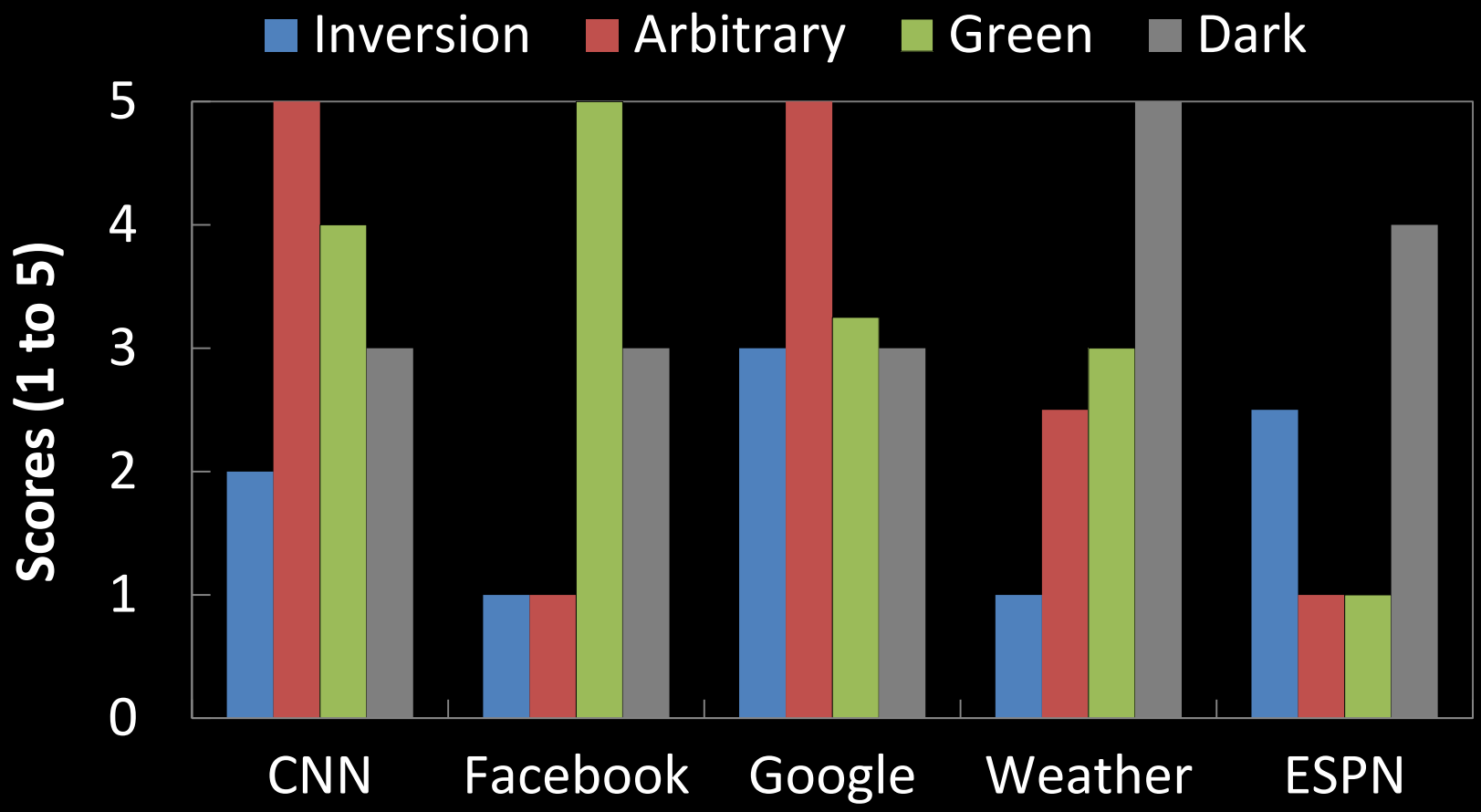


Original	Dark	Green	Arbitrary	Inversion
	$R' = \lambda R$ $G' = \lambda G$ $B' = \lambda B$ ↓25%	$R' = \lambda_R R$ $G' = \lambda_G G$ $B' = \lambda_B B$ ↓34%	$R' = R^*$ $G' = G^*$ $B' = B^*$ ↓72%	$R' = \lambda(1-R)$ $G' = \lambda(1-G)$ $B' = \lambda(1-B)$ ↓66%

