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

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Rice University

Display

is a major power consumer in a smartphone

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

Organi
c Light-
Emittin
g
Diode

2009 2010 2011

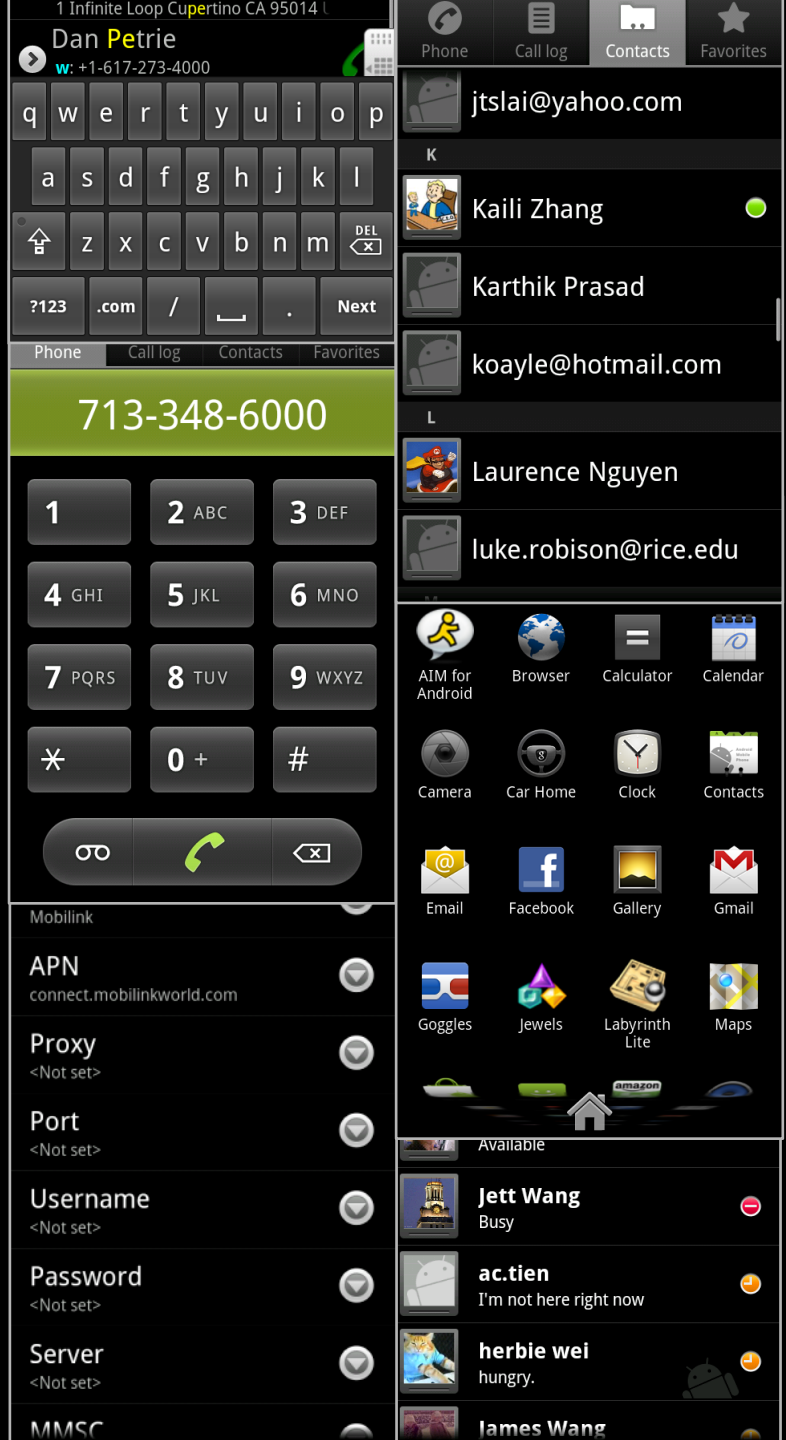
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!
OLED Rocks !!!

