

Ubiquitous and Mobile Computing

CS 528: Focus: A Usable & Effective Approach to OLED Display Power Management

Bin Yu,
Zhaojun Yang

*Computer Science Dept.
Worcester Polytechnic Institute (WPI)*





Introduction

- **What**
- *Focus:* a system for effectively and efficiently reducing power consumption of OLED displays on smartphones.
- **Why**
- OLED consumes up to 67% of the total device power consumption.
- Larger displays such as the 4 inch iPhone 5, 4.8 inch Galaxy S III, 5 inch Galaxy S IV, and the 5.3 inch Galaxy Note II

Introduction



- **How**
- 1) Convert the displayed colors into colors that consume less energy.
- 2) Darken or turn off portions of the displayed contents that are less interesting to the user ★
- Goal: reducing the power consumption, preserving the user experience.

Introduction



(a) BBC News (Original)



(b) With Focus "Default" Profile



(c) Facebook (Original)



(d) With Focus "Default" Profile



Related Work

- Reduce power consumption
 - Communication radio [4, 23]
 - Processing [2]
 - LCD backlight [1, 5, 7, 19]
 - OLED colour inversion [14, 20]
 - Colour-remapping [20,9]
 - Hardware-based solution [6, 21]

Approach



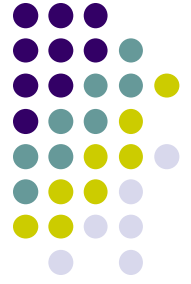
- Design requirements
 - User friendly: not affect the end user experience
 - Significant Power Savings
 - Generalisable: support all applications
 - Low computational requirements



Approach

- *Question:* Which portion can be dimmed?
- Study 520 Android applications in 26 categories.
- Use the concept of *saliency* to identify the appropriate Regions of Interest (ROI) for each of these categories
- Result:
 - 64% of Apps place new content at the top /bottom.
 - 69% of Apps use scrolling to access new content.
 - 77% of Apps are read-only.

Approach



- Result: Most Apps use half of the screen to display the NEW content.
- A simple ROI model based on that result. Just dim top/bottom.
- Implement Focus Inside The Android Framework, (user keypresses and the display framebuffer)
- Extend the Android drawing process that draws application content onto the screen.
(Alpha blending technique)

Approach

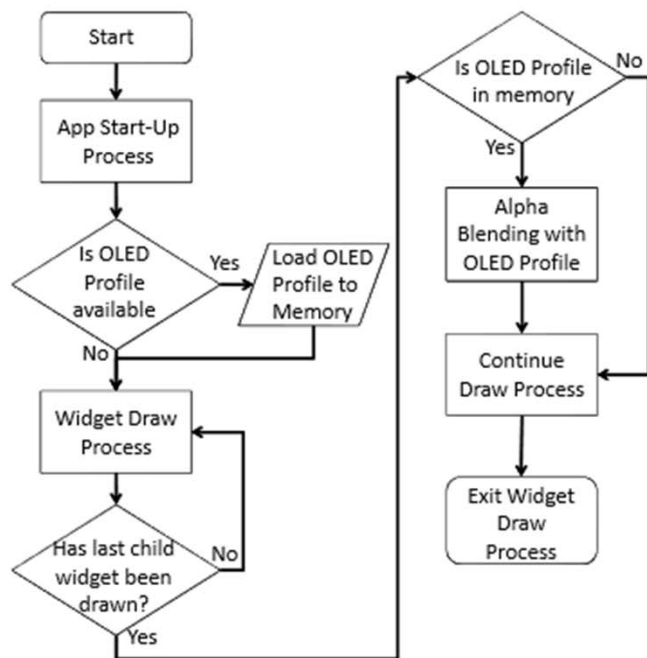
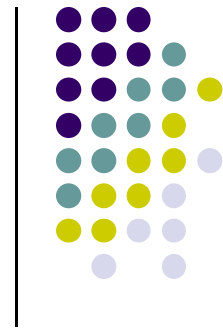