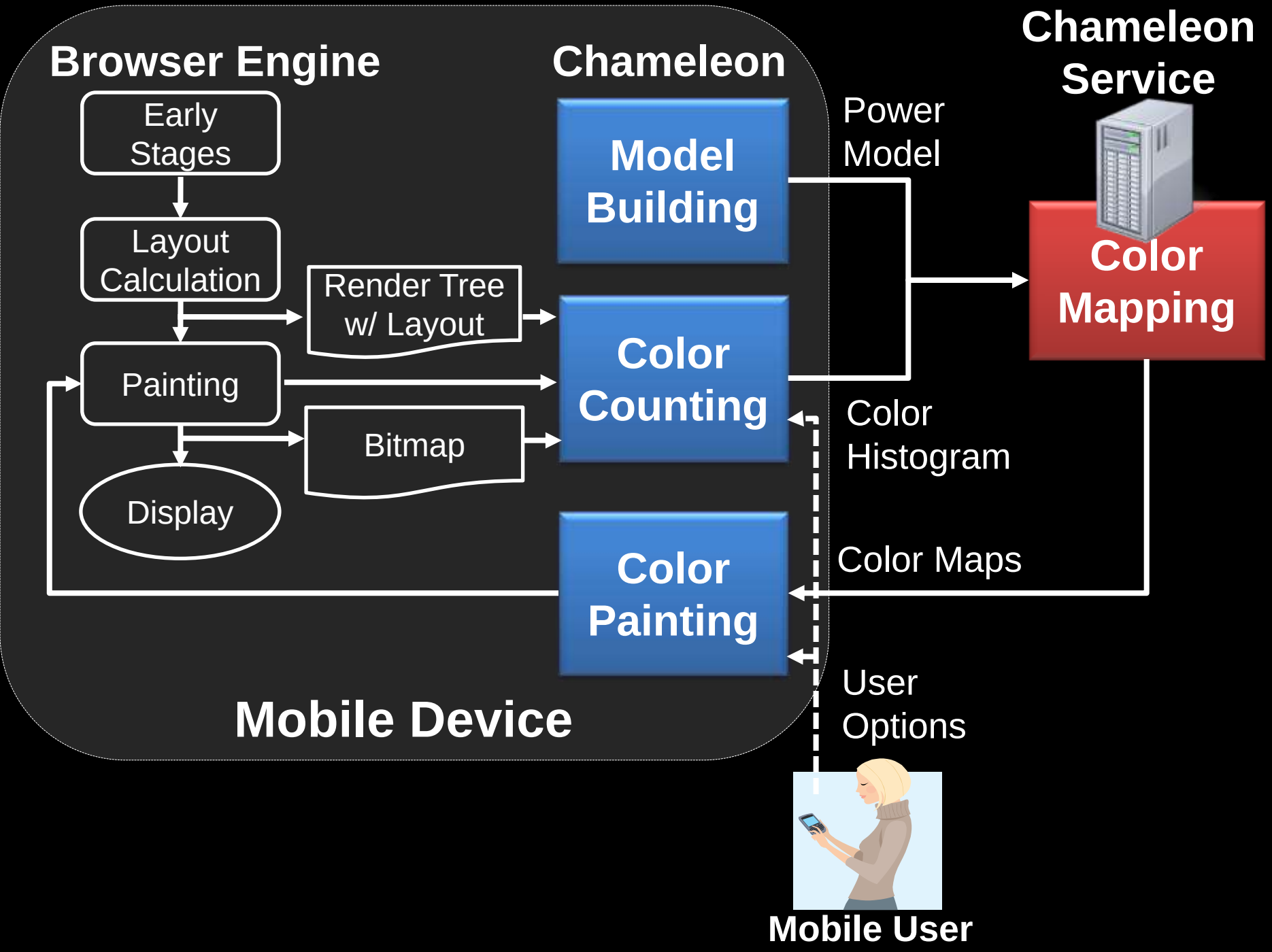
Different users prefer *different* transformations for a website