Power = 0.5W

20.0

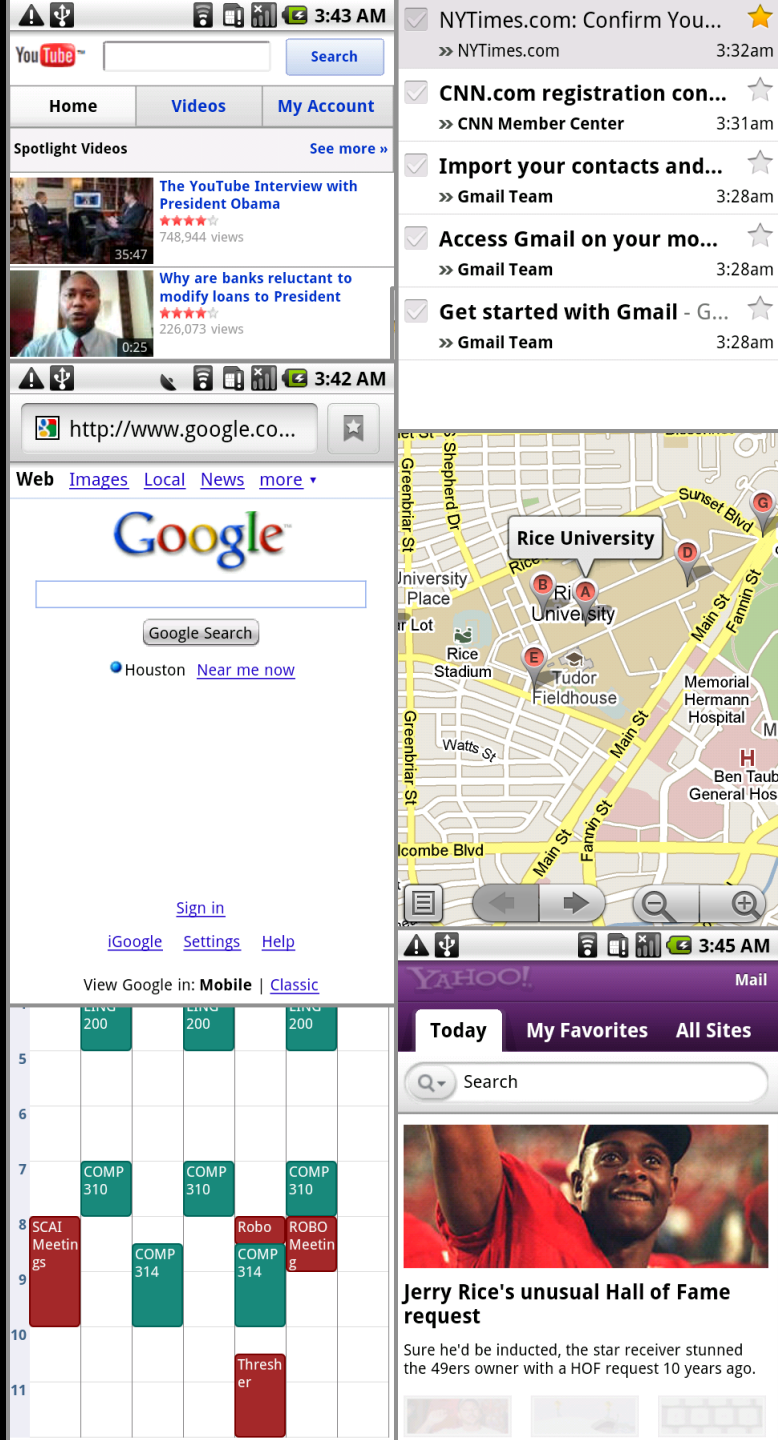
An OLED-friendly theme works for

GUIs



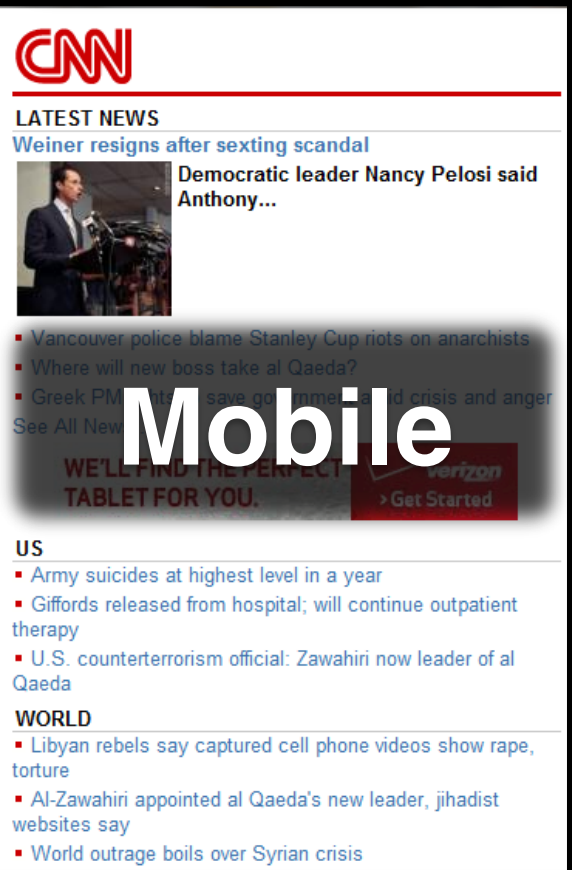
but not for

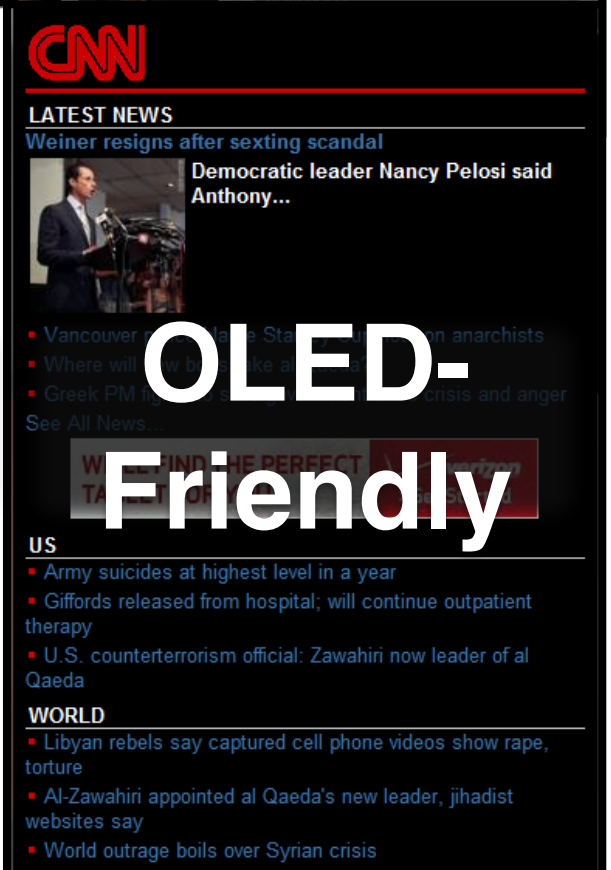
Contents



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

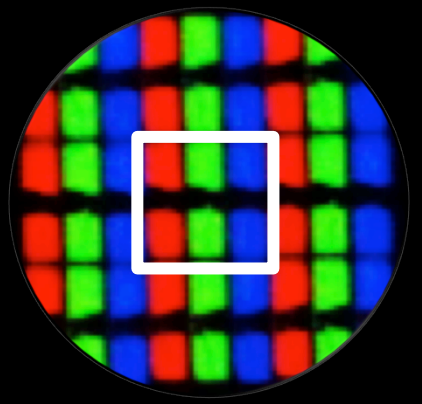
Max:	70%
Min:	20%
Median:	50%

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

1 Generate Device Specific OLED Power Model

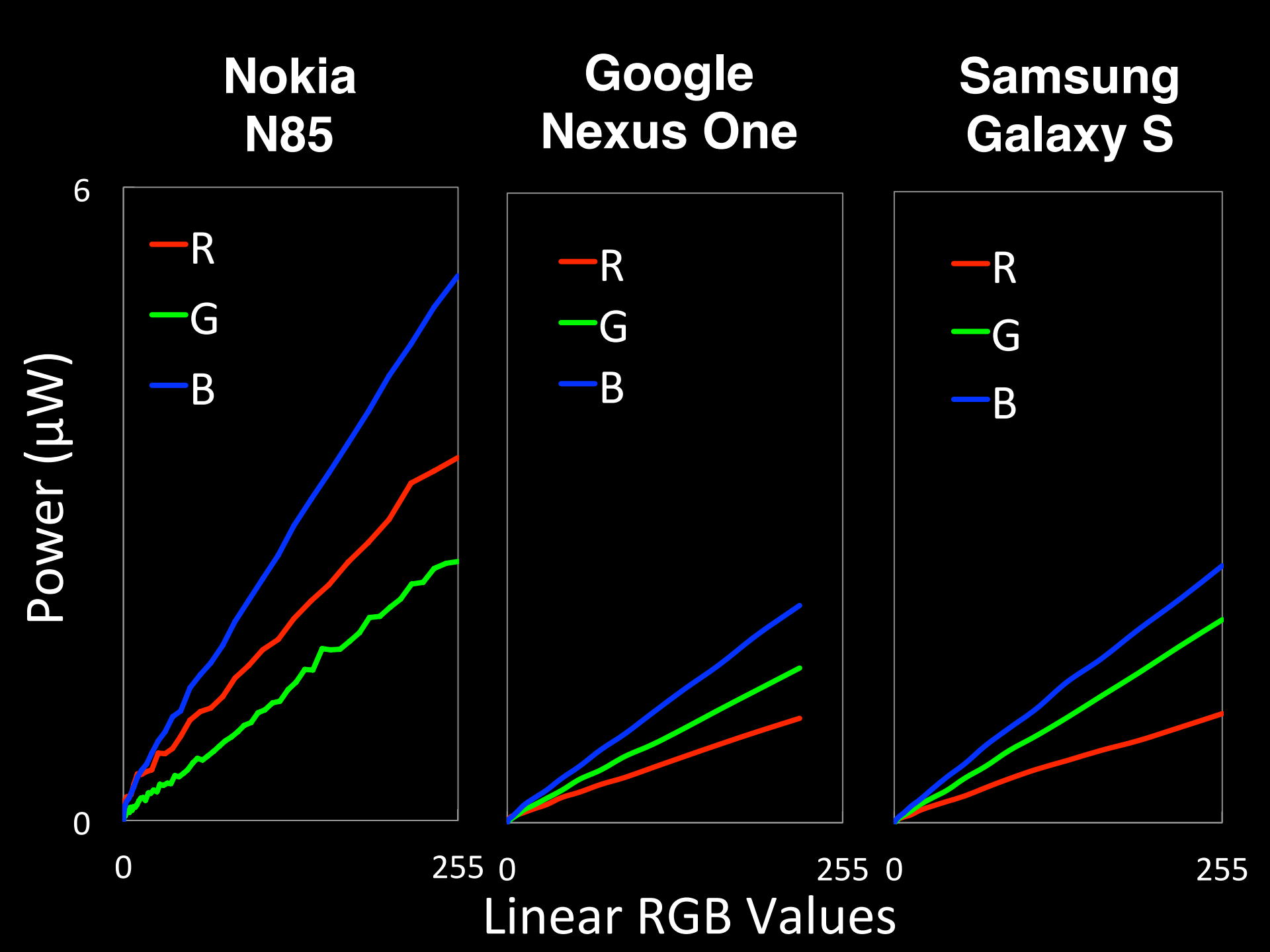
Single pixel i

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



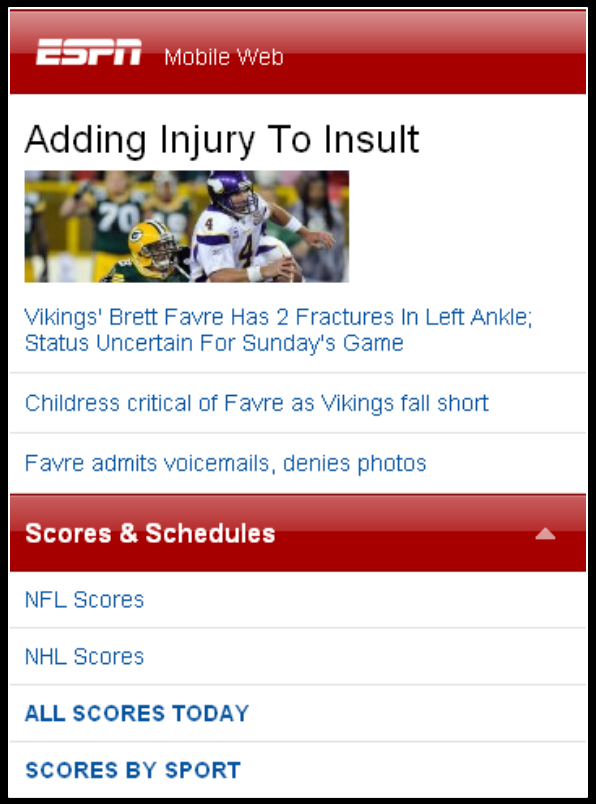
A display with N pixels

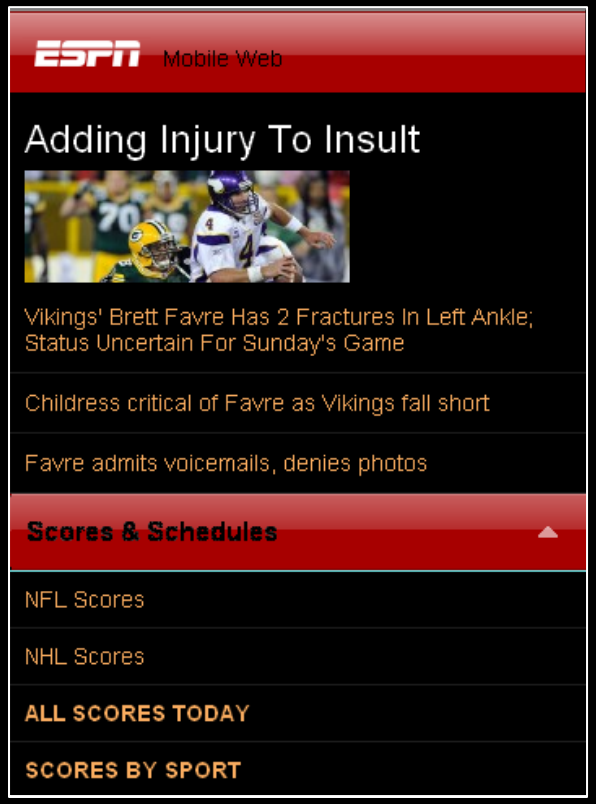
$$P = \sum_{i=1}^{N} P_i = \sum_{i=1}^{N} (a \cdot R_i + b \cdot G_i + c \cdot B_i)$$


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

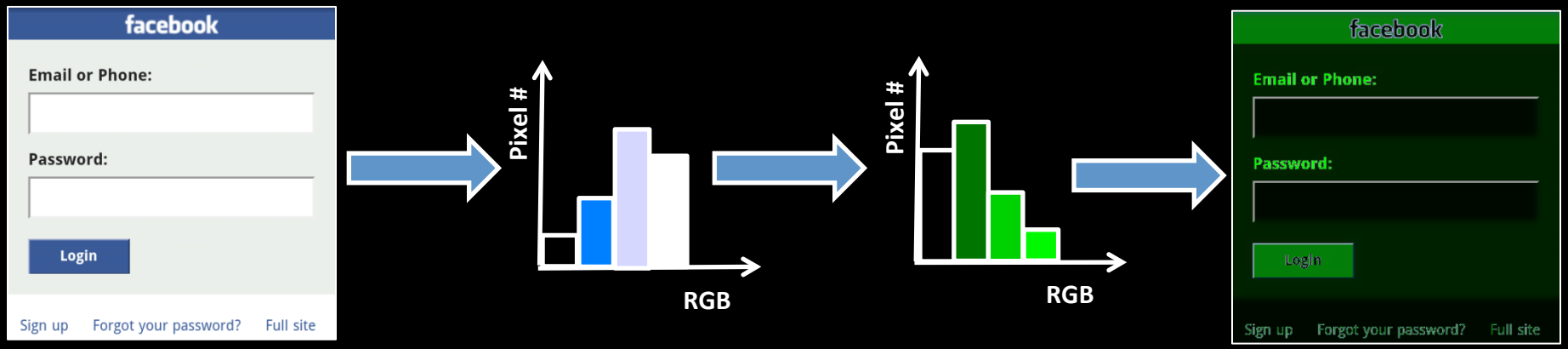
GUI Objects vs. Images





Color Transformation of GUI Objects

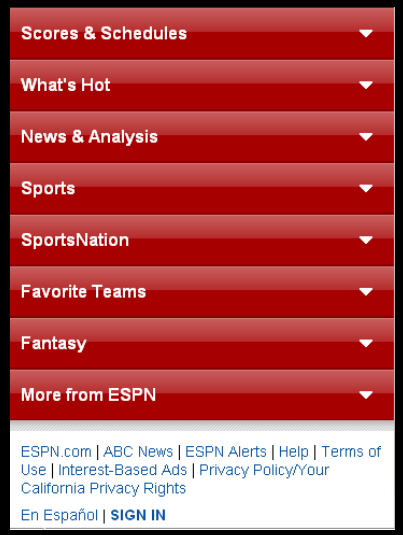
Color Counting **Color Mapping** **Color Painting**

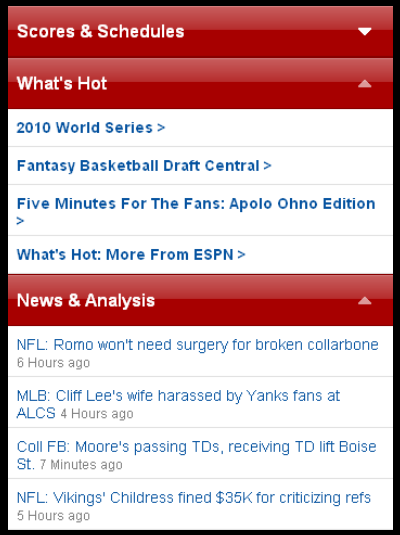


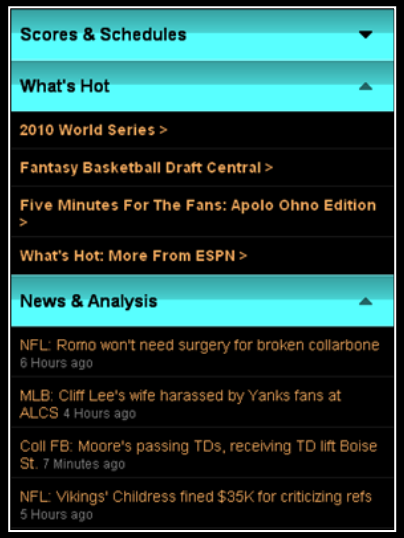
Color Transformation of Images

3 Keep Color Consistency for Each Website

Color Consistency per Website

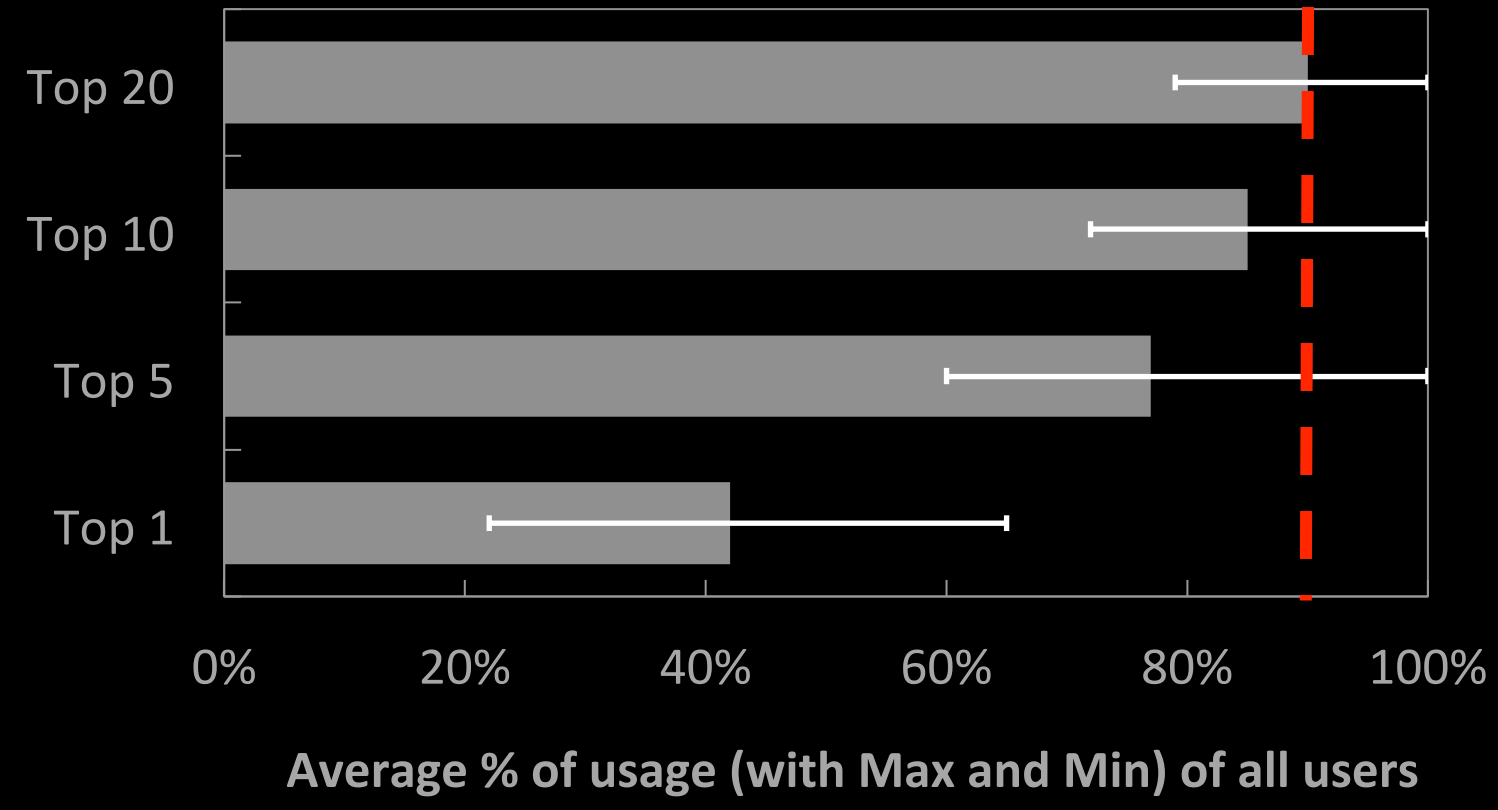






Top 20 websites contribute **90%**

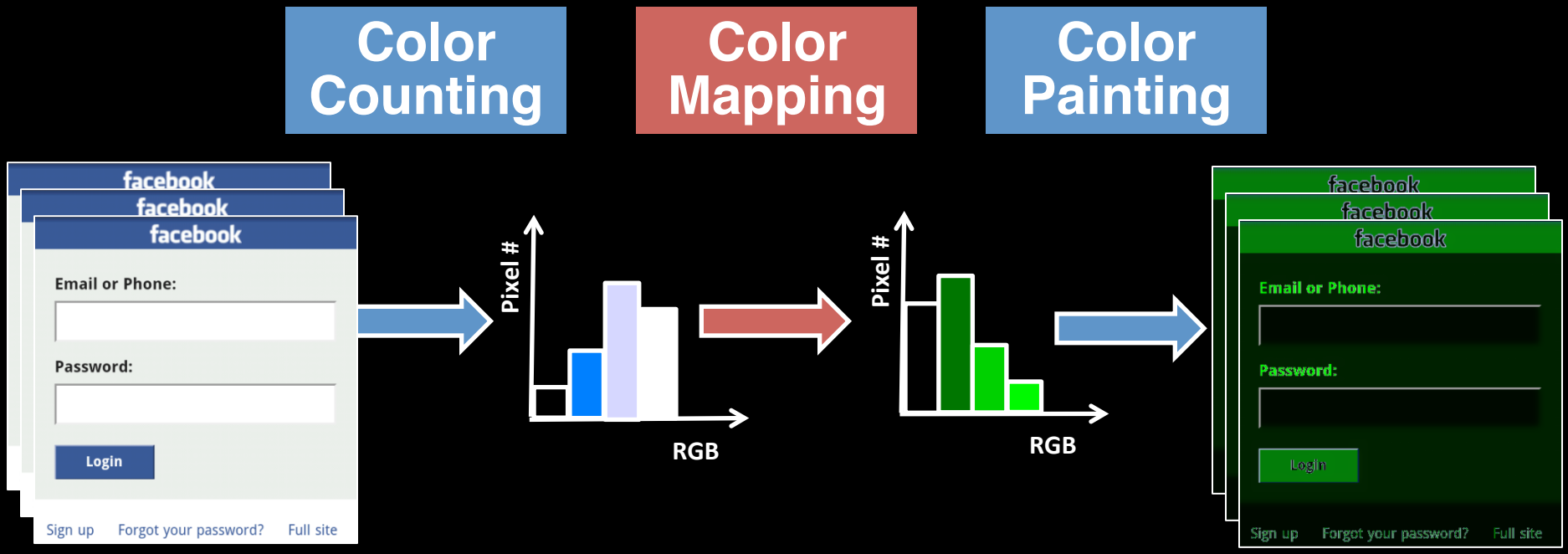
of the webpages visited by each user



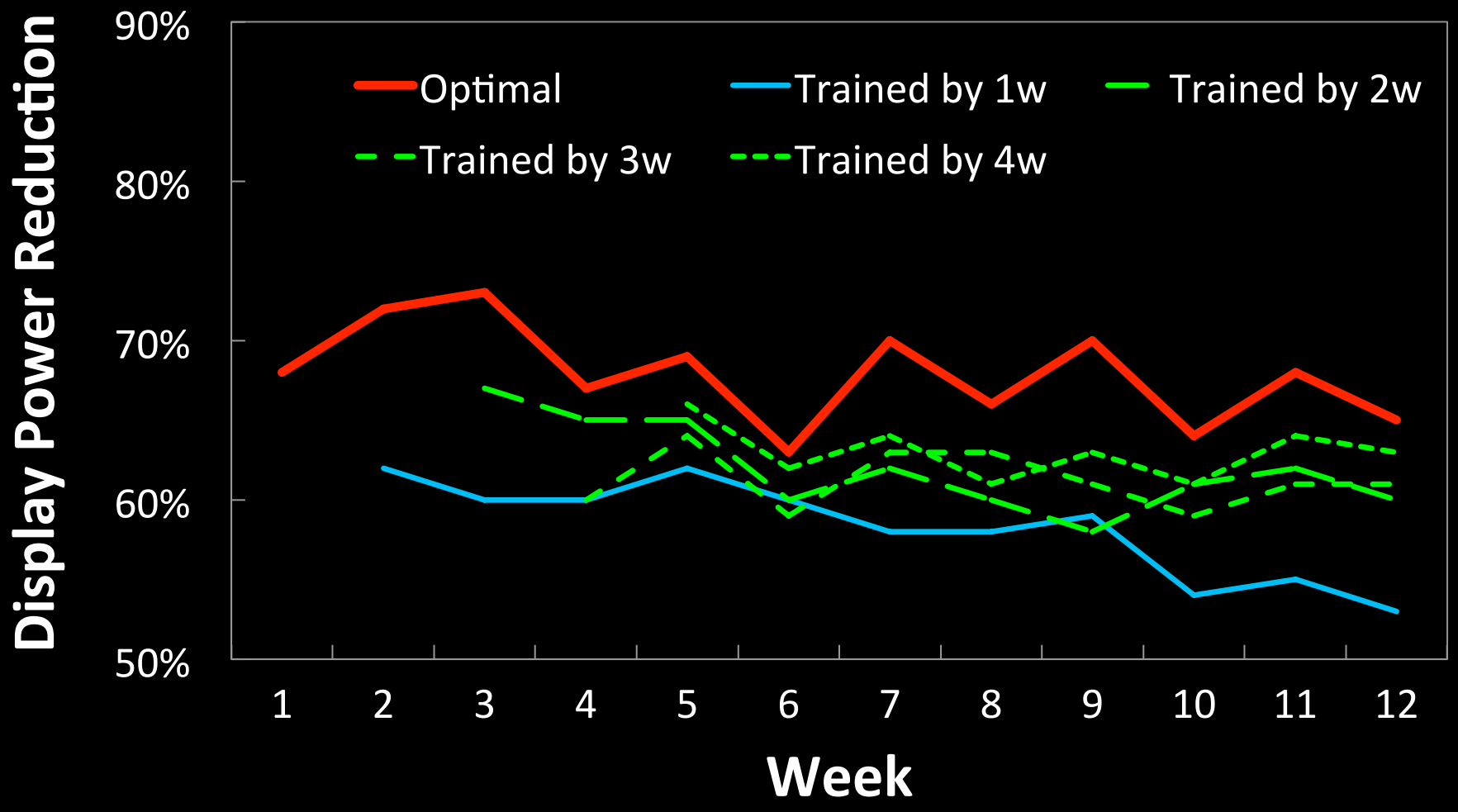
LiveLab: A field study (25 iPhone users; 12 months)

