Power and Network-Aware Software Infrastructure for Multiplayer Mobile Games

Profiles of Excellence Talk
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Key problem and Solution

• Problem: Display draws significant phone power

![Display 45-50% Network 35-40% CPU 4-15%]

 measured on HTC Magic while streaming a Youtube Video

• Key Challenge: No loss in end user experience
Two Types of Displays

• LCD – Liquid Crystal Display
  – Backlight shines through filter to produce images
  – Used on many phones, tablets, laptops (iPad etc.)

• OLED – Organic Light Emitting Diode
  – No backlight
  – Individual LEDs light up based on image being displayed
  – More power efficient
  • Still can be improved.
LCD Displays Made Easy

- LCD displays have two components:
  - Backlight - Provides light, and consumes power
  - LCD Panel - Filters light based on image to be displayed

- Power consumed mostly by the Backlight
- Thus brightening the image, and darkening the backlight saves power
Solution and Results - Primer

- Dynamically adjust image brightness and LCD display backlight levels

- 50-70% display power savings with no significant user experience impact
Background: Saving Display Power

- Method 1: Naively dim the display
  - Creates visible artifacts (flicker, brightness loss, etc)
  - Especially noticeable in high frame rate applications
Background: Saving Display Power

- Method 2: Adjust by increasing brightness
  - Linearly apply same transform to entire image
    - Leads to saturated images
Method 3: Method 2 + Non-Linear Adjustment

– Non linear approaches prevent saturation but cause contrast loss

• Our solution uses this approach intelligently
Non Linear Gamma Correction

• Gamma Correction, or gamma, is a tone mapping function used to brighten scenes
  – Very Low Saturation relative to linear
  – Low computational overhead

Before                                            After: Gamma 2
Effect of Gamma on Image Quality

Original

Image after Gamma Increase (gamma=2)

Image after Gamma Increase and backlight reduction
Test Applications

- Games are popular and resource intensive
  - Extremely high frame rates
  - Flicker and brightness changes very noticeable to users

- We use two representative games
  - Quake III – Commercial First Person Shooting (FPS) game
  - Planeshift – Massively Multiplayer Role Playing Game (MMORPG)
System Design: Key Challenges

- Ultimate goal: Save significant power with no loss in end user experience

- Challenge 1: Understanding the relationship between the backlight intensity, gamma, image brightness, and the power consumed

- Challenge 2: Identifying human thresholds for brightness compensation

- Challenge 3: Dynamically applying the solution
Challenge 2: Human Thresholds

• Obtained via small user study
  – 5 postgraduate students

• Each user shown a range of images
  – Covered a full range of brightness

• For each image, users had to boost gamma to obtain two quality thresholds
  – Described in next slide
  – Tool provided boosted gamma at .1 intervals with automatic backlight compensation
Challenge 2: Two Thresholds

- **Conservative**: Image quality comparable to original
- **Aggressive**: Image quality is affected but acceptable

![Graph showing Gamma Value vs Image Brightness Levels (Darkest to Brightest)]
Challenge 3: Runtime Algorithm

Start

Calculate Average Brightness of last X Samples. Is there a change?

Yes
Mode + Brightness -> Gamma & Backlight

No
Leave Settings as it is

Sleep Thread for Y ms
Evaluation Methodology

• Objective Analytical Experiments
  – Power measurements on phones and laptops
  – Measured power saved in different modes

• Perceived User Impact
  – Large scale user study (60 users) with Quake III
  – Measured perceived quality loss in different modes
Evaluation: Three Test Cases

Two bounding modes tested but omitted for simplicity

- Aggressive
- Conservative

Gamma Value vs. Image Brightness Levels (Darkest to Brightest)
Evaluation: Power Savings

- A recorded trace used to measure power

![Bar Chart](chart.png)