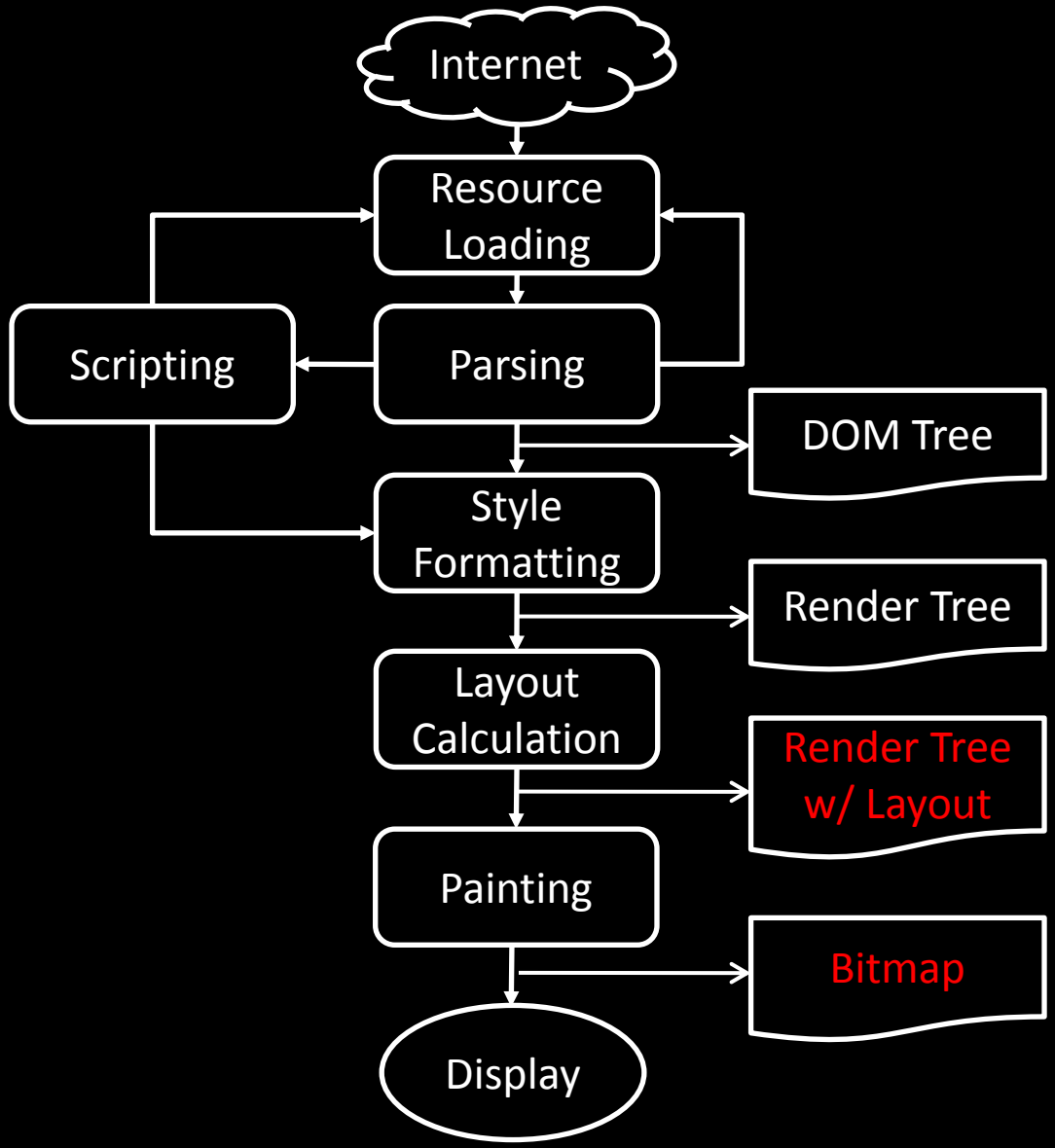
Even the ***same*** user may favor ***different*** color transformations for ***different*** websites