4 Calculate Color Maps Offline

Color Transformation of GUI Objects



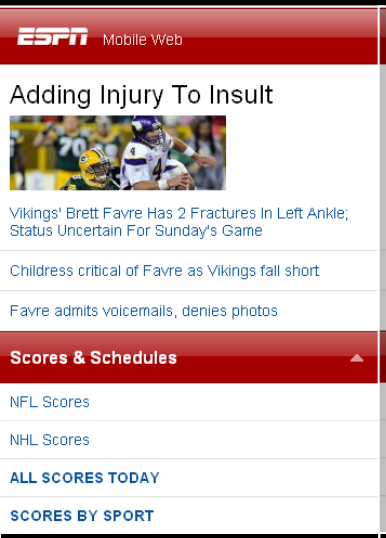
2 Weeks of training work for **3 Months**



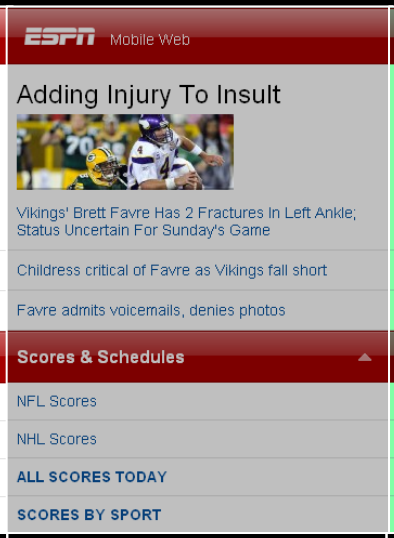
http://confabulator.blogspot.com/2007/01/how-little-web-sites-have-changed-over.html