Figure 4. Focus Flowchart When Used With Applications

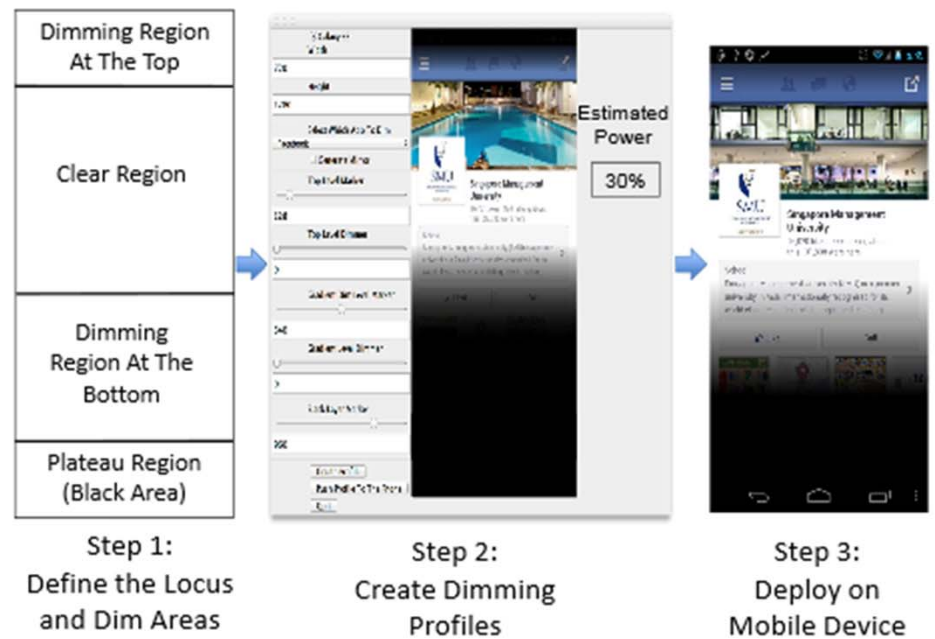


Figure 2. Applying Application-specific Profiles In Focus

Approach

Galaxy S3

Width: 720

Height: 1280

Select Which App To Dim: Facebook

Generate Mirror

Top Level Marker: 128

Top Level Dimmer: 0

Gradient Dim Level Marker: 640

Gradient Level Dimmer: 0

Black Layer Marker: 960

Create Profile

Push Profile To The Phone

Quit

Estimated Power: 30%

SMU Singapore Management University

Singapore Management University

16,751 likes · 334 talking about this · 32,525 were here

School

Singapore Management University (SMU) is a premier university in Asia, internationally recognised for its world class research and distinguished teaching.

Liked Call





Evaluation

- The evaluation is done to answer the following questions:
 - 1)How effective is *Focus* in saving power?
 - 2)What is the impact on task completion time?

Evaluation of Effectiveness



- **Tool:** Monsoon external hardware power monitor
 - **Apps:** 15 popular applications with various categories
- **Approach:** Running application with “main” page without *Focus* for one minute and with *Focus* for one minute.



Result: Effectiveness

Application	One Minute Continuous Usage Scenario					
	Power Consumption (mW)			% Improvement		
	Base (1)	“Default” (2)	“Customised” (3)	(2) over (1)	(3) over (1)	(3) over (2) (% & Diff.)
Aldiko Book Reader	1952.30	1337.65	1236.27	31.48	36.68	16.52 (5.20)
Documents To Go 3.0	1620.04	1357.11	1267.67	16.23	21.75	34.01 (5.52)
Gmail	1707.48	1243.77	1006.59	27.16	41.05	51.14 (13.89)
Firefox Browser	1703.89	1255.24	1047.32	26.33	38.53	46.33 (12.20)
WhatsApp Messenger	1237.10	1218.18	952.98	1.53	22.97	1401.31 (21.44)
OCBC Banking	1696.96	1249.17	1036.19	26.39	38.94	47.56 (12.55)
YouTube	1452.80	1113.60	787.30	23.35	45.81	96.18 (22.46)
BBC News	1550.99	1118.97	881.51	27.85	43.11	54.79 (15.26)
Adobe Reader	1923.19	1437.42	1261.15	25.26	34.42	36.26 (9.16)
Dropbox	1921.80	1358.99	1284.40	29.29	33.17	13.25 (3.88)
ES File Explorer	889.71	790.46	768.43	11.16	13.63	22.13 (2.47)
Calendar	1520.55	1149.23	1092.58	24.42	28.15	15.27 (3.73)
eBay	1766.78	1259.86	1238.60	28.69	29.90	4.22 (1.21)
Facebook	1557.35	1288.49	1041.78	17.26	33.11	91.83 (15.85)
Twitter	1823.38	1230.84	1020.18	32.50	44.05	35.54 (11.55)



Evaluation of Impact

- **Approach:** Completing a Specific Task.

Aldiko Book Reader	Flip to 1st page and read the 1st page
Documents To Go 3.0	Open a specific word document and read to specified point
Gmail	Browse content of a selected email
Firefox Browser	Use Google, search: cnn and browse to www.cnn.com

- **Measure:** Time & Energy consumption

Result: Impact



Application	Specific Task Scenario % Improvement			
	“Default”		“Customised”	
	Time	Energy	Time	Energy
Aldiko Book Reader	-0.37	23.21	0.49	29.06
Documents To Go 3.0	-0.17	11.79	0.18	7.23
Gmail	0.90	19.34	-10.09	16.62
Firefox Browser	1.09	10.22	-12.75	3.39
WhatsApp Messenger	-1.10	21.82	-1.45	15.99
OCBC Banking	-0.59	20.98	-0.75	29.31
YouTube	0.01	27.88	0.02	36.81
BBC News	4.77	27.36	5.09	42.37
Adobe Reader	2.58	5.31	4.95	7.82
Dropbox	-1.57	15.79	0.46	14.23
ES File Explorer	-0.07	2.78	0.44	12.10
Calendar	-0.16	22.02	0.68	24.71
eBay	0.26	8.02	-0.14	4.62
Facebook	0.28	14.47	-1.01	8.93
Twitter	0.73	31.57	-0.33	38.71