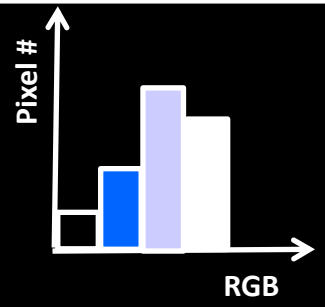


1. Generate Device Specific OLED Power Model
2. Treat GUI Objects and Images Differently
3. Keep Color Consistency for Each Website
4. Calculate Color Maps Offline
5. Give User Options


Browser Engine
Chameleon
Early Stages
Layout Calculation
Render Tree w/ Layout
Painting
Bitmap
Display
Model Building
Color Counting
Color Painting
Mobile Device
Power Model
Color Histogram
Color Maps
User Options
Chameleon Service
Color Mapping
Mobile User

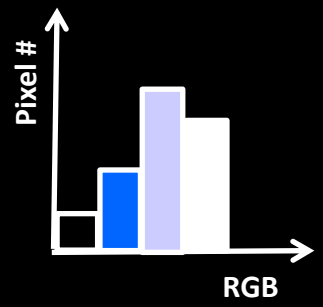
Color Counting

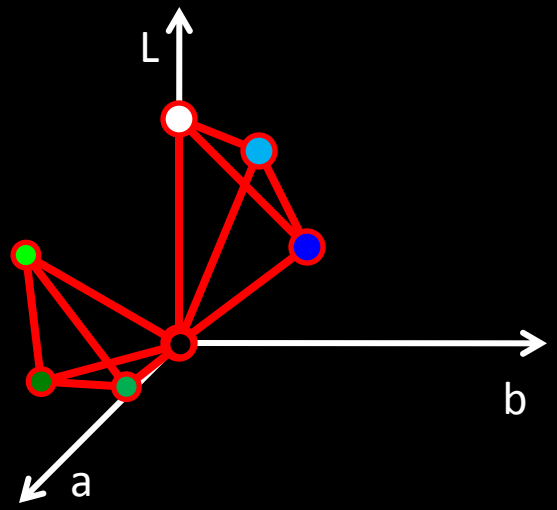




Mapping Optimization

- Input:





- Output: RGB

R'G'B'