5
Give User Options

20 Participants



Original



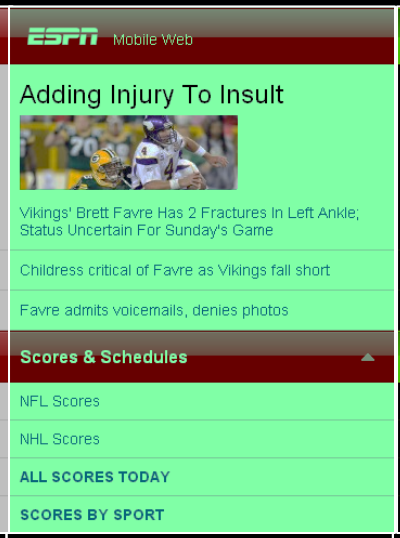
Dark

$R' = \lambda R$

$G' = \lambda G$

$B' = \lambda B$

↓ 25%



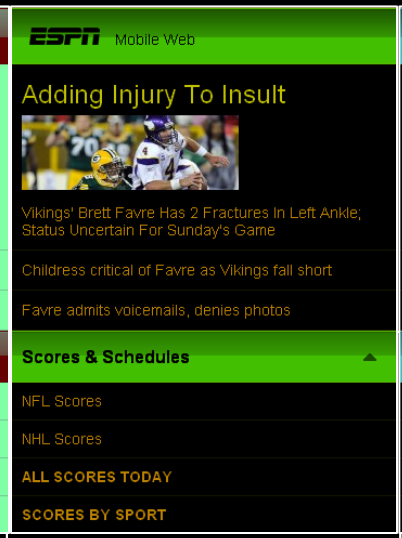
Green

$R' = \lambda_R R$

$G' = \lambda_G G$

$B' = \lambda_B B$

↓ 34%



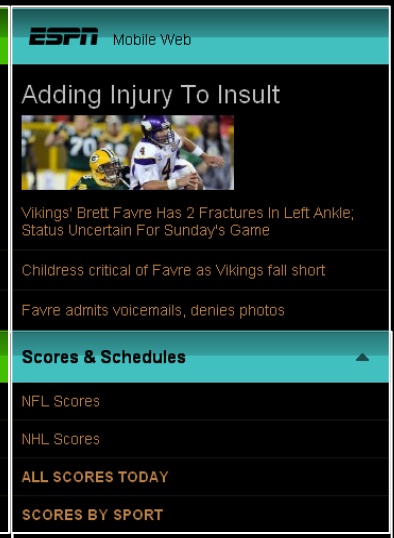
Arbitrary

$R' = R^*$

$G' = G^*$

$B' = B^*$

↓ 72%



Inversion

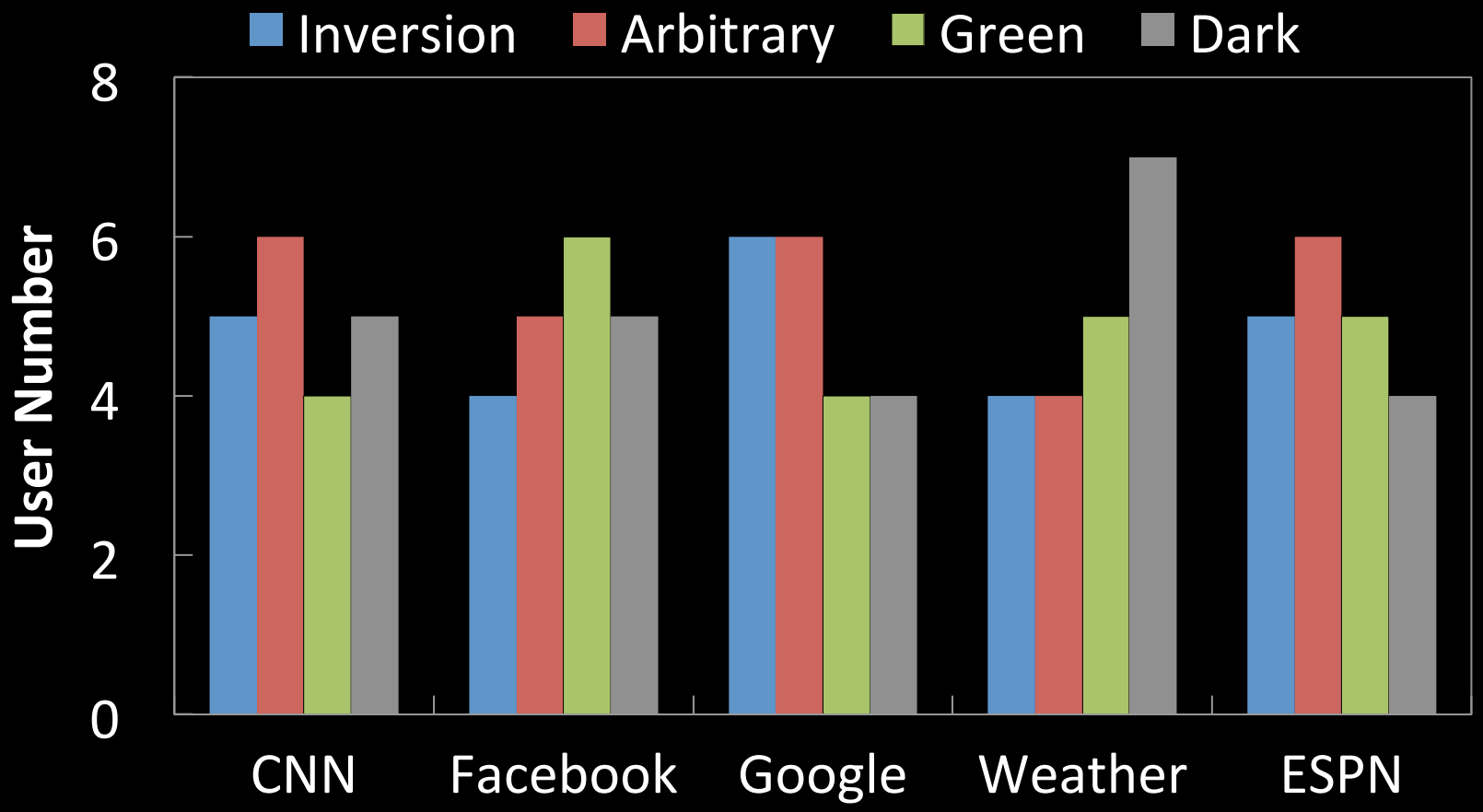
$R' = \lambda(1-R)$

$G' = \lambda(1-G)$

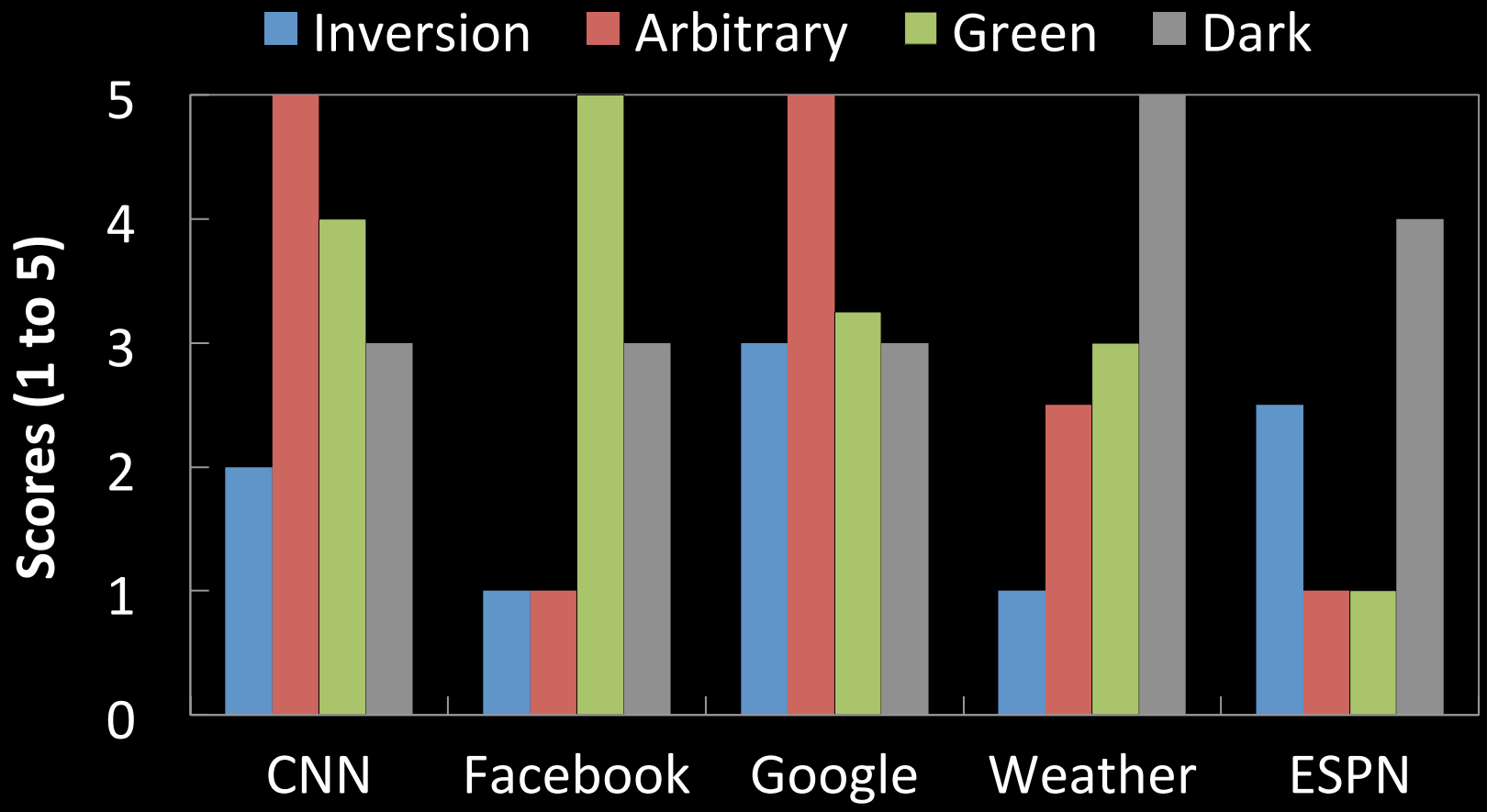
$B' = \lambda(1-B)$

↓ 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
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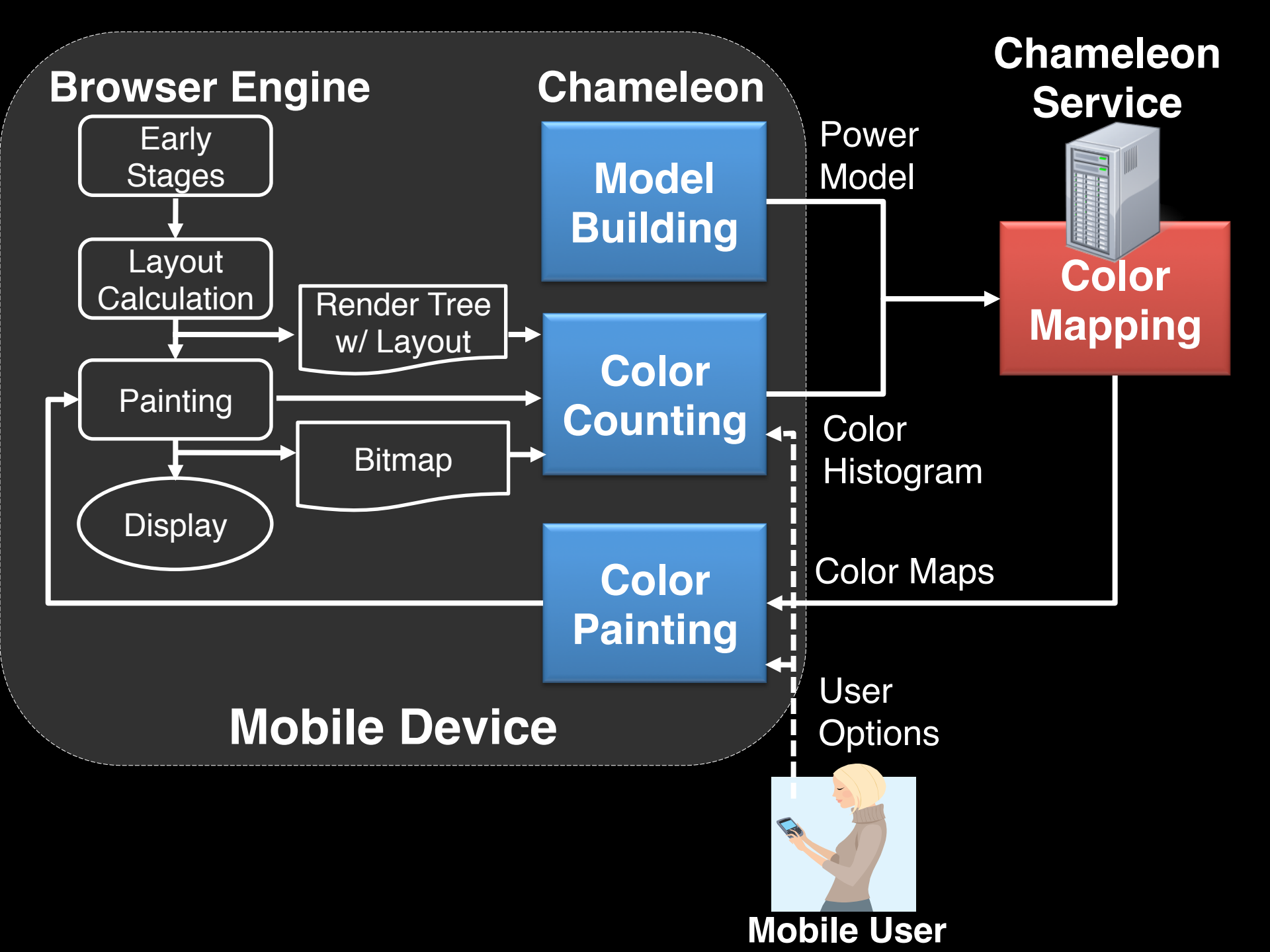
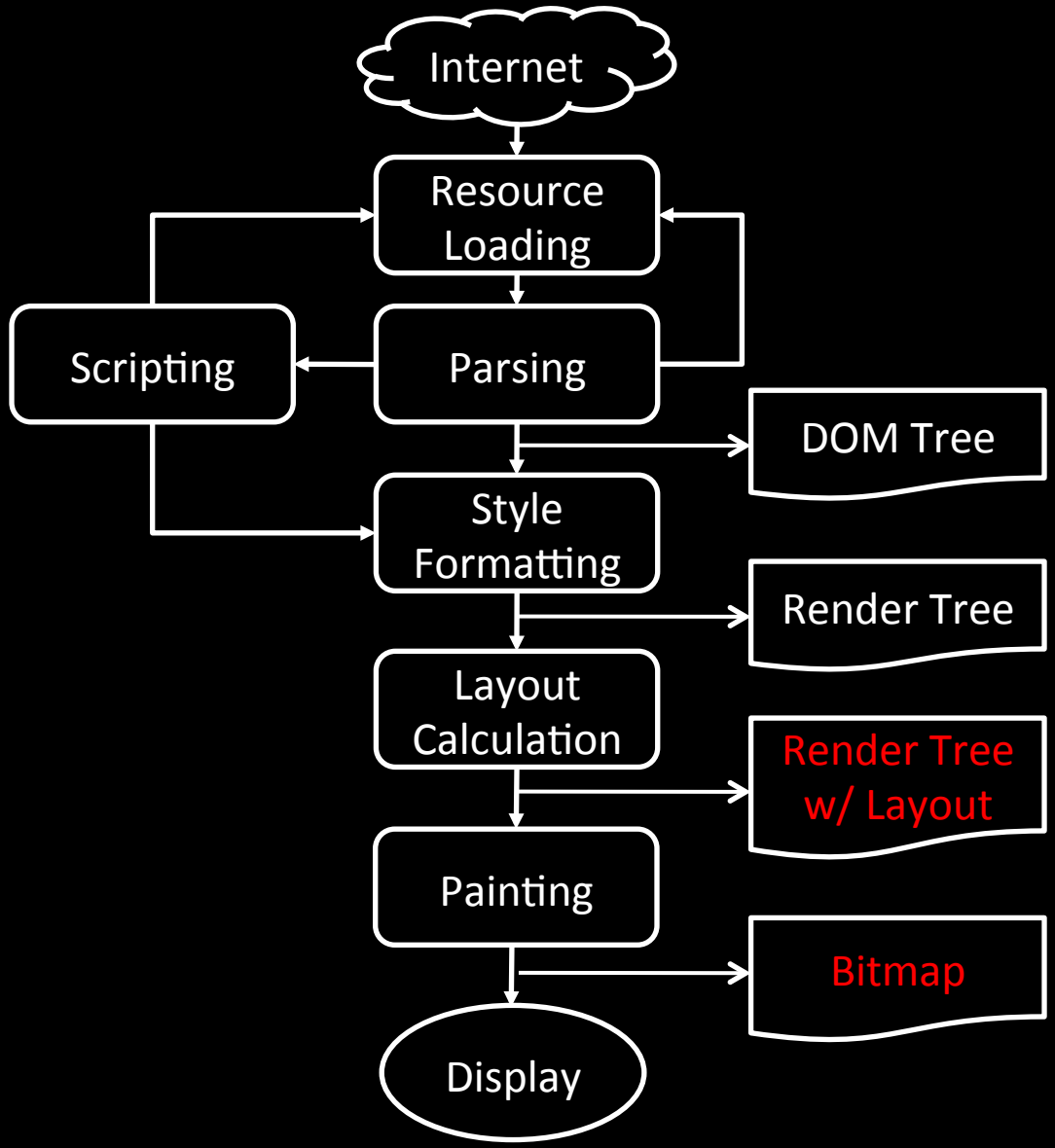
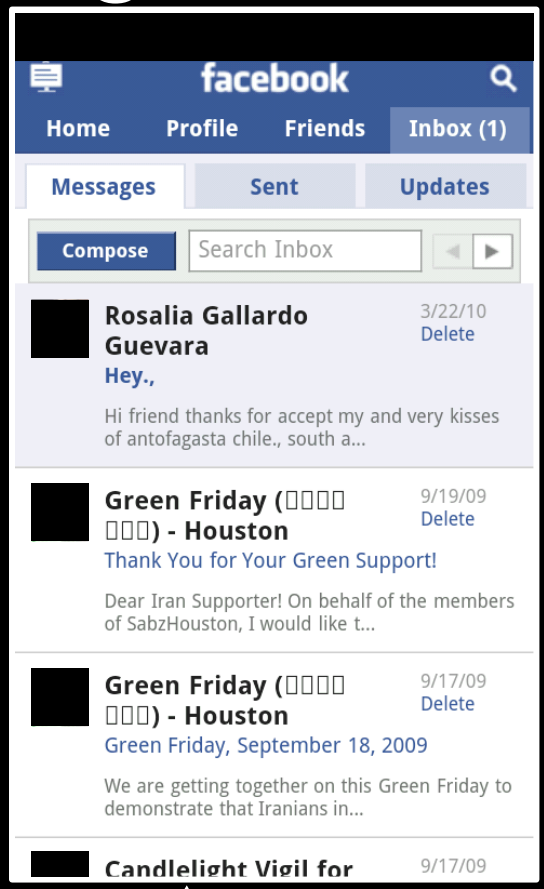
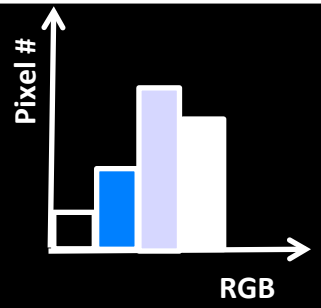

Browser Engine
Chameleon
Chameleon Service
Early Stages
Layout Calculation
Painting
Display
Render Tree w/ Layout
Bitmap
Model Building
Color Counting
Color Painting
Power Model
Color Mapping
Color Histogram
Color Maps
User Options
Mobile Device
Mobile User

Color Counting

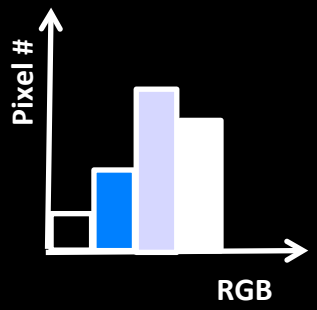


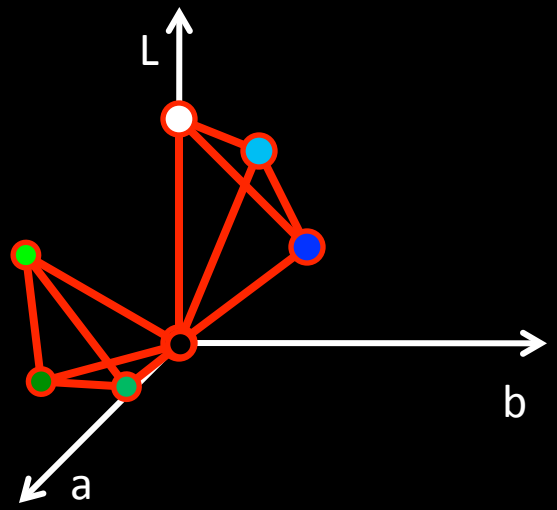




Mapping Optimization

- Input:





- Output: **RGB**

R'G'B'

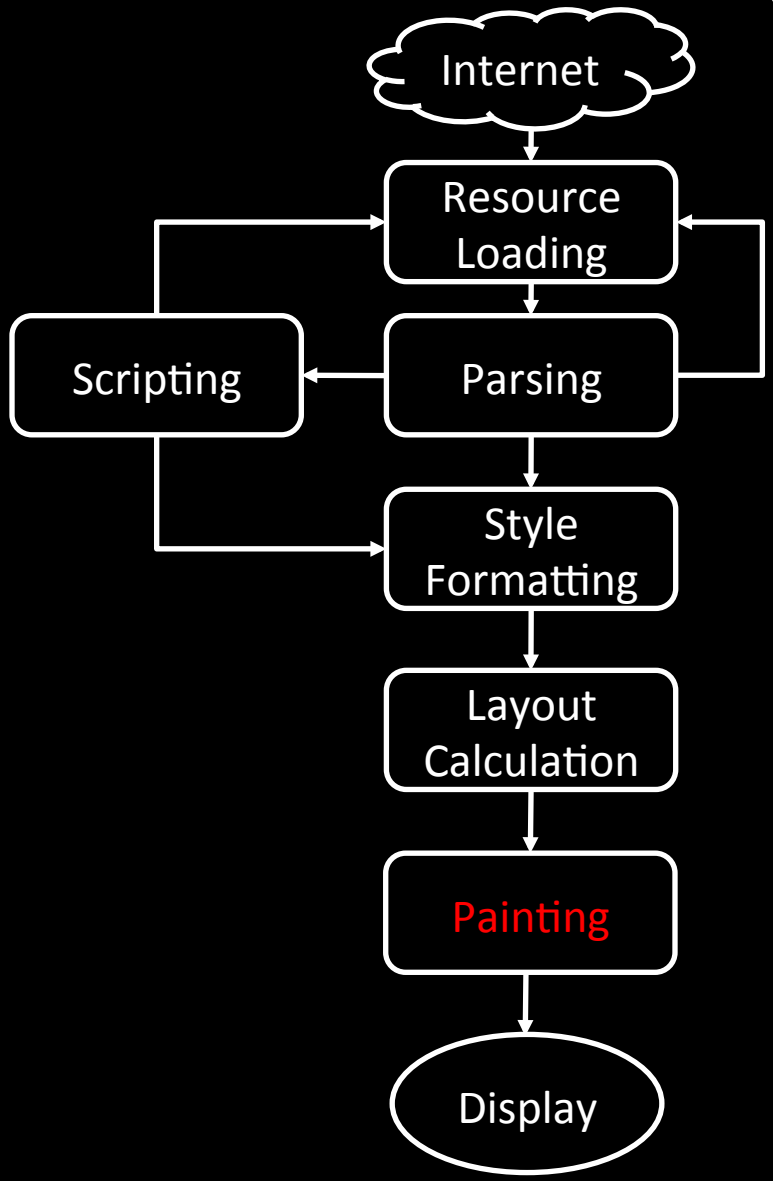
- Algorithm
  - Arbitrary

    min Power

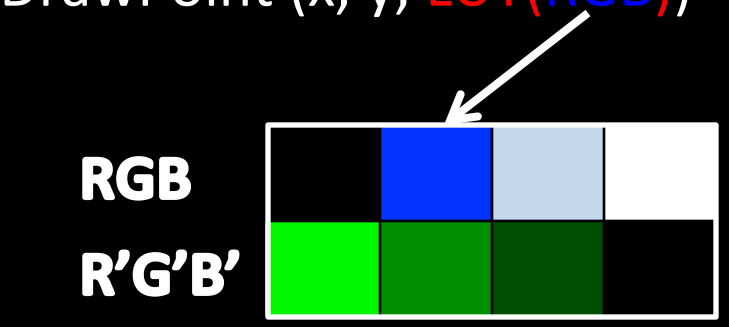
    s.t. for any i, j

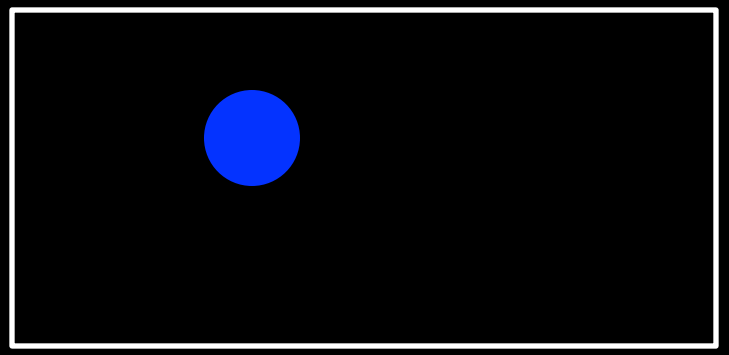
    $\Delta E((L_i', a_i', b_i'), (L_j', a_j', b_j')) = \lambda \cdot \Delta E((L_i, a_i, b_i), (L_j, a_j, b_j))$

Painting GUI Objects



DrawPoint (x, y, LUT(RGB))