User Study

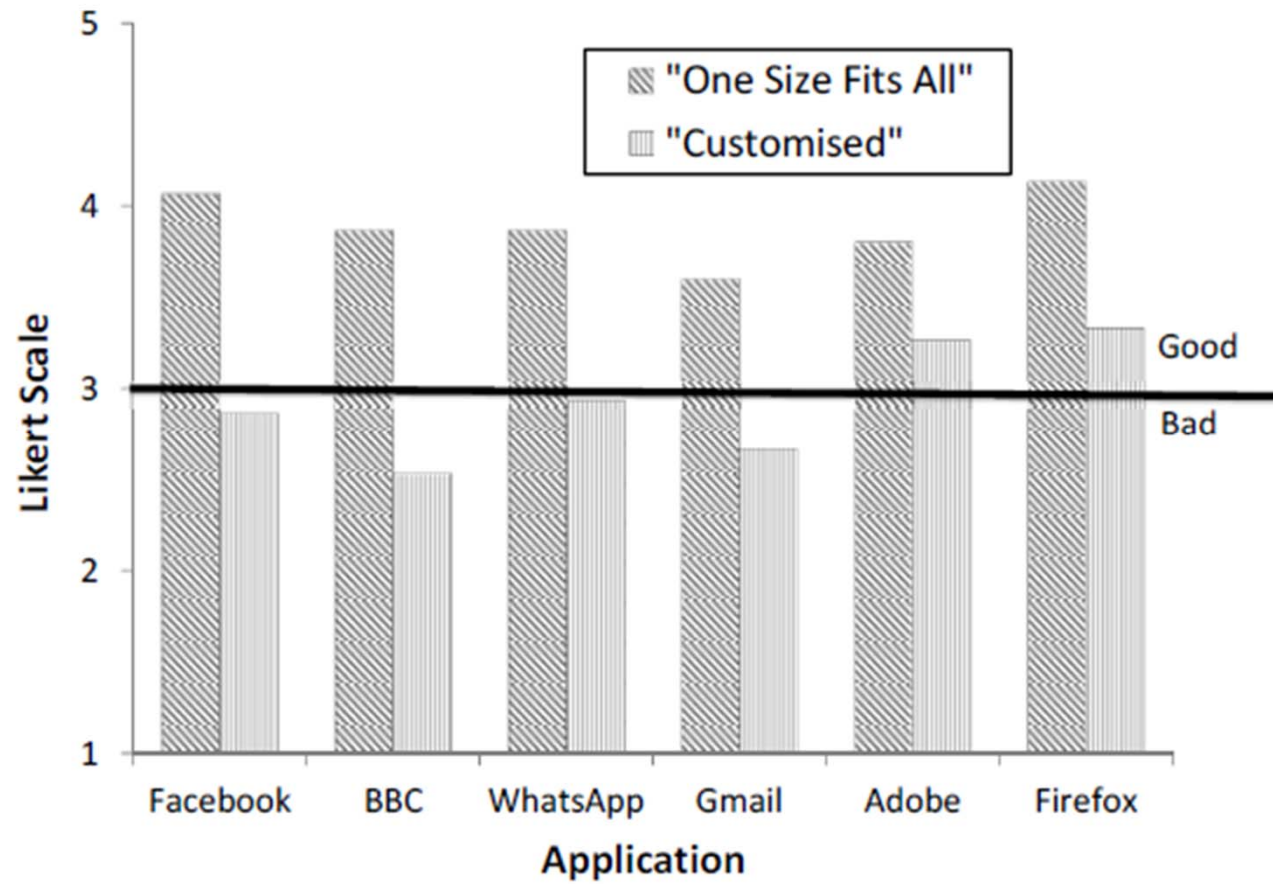
- **User study is designed to answer the following questions:**
- 1) Are the “Default” and “Customised” profiles usable?
- 2) Are Supplied Profiles Good Enough?:



User Study: Usability

- **Participants:** 30 undergraduate participants from SMU's Information Systems school
 - **Apps:** 6 popular applications total, 4 apps each participant
- **Approach:** Participants use unmodified version first then two modified versions.
- **Evaluation:** Participants answer two questions using a 5-point Likert scale

Result: Usability





User Study: Supplied Profiles

- **Approach:** Let participants design their own profiles by setting the three dimming areas
- **Evaluation:** Comparing participants' designs with "default" profile and "customized" profile.
- **Result:** Many of the user profiles looked very similar to the "Default" profile. Some are similar to "customized" profile.



Discussion: Limitations

- Game Supporting
- User study: limited of participants, environments and time
- *Focus* profiles currently only work in portrait mode.



Discussion: Comparison

- **Baselines:**
 - 1) Uniform dimming the entire screen
 - 2) Reduction of the screen resolution
- **Approach:** Application of different techniques on the screen shots of different apps.
- **Result:** Similar savings with bad usability



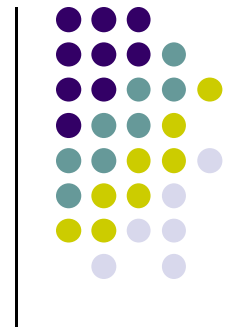
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Questions?