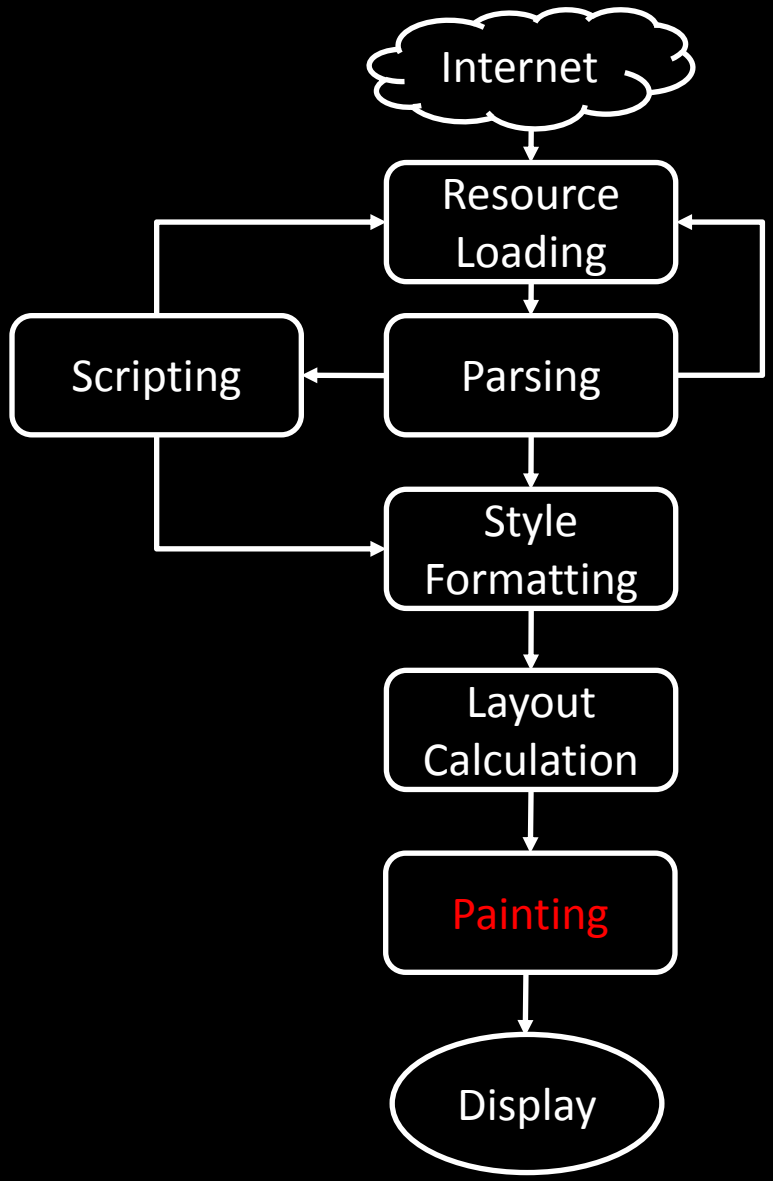
- Algorithm
  - Arbitrary

    min Power

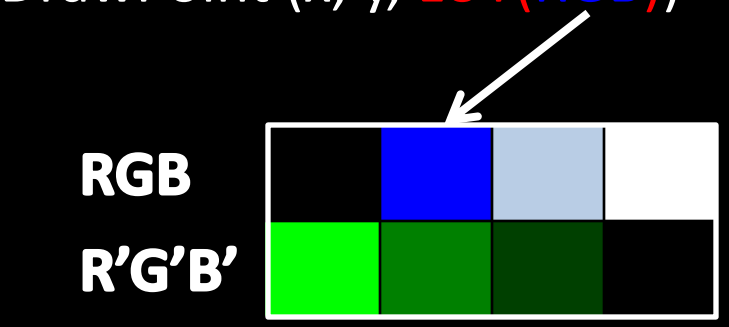
    s.t. for any i, j

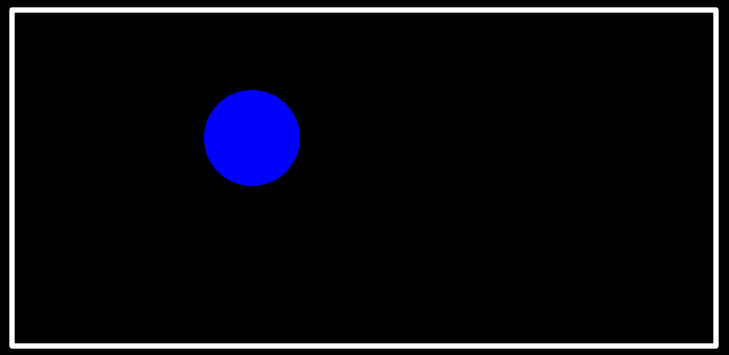
    $\Delta E((L_i', a_i', b_i'), (L_j', a_j', b_j')) = \lambda \cdot \Delta E((L_i, a_i, b_i), (L_j, a_j, b_j))$

Painting GUI Objects



DrawPoint (x, y, LUT(RGB))