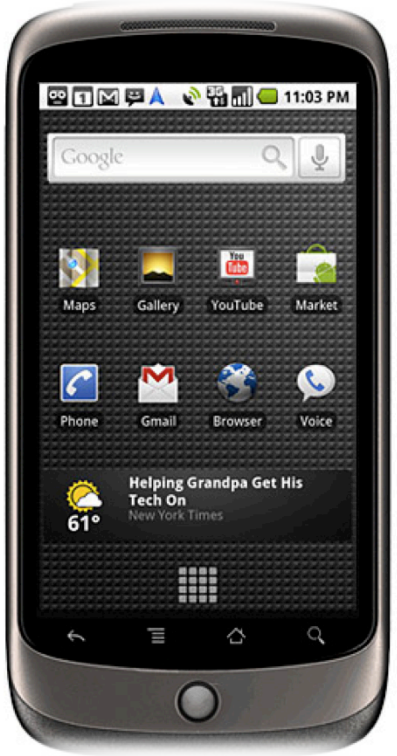




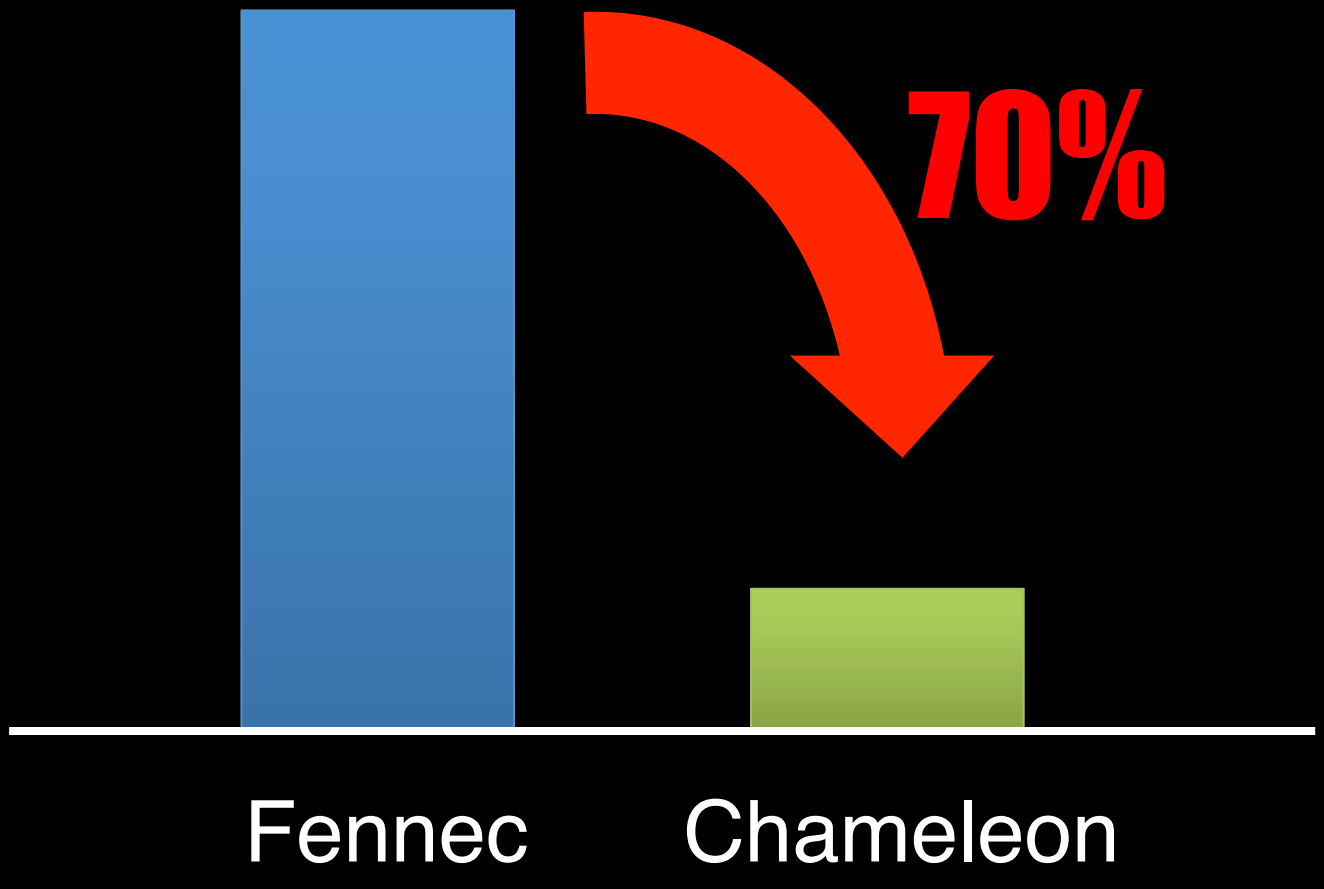
Implementation

Fennec

Mozilla for Mobile

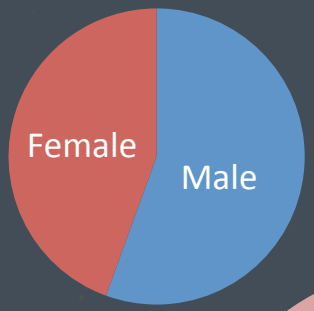


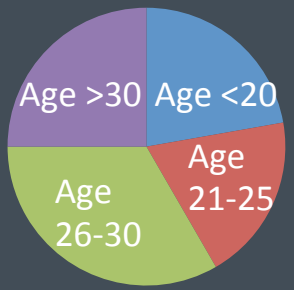
Display Power Consumption

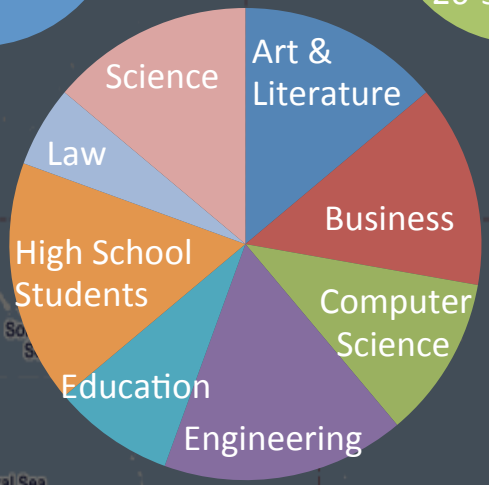


A Field Trial

36 Participants; 3 Months

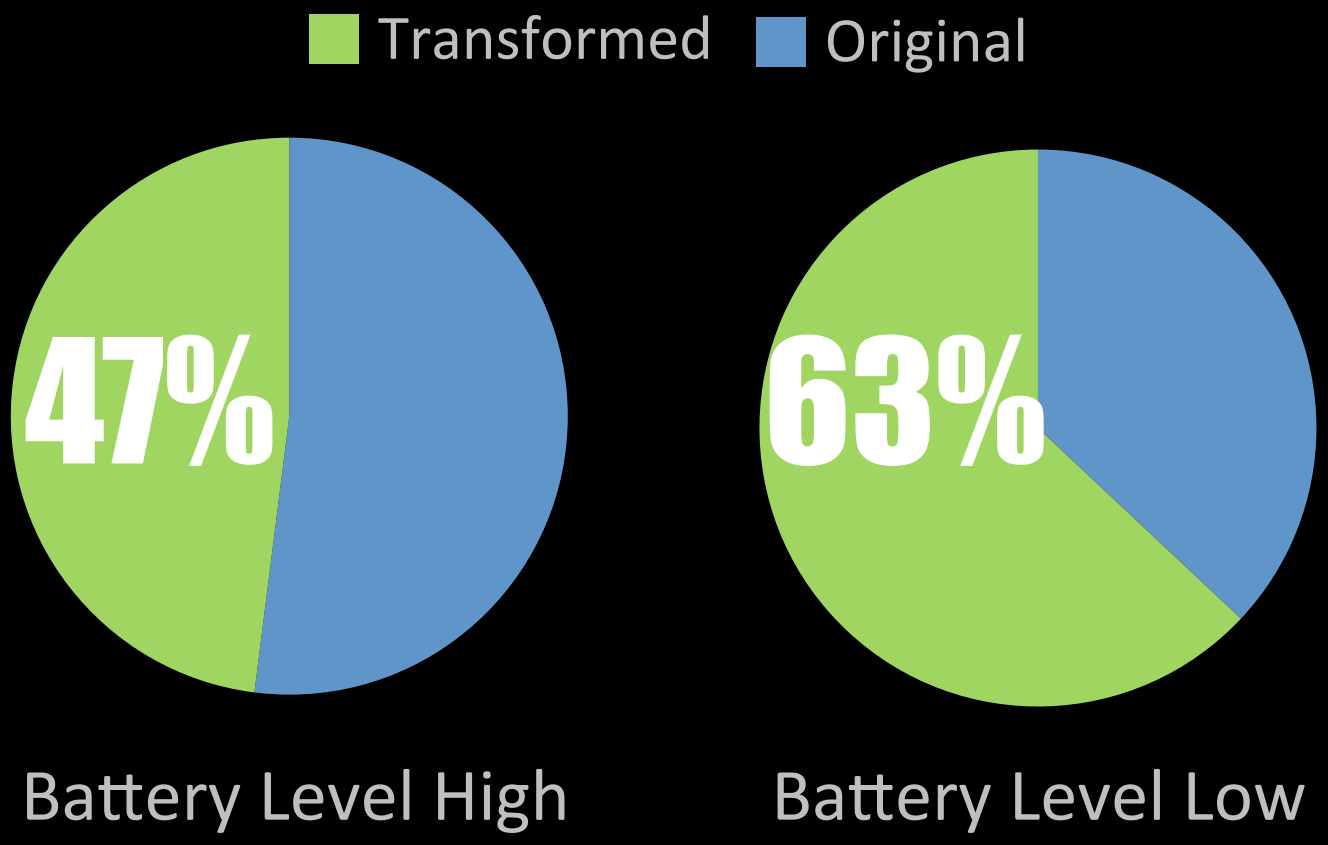






Map data ©2011 Europa Technologies, Geocentre Consulting, INEGI, Tele Atlas, MapLink, Whereis(R), Sensis Pty Ltd - Terms of Use

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

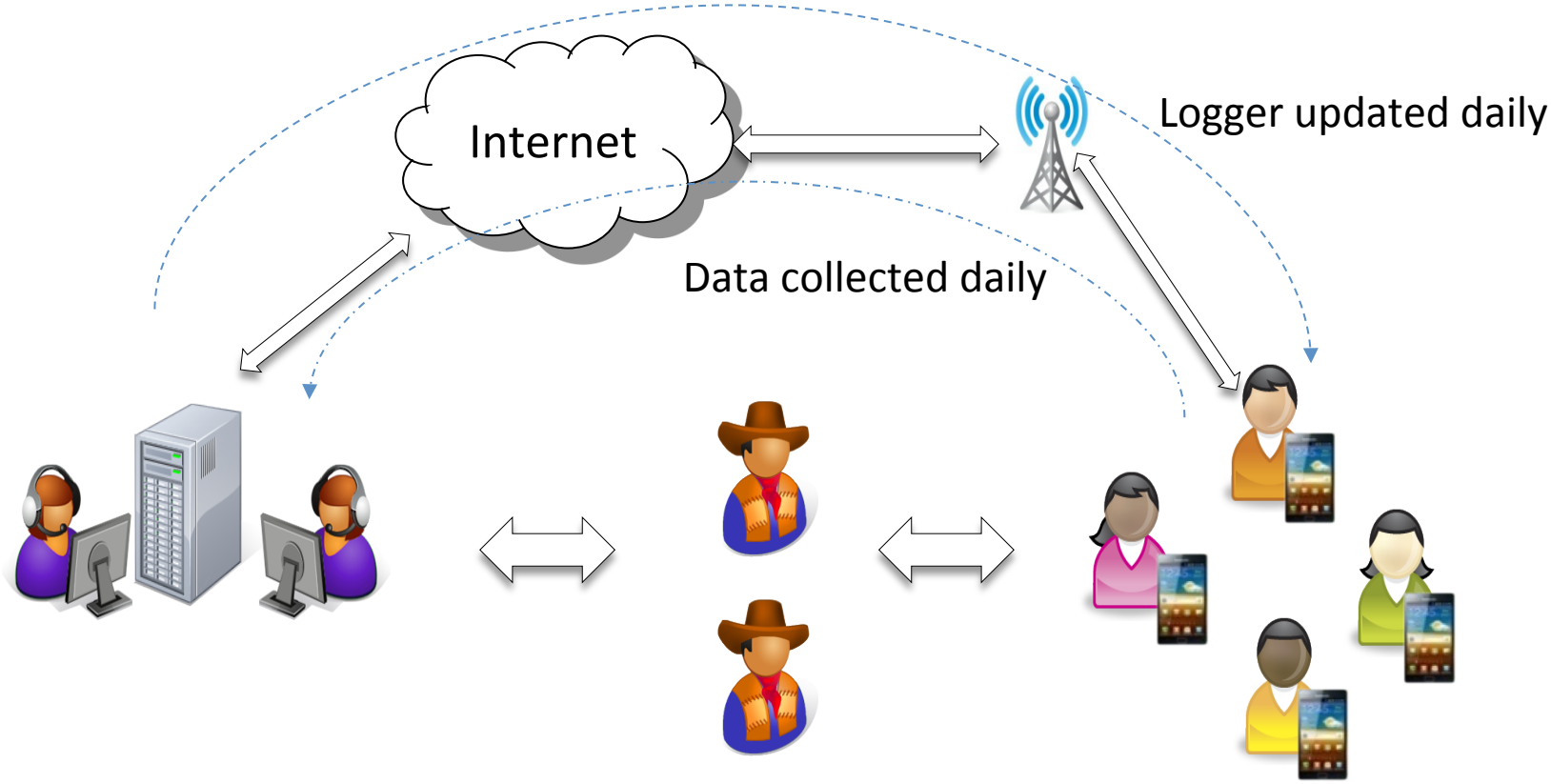
http://www.ruf.rice.edu/~dongmian/Chameleon.html

Backup

Outline

1. Motivation
2. Theory
3. Design
4. Evaluation
5. Conclusion

LiveLab: 25 users; 12 months

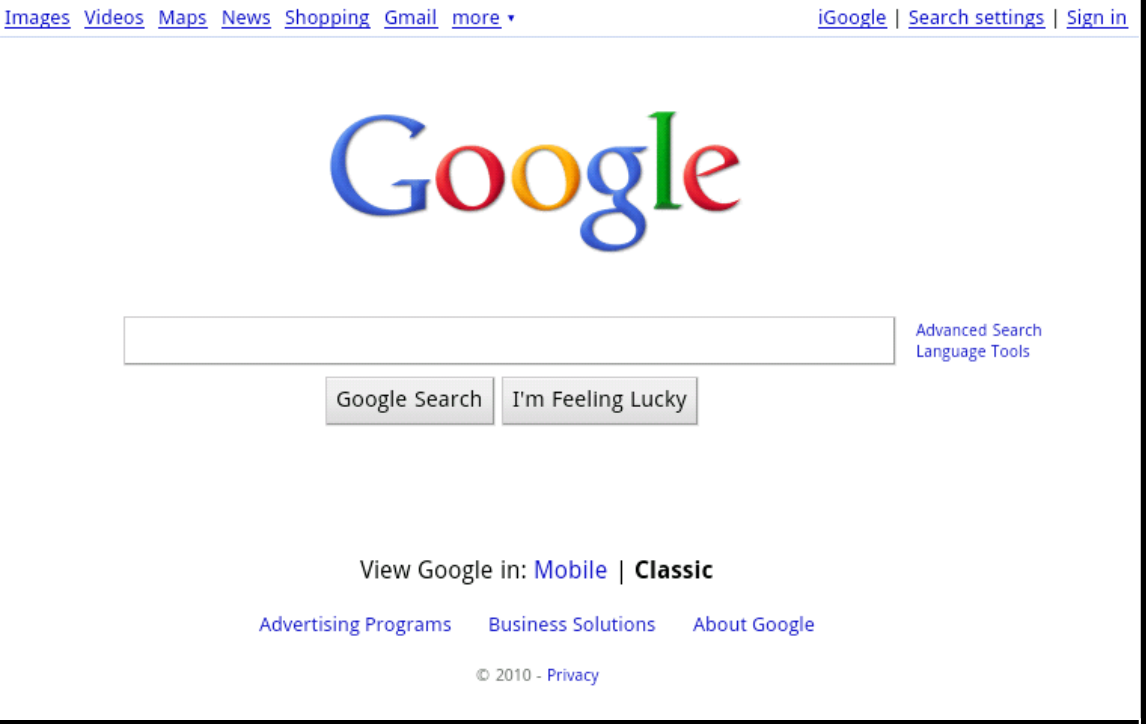


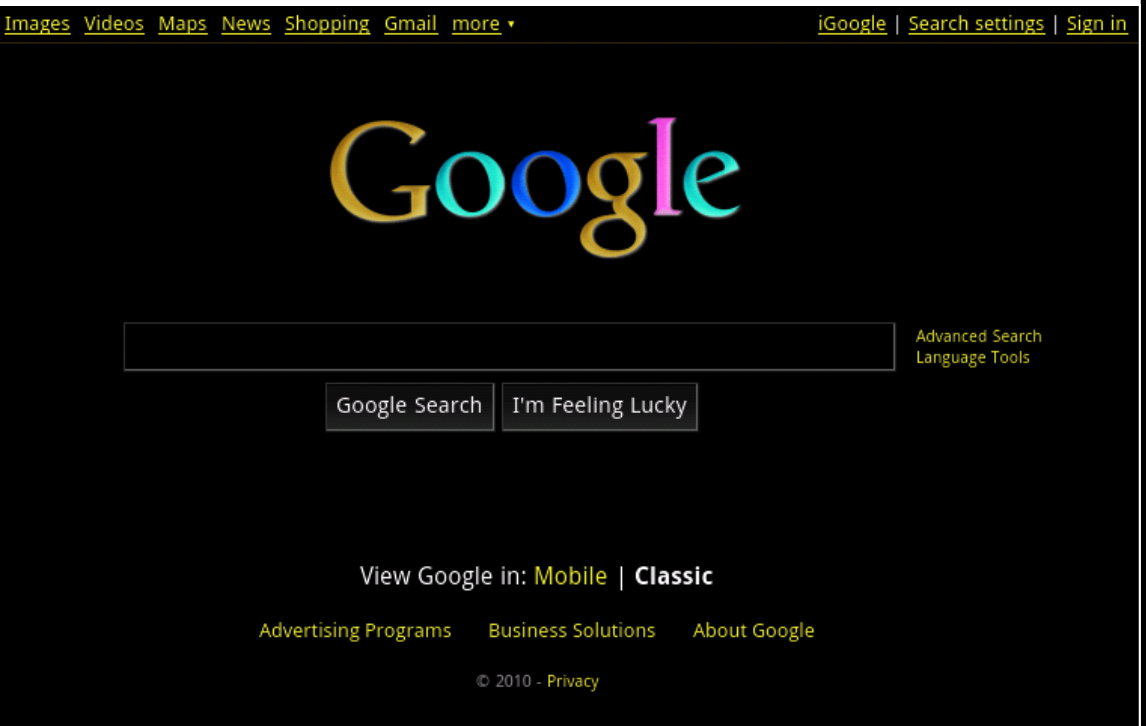
Software team deals with the logger and data without knowing the participants

