Tackling the Battery Problem
for Continuous Mobile Vision

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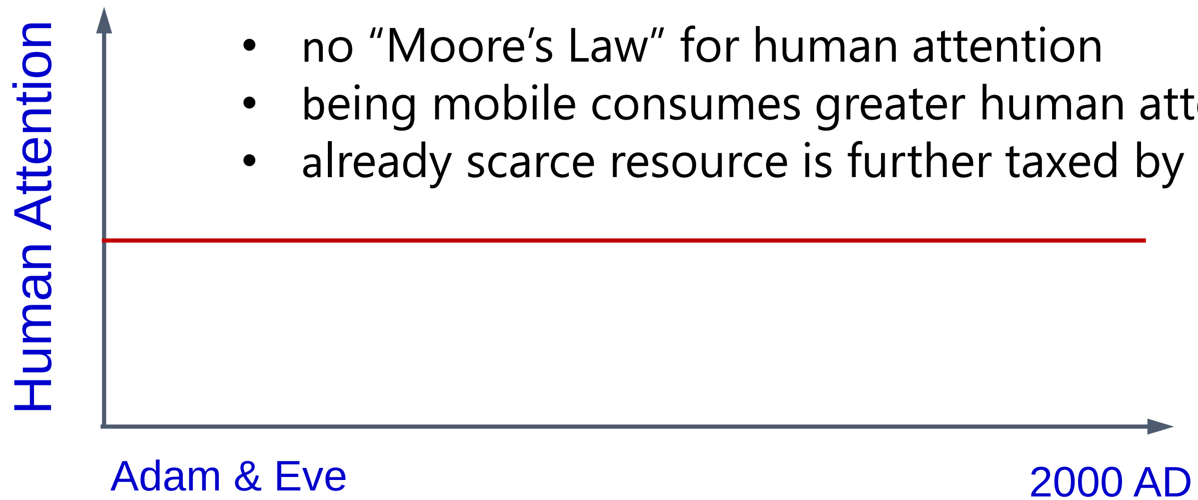
resource poverty hurts



- 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)

C-3PO (1977)

Mission Impossible 4 (2011)

iRobot (2004)

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perennial challenges

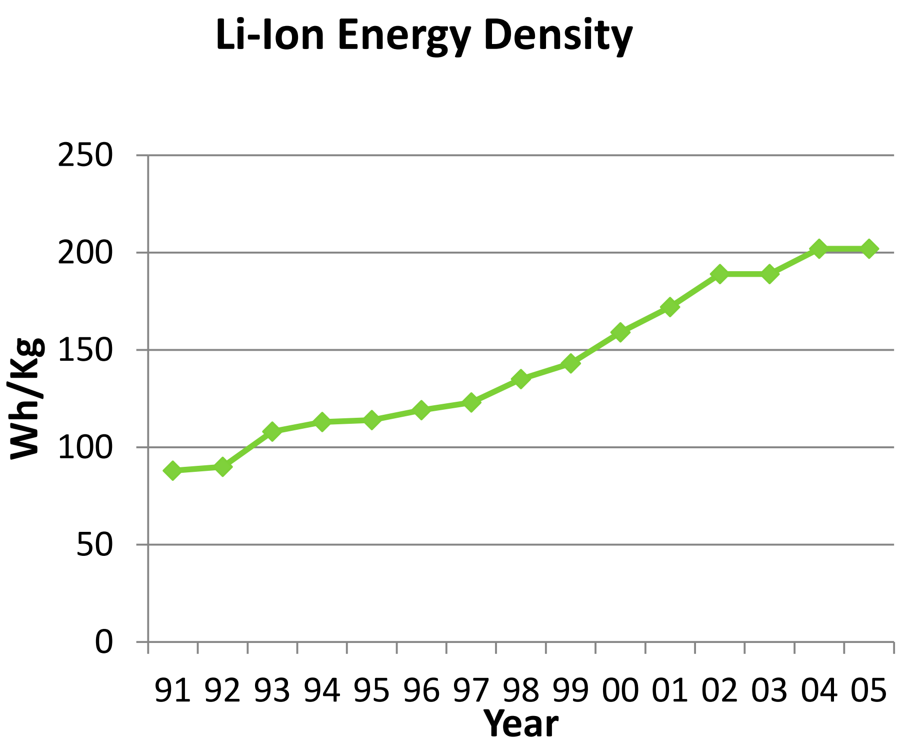
MSR's SenseCam for memory assistance

Augmented Reality

- computation } cloudlets
- connectivity & bandwidth } white space networks, small cell networks, mm-wave networks
- battery