- Aggressive: 68%
- Conservative: 49%
- Default: 0%
User Study Methodology

• Large Scale User study
  – 60 Singapore Management University undergrads.
  – 34 Male and 26 Female students with differing background and game experiences

• Participants trained on an unmodified version of the game
  – They played the 3 different versions of the game
  – Play order randomized & recalibration at every step
Evaluation: User Study Results

- Users rated each version by 6 criteria
  – Covered different quality dimensions

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Average Acceptability Score

Strongly Agree = 5
Neutral = 3
Strongly Disagree = 1

Aggressive
Conservative
Default

Good
Bad
```

School of Information Systems

SMU
Evaluation: Aggressive vs Conservative

- Difference between Aggressive and Conservative significant
Evaluation: Power vs Perception

- Difference betw. Conservative and Default
Evaluation: Conclusions

• Conservative (Dynamic Conservative)
  – High Quality
    • Perceived quality comparable to default.
  – Significant Savings – 49%

• Aggressive (Dynamic Aggressive)
  – High Power Saving – 68%
  – Acceptable Quality
But What About OLED Displays?

• Increasingly common on modern phones
  – Galaxy S2, S3, etc.

• LCD techniques don’t work
  – No backlight
  – Each “pixel” individually lighted
    • Red, blue, and green LEDs
  – Power consumption dictated by number of pixels lighted and colour used
    • Black is best
    • White is terrible!
Solution: Black out “Boring” Bits!

• Nexus One Resolution 800 x 400 (Landscape)
  – Locus of attention size is 300 x 180
  – Centered at coordinates 400, 200
Solution: Black out “Boring” Bits!

- Dim around locus of attention
- Gradual dimming to edge
- Heuristic: Edges still visible with content
Solution: Black out “Boring” Bits!

- Dim around locus of attention.
- Gradual dimming to edge.
- Heuristic: Edges still visible with content.
Applying The Technique

Users Starts Game

Power Normal Mode

User Stationary

Power Saving Mode (Gradual Dimming/Brightening)

User Moving/Panning
Technique In Action

User interaction on the mobile device

What user sees
Results Summary

• Power savings are reasonable
  – 15% overall savings with optimisations

• Still work in progress
  – Apply technique to other apps
  – Reduce user impact
Problem Solved? No!

- Problem: The Network interface also draws significant phone power

- Key Challenge (revisted): No loss in end user experience
Key Idea to Save Network Power

- Put Network Interface to sleep
  - The packet that is not sent is a joule saved!
  - But need to make sure that no important packets are lost
What is an Important Packet?

• A packet is important only if it contains information about an opponent

  – But what does that mean for a game?
    • Too many cases to handle (shooting, running, idling, shopping, gossiping etc.)

  – Simplest Solution - If no opponent is visible, safe to sleep network card for some time
Challenge With This Idea

• We need to make sure no opponent can “see” the player while player’s network card is sleeping

  – Advanced Solution – Predict in advance all possible player movements and calculate maximum safe sleep time
Implementation

- Game area is discretised into 2D grid
- Grid element size is related to MAX distance traveled in a set interval of time.
- Game provides function to check visibility between two points
- Used to pre-compute visibility between grid elements
What Does This All Mean Visually?

Map Divided into 2d grid

Obstacles

Not Visible

Visible
What Does This All Mean Visually?

Position of player

1

2

3

Not Visible

Visible

Not Visible
What Does This All Mean Visually?

Possible position of the player in $\Delta t$, say 200ms.
What Does This All Mean Visually?

Players not visible to each other, but potentially visible in $\Delta t$.
What Does This All Mean Visually?

Player 1 not visible to others in $\Delta t$, safe to sleep for $\Delta t$
Evaluation and Results

- Performance depends on map size and number of players
  - On an average map, we are able to save up to 25% of network power with little noticeable impact to the game

- User study conducted to study impact
  - Performance of solution is generally good
  - Any artifacts only manifest when the player first comes into vision
The End

Questions?