Human factor team interacts with the participants

Participants use the instrumented phone in the field

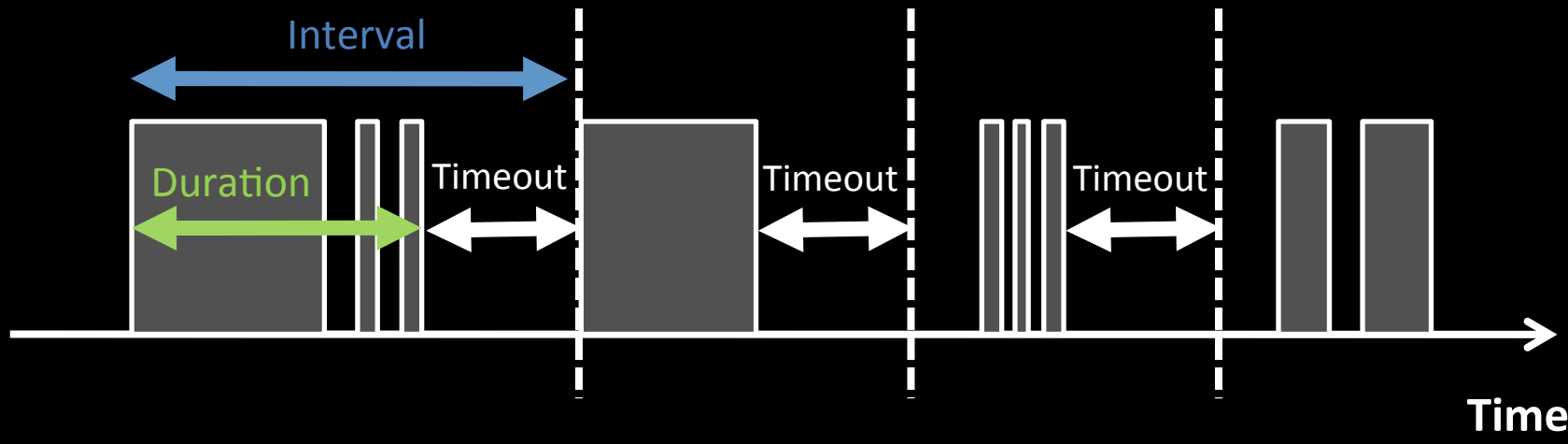
C. Sheperd, "LiveLab: measuring wireless networks and smartphone users in the field," 2010

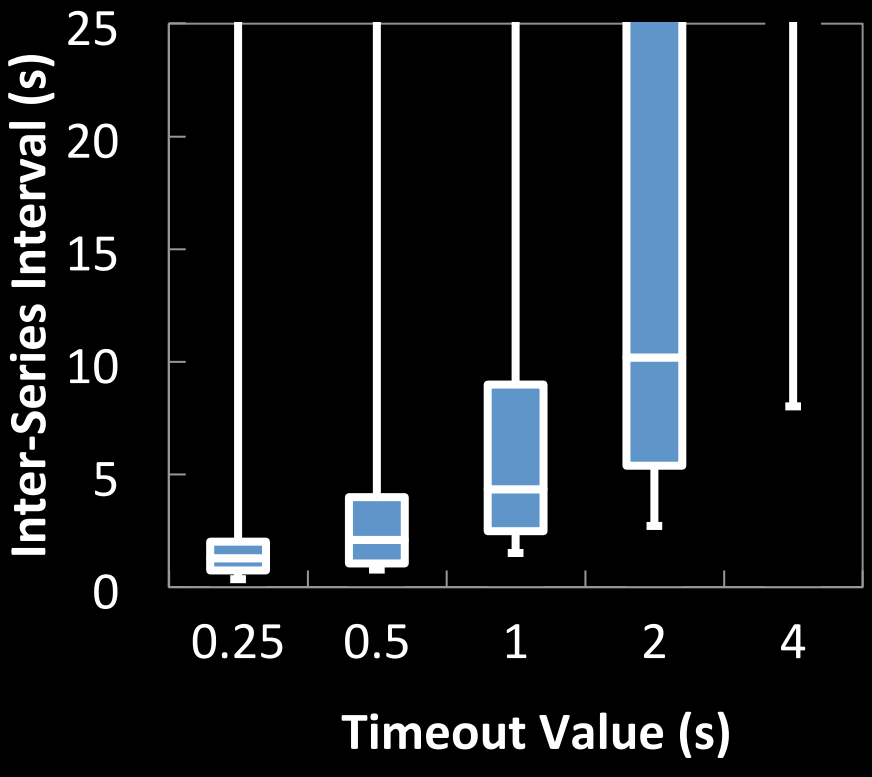


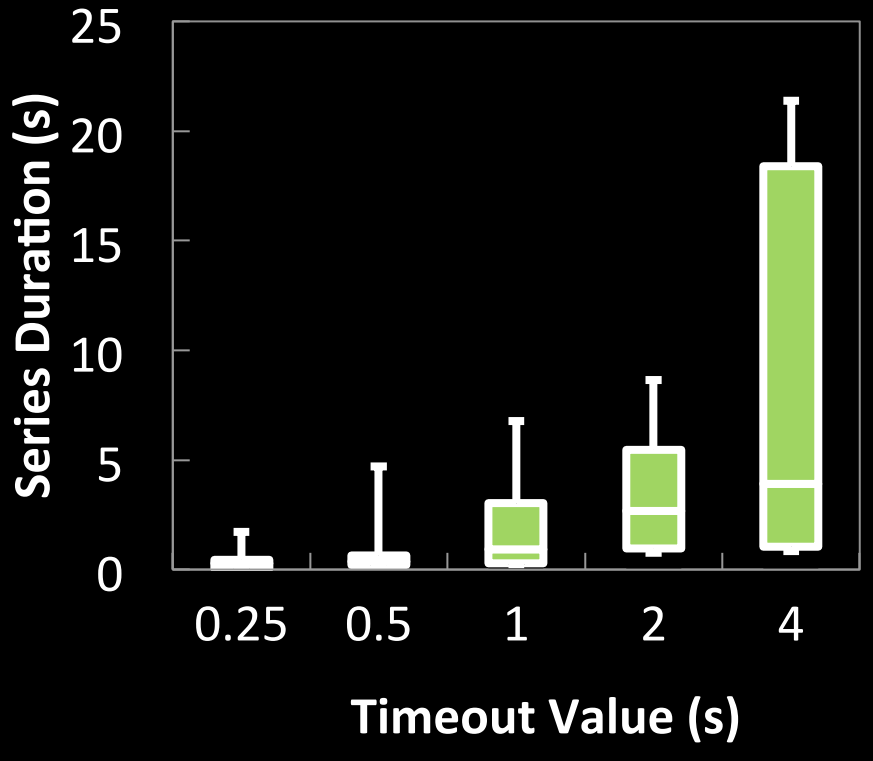


Logo Images

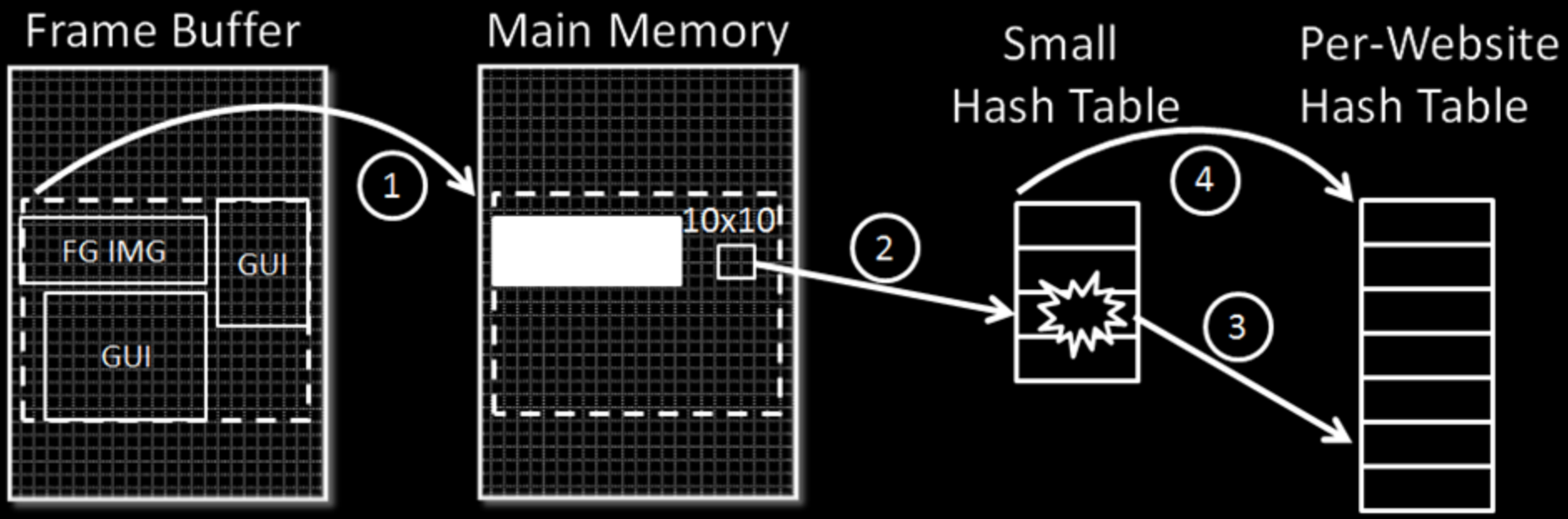
Background Images


Interval
Duration
Timeout
Timeout
Timeout
Time

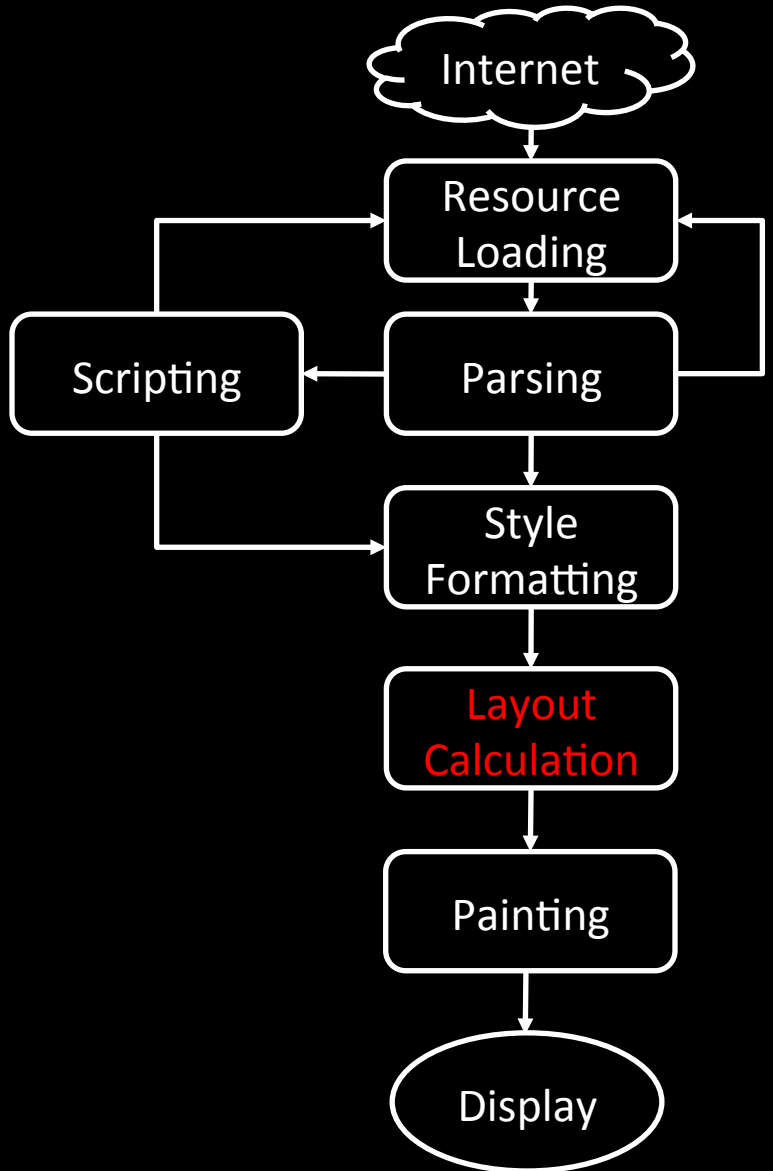

Inter-Series Interval (s)
25
20
15
10
5
0
0.25
0.5
1
2
4
Timeout Value (s)

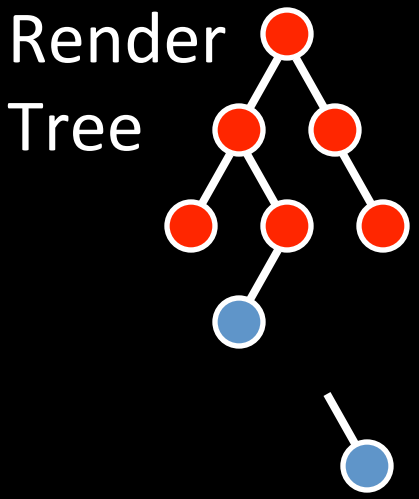

Series Duration (s)
25
20
15
10
5
0
0.25
0.5
1
2
4
Timeout Value (s)