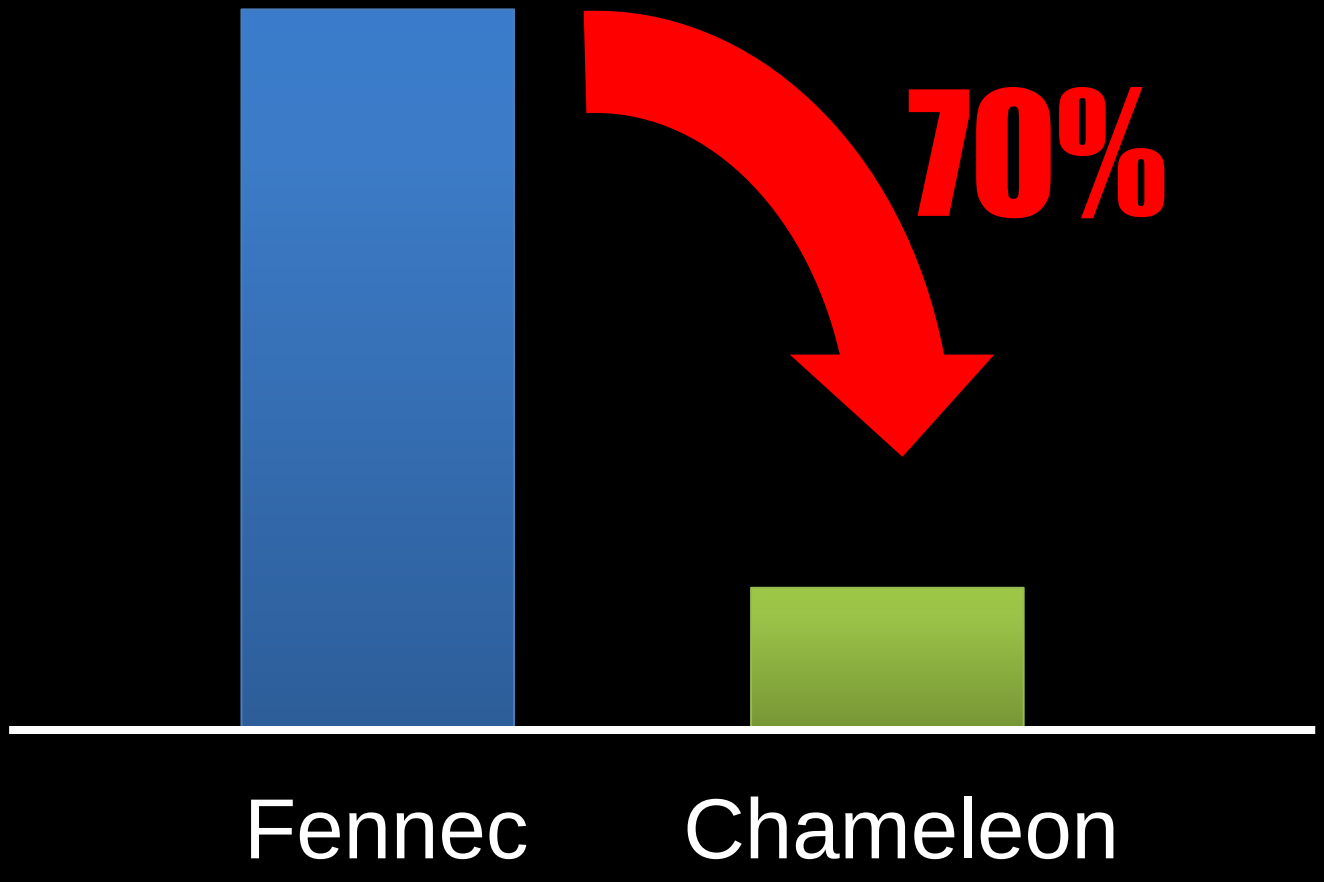


Implementation

Fennec

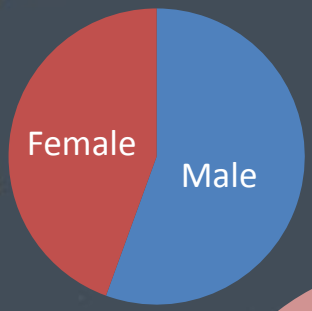
Mozilla for Mobile

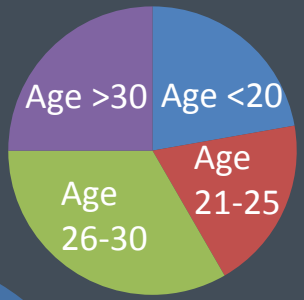
Display Power Consumption

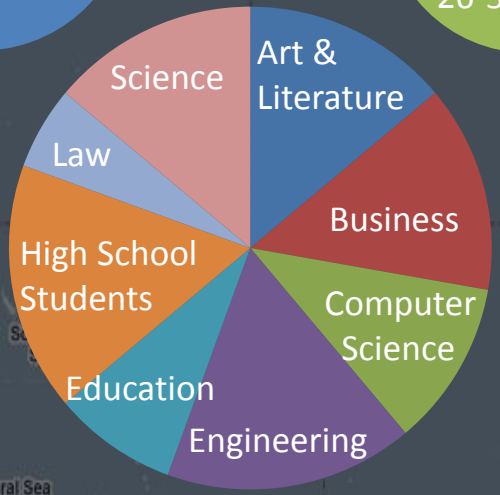


A Field Trial

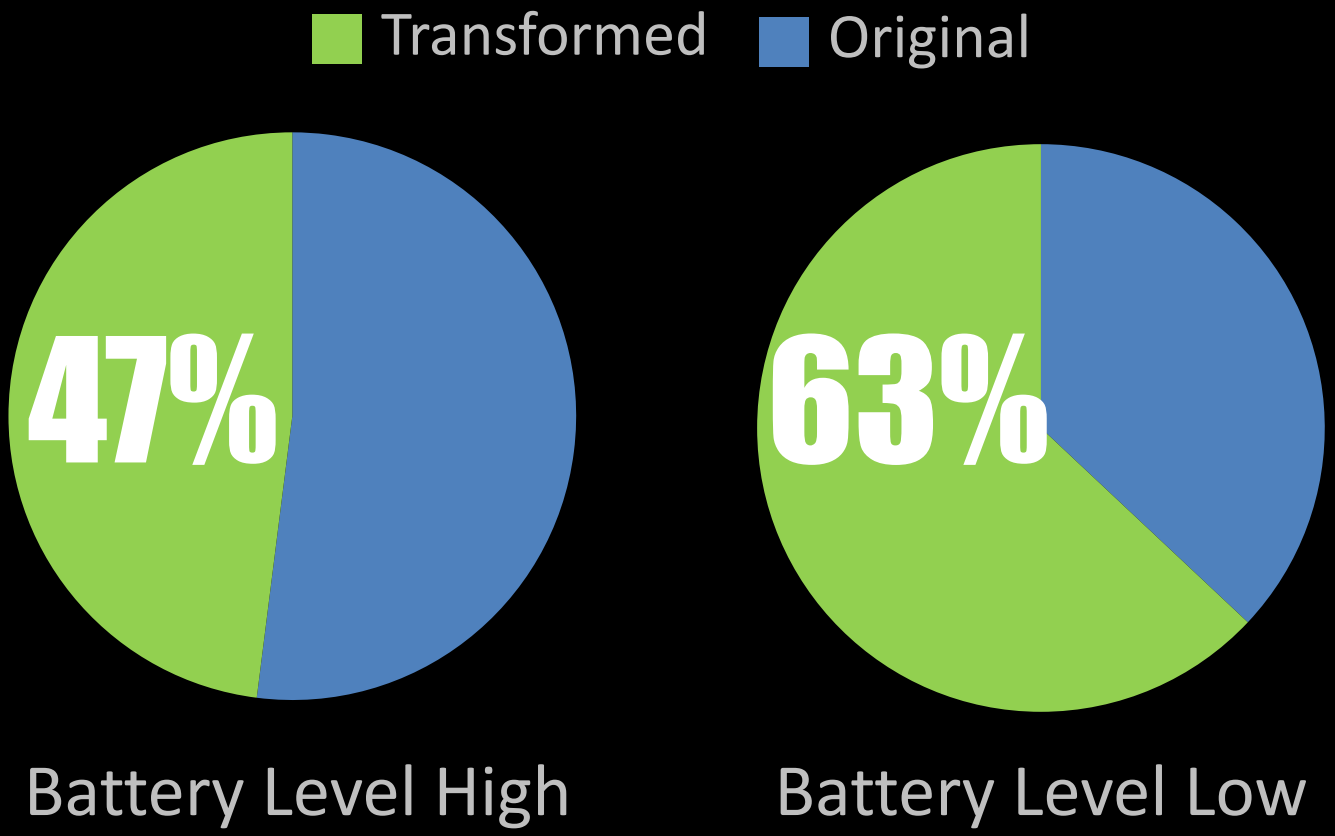
36 Participants; 3 Months







Transformation is **Well Accepted** especially with a **Low** battery level



Summary

- Color transformation is beneficial: 40% system power reduction for web browsing
- Color transformation is well accepted by users if performed properly
- Chameleon tremendously benefited from studying users