Tackling the Battery Problem for Continuous Mobile Vision

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resource poverty hurts

- no “Moore’s Law” for human attention
- being mobile consumes greater human attention
- already scarce resource is further taxed by resource poverty

technology should reduce the demand on human attention

clever exploitation of {context awareness, computer vision, machine learning, augmented reality} needed to deliver vastly superior mobile user experience

courtesy. M. Satya, CMU
continuous mobile vision

reality vs. movies

Steve Mann (early 90s)

COBOT, CMU (2013)

Mission Impossible 4 (2011)

iRobot (2004)

C-3PO (1977)

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perennial challenges

- computation
- connectivity & bandwidth
- battery

Resource constraints prevent today’s mobile apps from reaching their full potential

MSR’s SenseCam for memory assistance

Augmented Reality

- white space networks, small cell networks, mm-wave networks

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battery trends

- CPU performance improvement during same period: **246x**
- A silver bullet seems unlikely

**Li-Ion Energy Density**

- **Lagged behind**
  - Higher voltage batteries (4.35 V vs. 4.2V) – 8% improvement
  - Silicon anode adoption (vs. graphite) – 30% improvement

- **Trade-offs**
  - Fast charging = lower capacity
  - Slow charging = higher capacity

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so where is the energy going?

assuming a typical Smartphone battery of 1500 mAh (~5.5 W)

- Sensors + Memory + Disk: ~15 mW
- Display: ~500 mW
- Single Core Processor (CPU + GPU): ~150 mW
- Network Stack (5 min. of usage / hour): ~100 mW

battery lifetime ~7.25 hours
power consumption of a typical image sensor

- **Reduce frame rate**
  - 5 MP, 5 fps: 345 mW
  - 1 MP, 5 fps: 250 mW
  - 0.3 MP, 5 fps: 232 mW
  - 1 MP, 15 fps: 295 mW
  - 0.3 MP, 15 fps: 245 mW
  - 0.3 MP, 30 fps: 268 mW

- **Reduce resolution**

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low resolution, low frame rate image sensing for vision related tasks can reduce battery life by > 25%
Energy / pixel is inversely proportional to the frame rate & image resolution.

Profiled 5 image sensors from 2 manufacturers.

**Power vs. Resolution**
Video at 30 fps

**Power vs. Frame Rate**
Video at 0.1 MP

Regardless of image resolution & frame rate, image sensors consume about the same power.
digging deeper (1 MP, 5 fps)

$$E_{frame} = P_{active}T_{active} + P_{idle}T_{idle}$$
reduce power by reducing pixel readout time

one pixel is read out per clock period

\[ E_{frame} = P_{active} T_{active} + P_{idle} T_{idle} \]

\[ T_{active} = \frac{N}{f} \]

Number of Pixels divided by Clock Frequency
reducing pixel count (N)

Region-of-Interest (Windowing)
Scaled Resolution (Pixel Skipping)
reduce power by aggressive use of standby

Turn off sensor during idle period
Idle mode necessary to allow exposure before readout

Best when frame rate and resolution are sufficiently low
reduce power by adjusting clock frequency

Adjust clock frequency to minimize power

\[ T_{active} = \frac{N}{f} \]

At low frame rates, run the clock as slow as possible

Tradeoff

Power \uparrow

Frequency \uparrow

Frequency \downarrow

Power \downarrow

5 fps

1 fps

FREQ. (MHz)

Power (mW)
summarizing power reduction techniques

- reduce $T_{active}$ & increase $T_{idle}$
  - decrease frame rate
  - reduce total pixel readout time (by reducing N)
  - adapt clock frequency

- Instead of idle-ing put sensor in *standby state*

- reduce $P_{active}$ (not covered in this talk, see paper)
applying these techniques

Unoptimized

Aggressive Standby & Clock Optimization
impact on vision algorithms

<table>
<thead>
<tr>
<th></th>
<th>Image Registration Success</th>
<th>Person Detection Success</th>
<th>Actual Power Reduction with software assist</th>
<th>Estimated Power Reduction with hardware assist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Resolution (129600 pixels)</td>
<td>99.9%</td>
<td>94.4%</td>
<td>51%</td>
<td>84%</td>
</tr>
<tr>
<td>Frame Rate- 3 FPS</td>
<td>95.7%</td>
<td>83.3%</td>
<td>95%</td>
<td>98%</td>
</tr>
<tr>
<td>30% Window (63504 pixels)</td>
<td>96.5%</td>
<td>77.8%</td>
<td>63%</td>
<td>91%</td>
</tr>
<tr>
<td>Subsampled by 2 (32400 pixels)</td>
<td>91.8%</td>
<td>72.2%</td>
<td>71%</td>
<td>94%</td>
</tr>
</tbody>
</table>
MSR’s Glimpse project
collaborators & references

Robert  Bodhi  Matthai  Lin


Thanks!