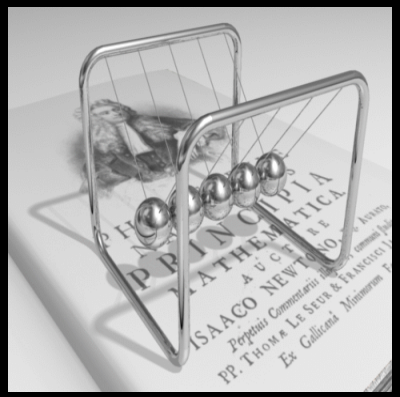
Counting Pixels

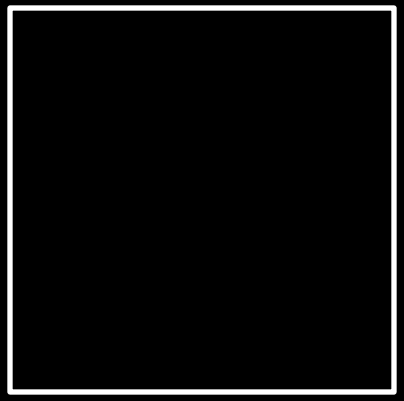


Videos

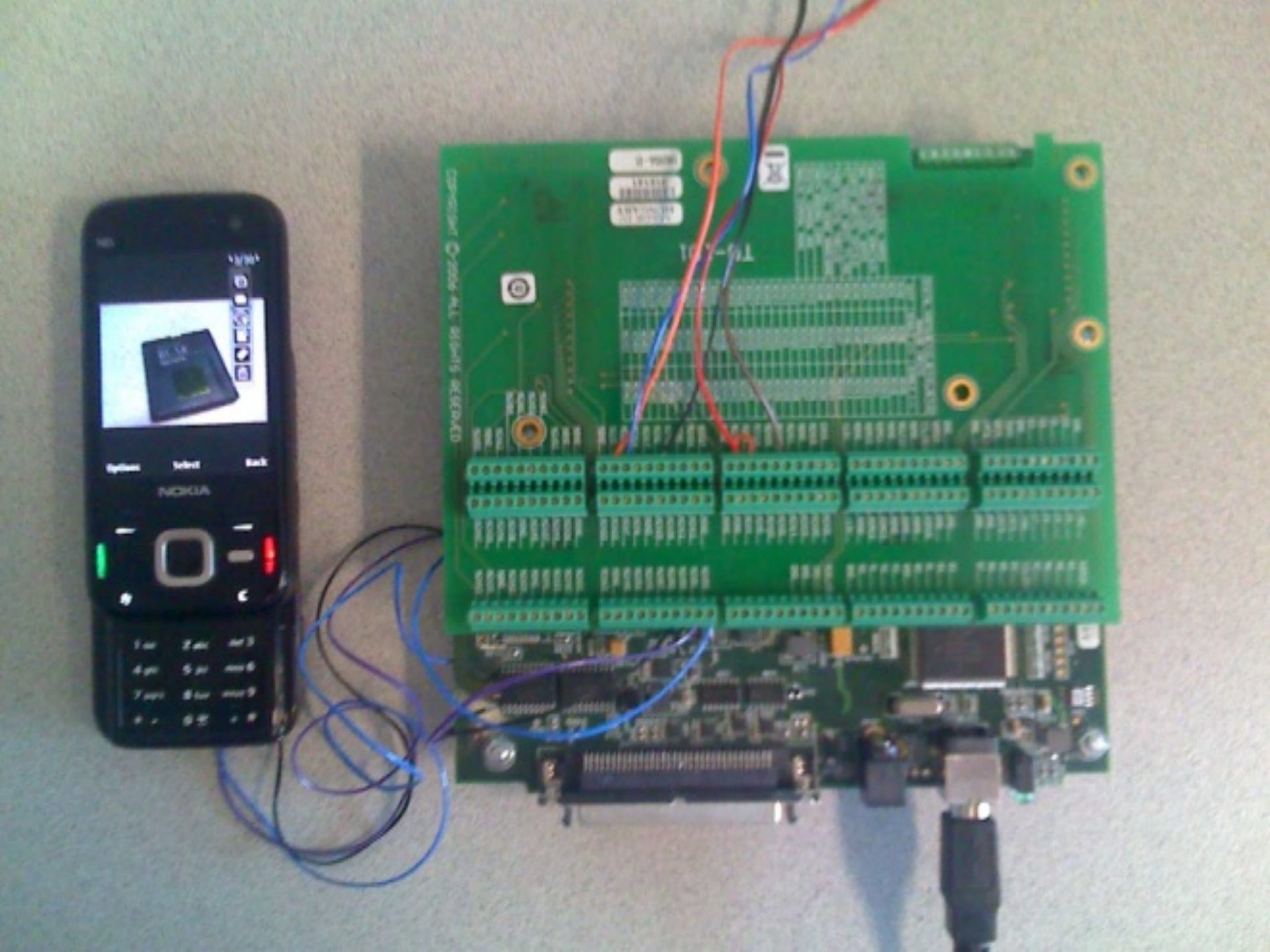


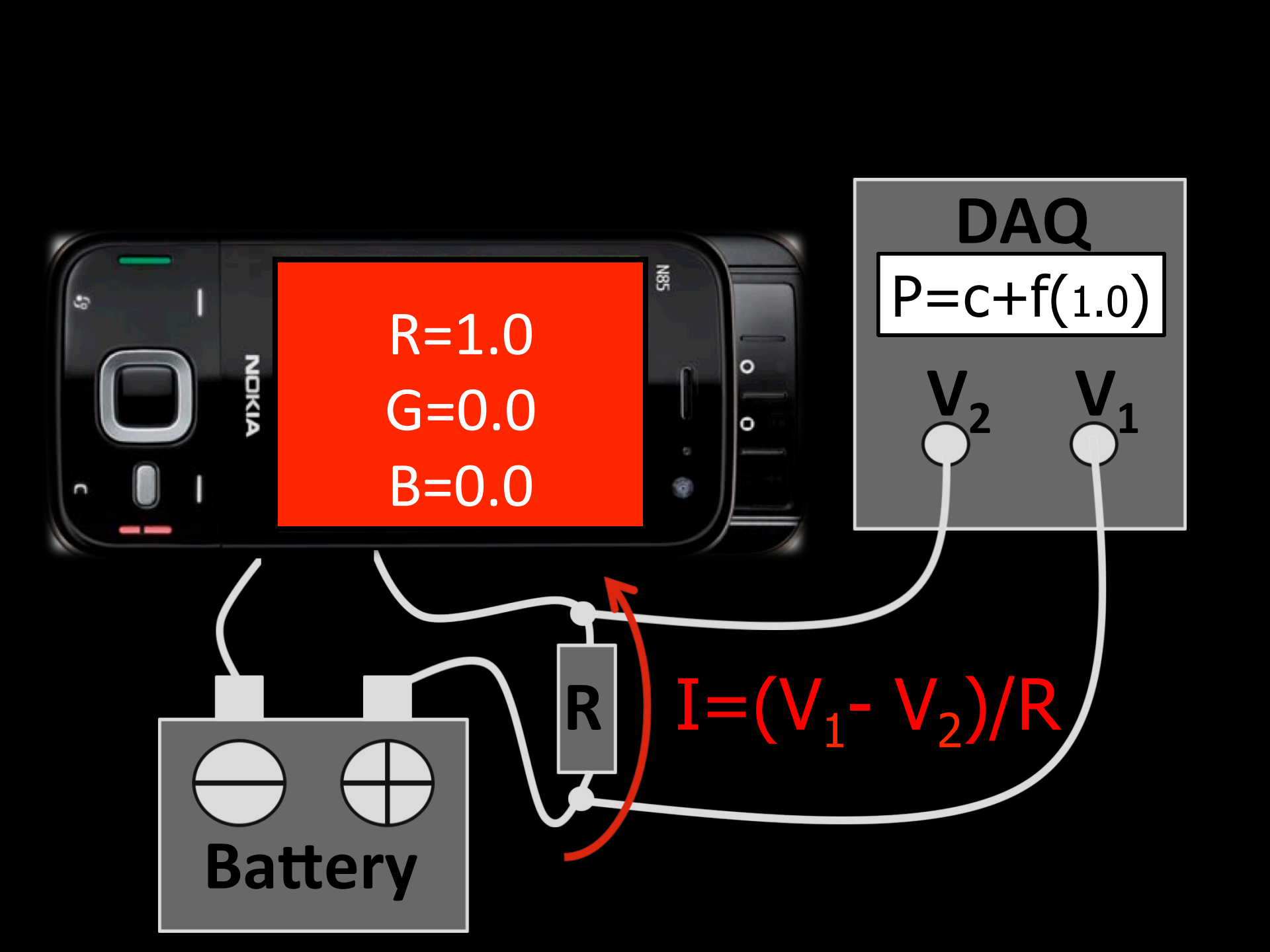




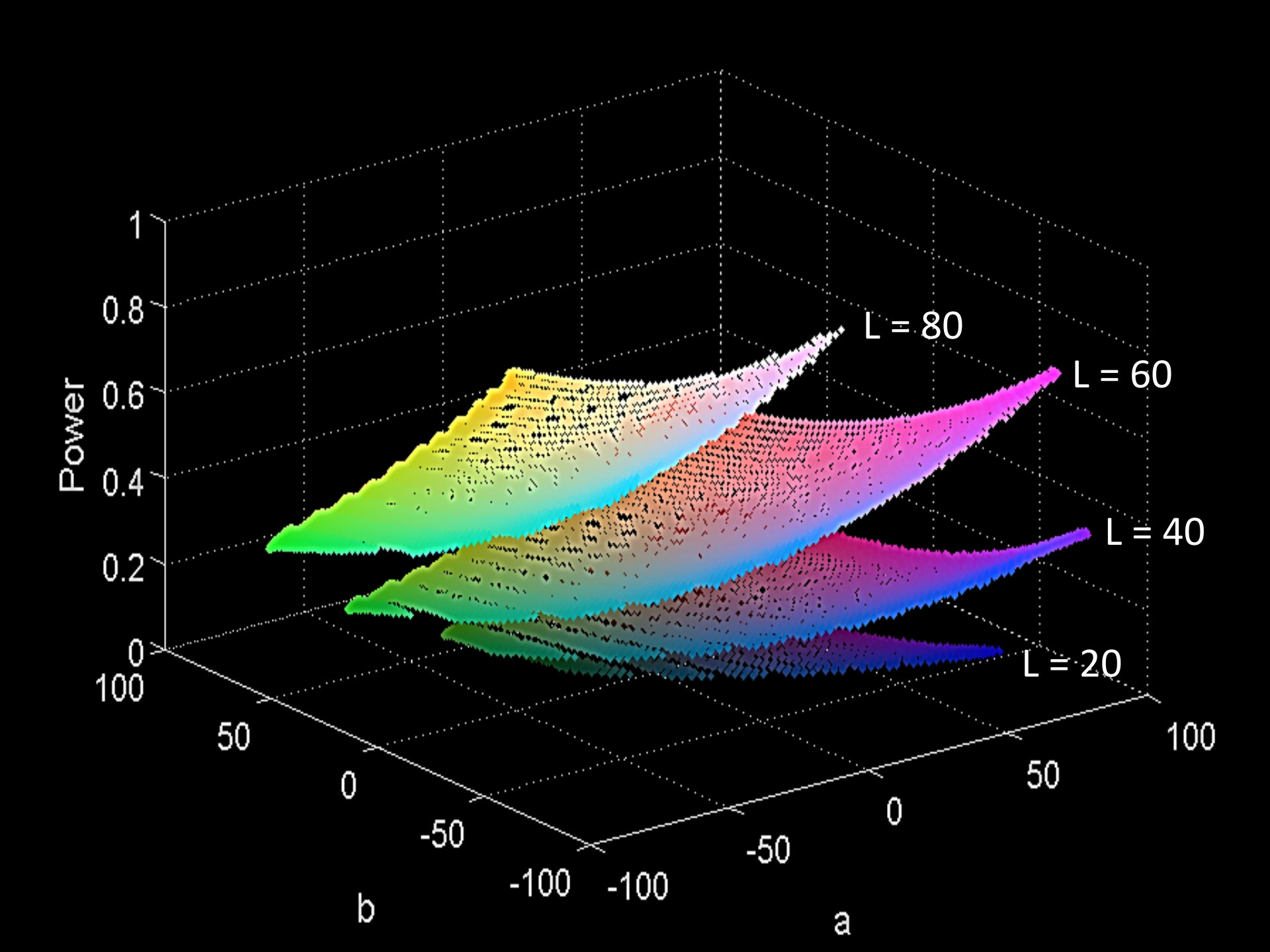


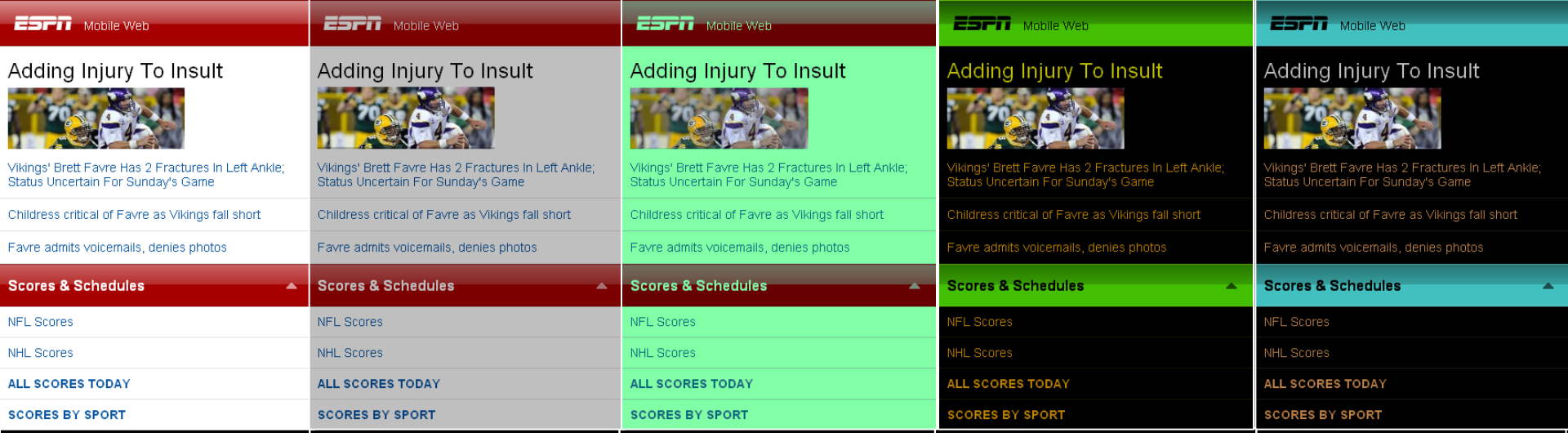
alpha=50%


Options
Select
Back
NOKIA


DAQ
P=c+f(1.0)
V2
V1
R=1.0
G=0.0
B=0.0
NOKIA
N85
R
I=(V1- V2)/R
Battery

Web Browser is among the most often used applications


Power
1
0.8
0.6
0.4
0.2
0
L = 80
L = 60
L = 40
L = 20
100
50
0
-50
-100
b
-100
-50
0
50
100
a



Original

Dark

$R' = \lambda R$

$G' = \lambda G$

$B' = \lambda B$

↓ 25%

Green

$R' = \lambda_R R$

$G' = \lambda_G G$

$B' = \lambda_B B$

↓ 34%

Arbitrary

$R' = R^*$

$G' = G^*$

$B' = B^*$

↓ 72%

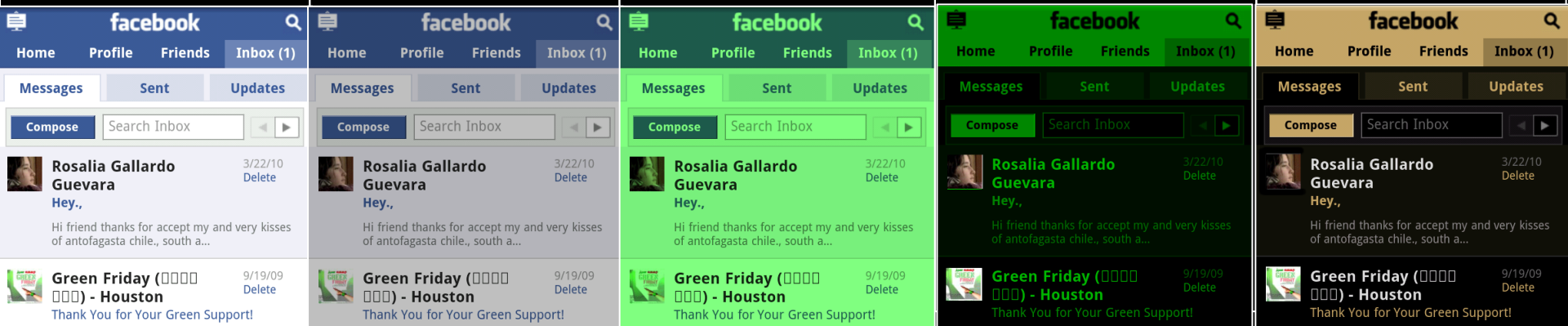
Inversion

$R' = \lambda(1-R)$

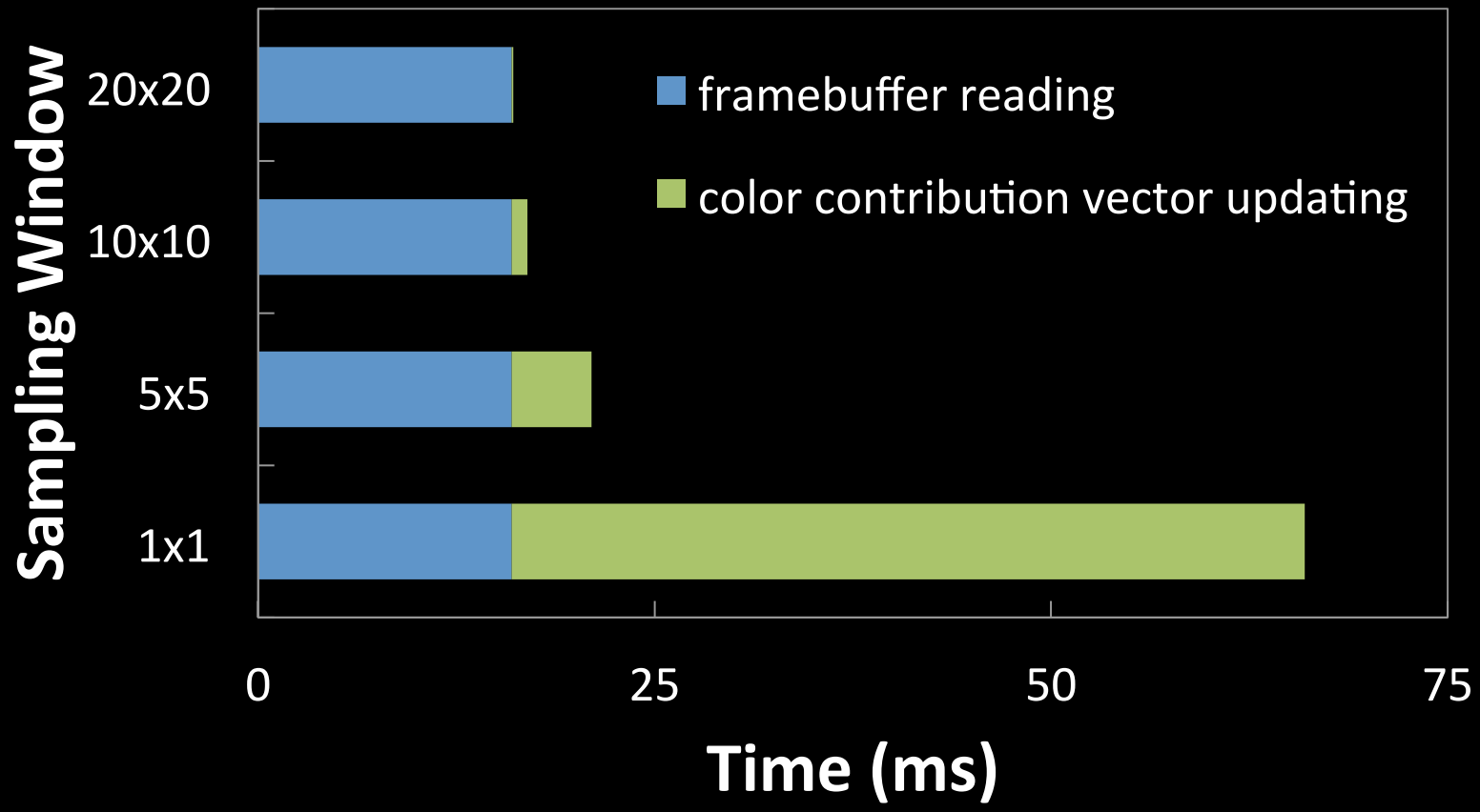
$G' = \lambda(1-G)$

$B' = \lambda(1-B)$

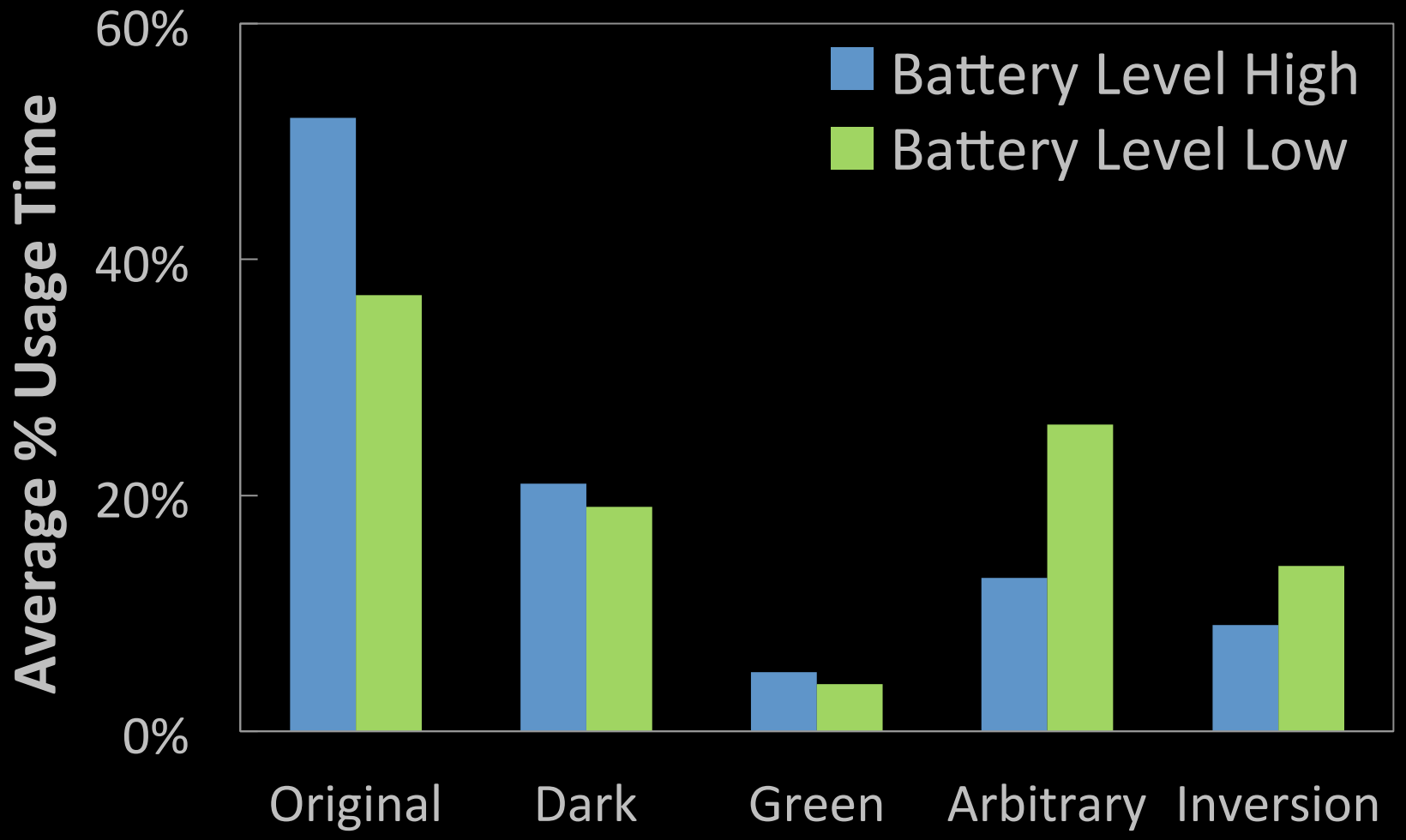
↓ 66%



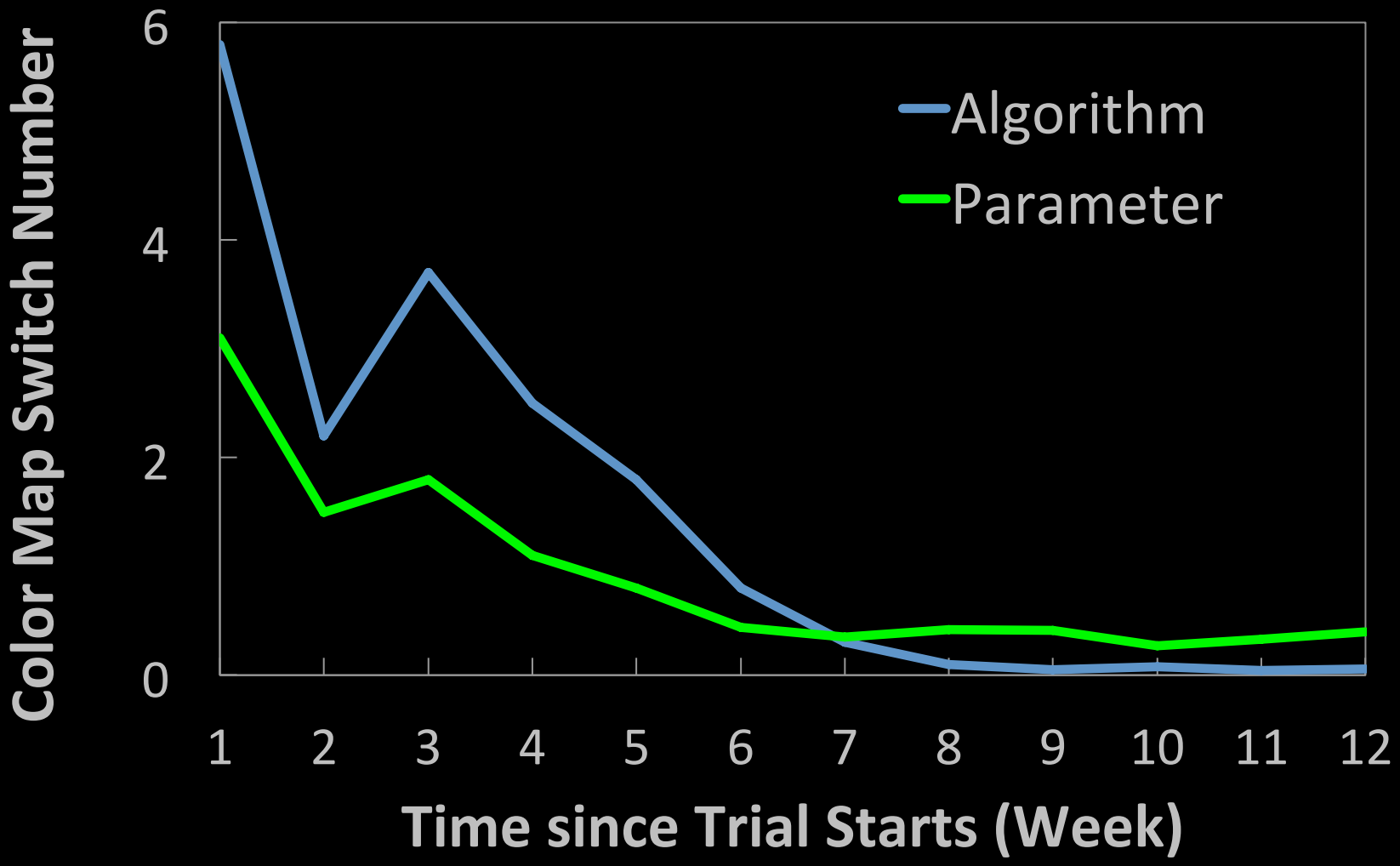
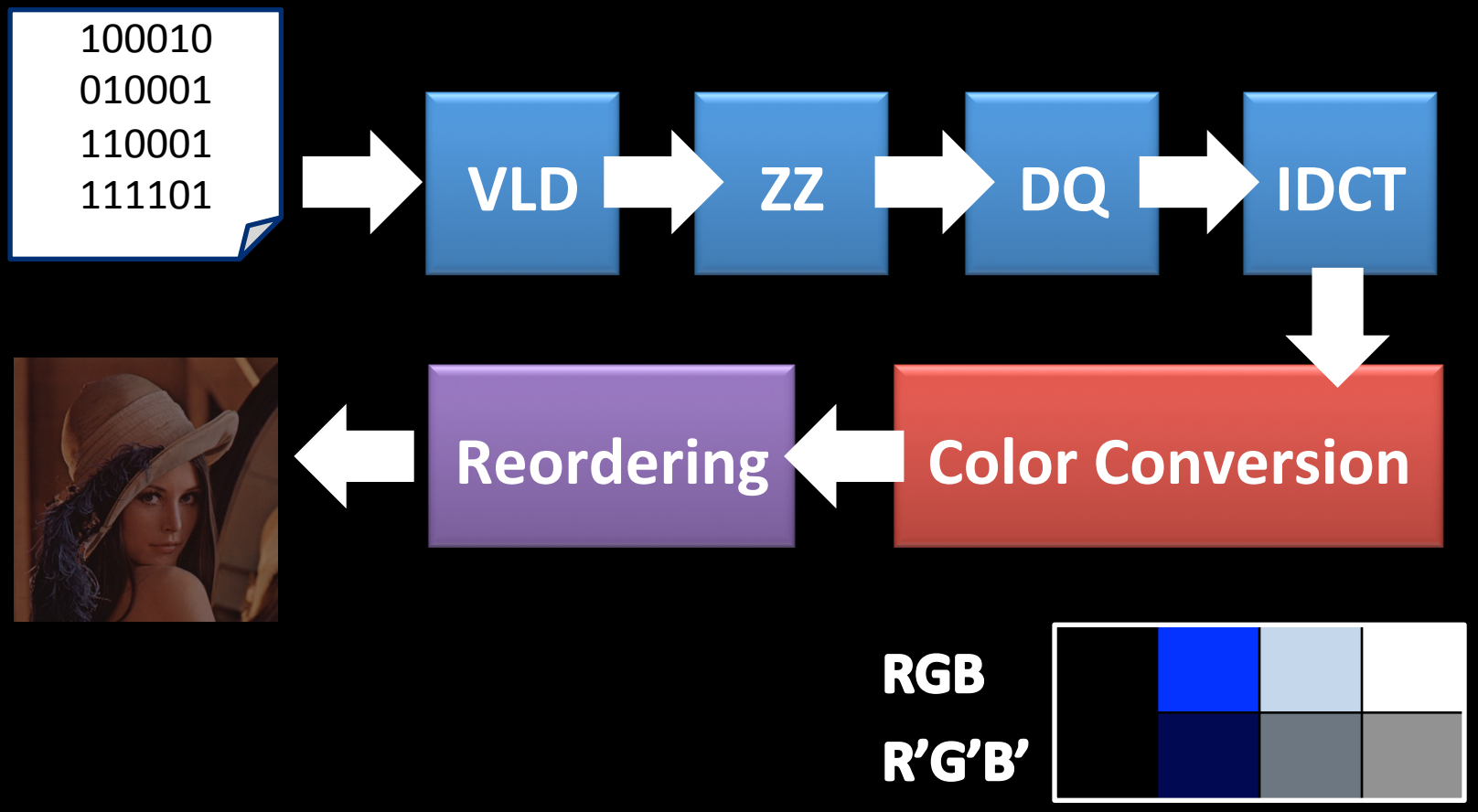
Delay


Sampling Window
20x20
10x10
5x5
1x1
framebuffer reading
color contribution vector updating
0
25
50
75
Time (ms)

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



Favorite Color Maps are **Decided** in **Six Weeks**



Painting Images