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

battery trends



- 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

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

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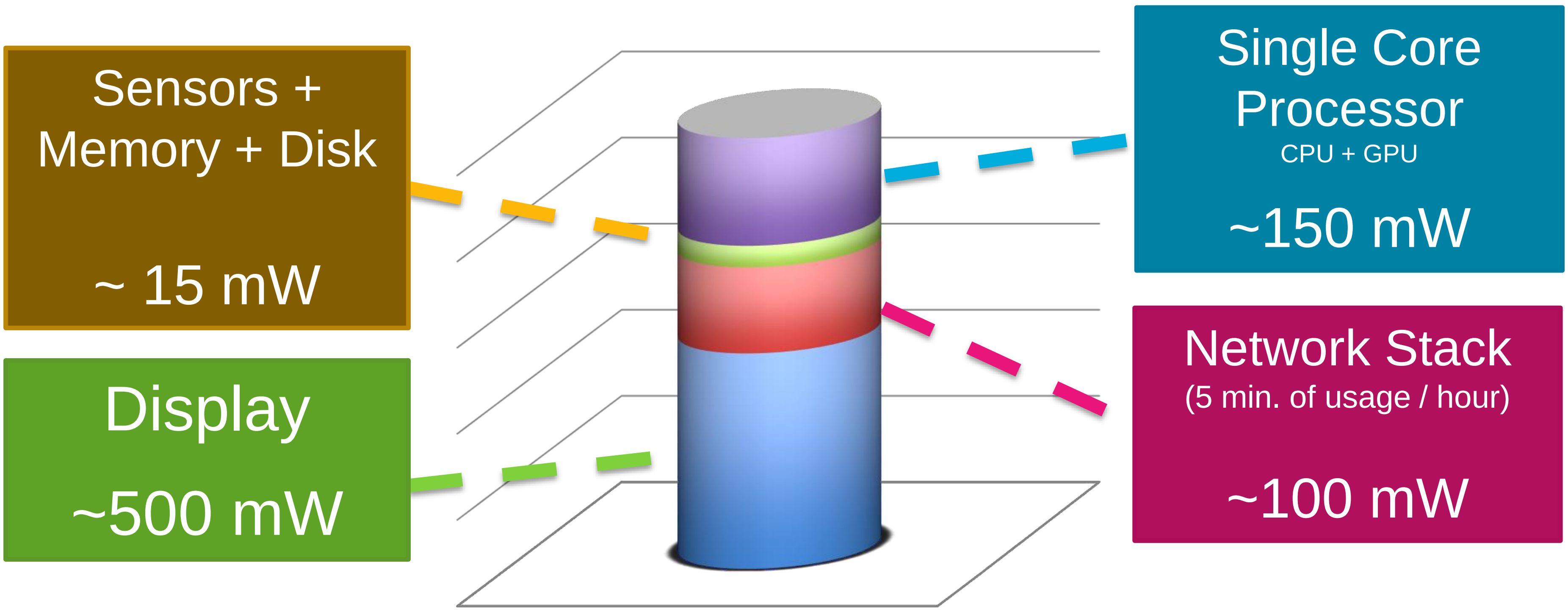
so where is the energy going?

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



battery lifetime ~7.25 hours

power consumption of a typical image sensor

Reduce frame rate ←

Reduce resolution ↓

5 MP, 5 fps 345 mW		
1 MP, 5 fps 250 mW	1 MP, 15 fps 295 mW	
0.3 MP, 5 fps 232 mW	0.3 MP, 15 fps 245 mW	0.3 MP, 30 fps 268 mW

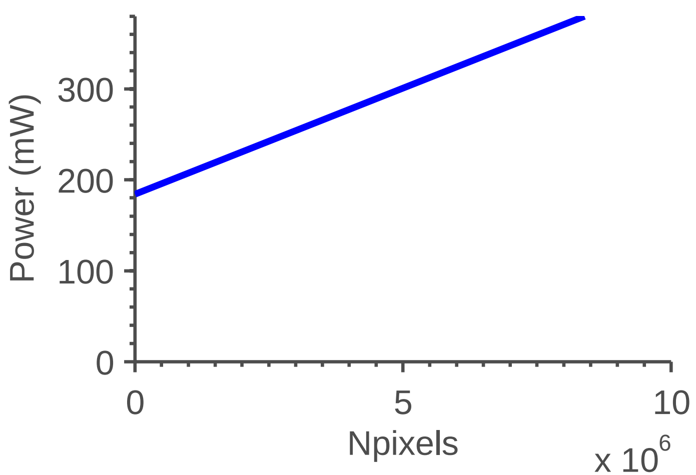
low resolution, low frame rate image sensing for vision related tasks can reduce battery life by > 25%

state of art

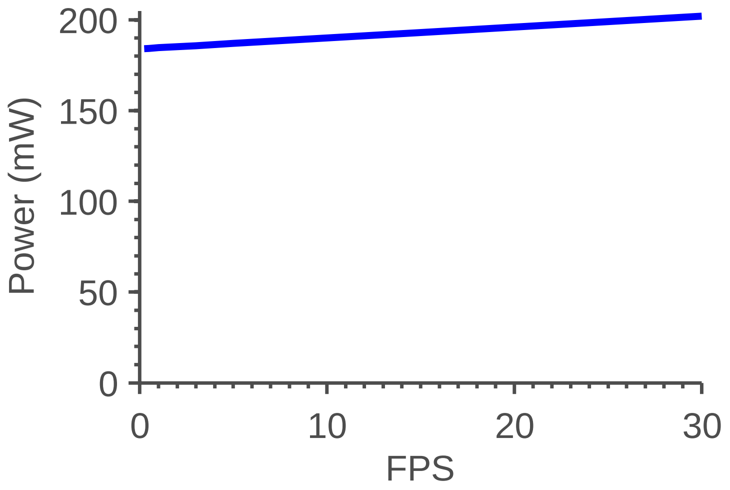
Energy / pixel is **inversely proportional** to the frame rate & image resolution

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

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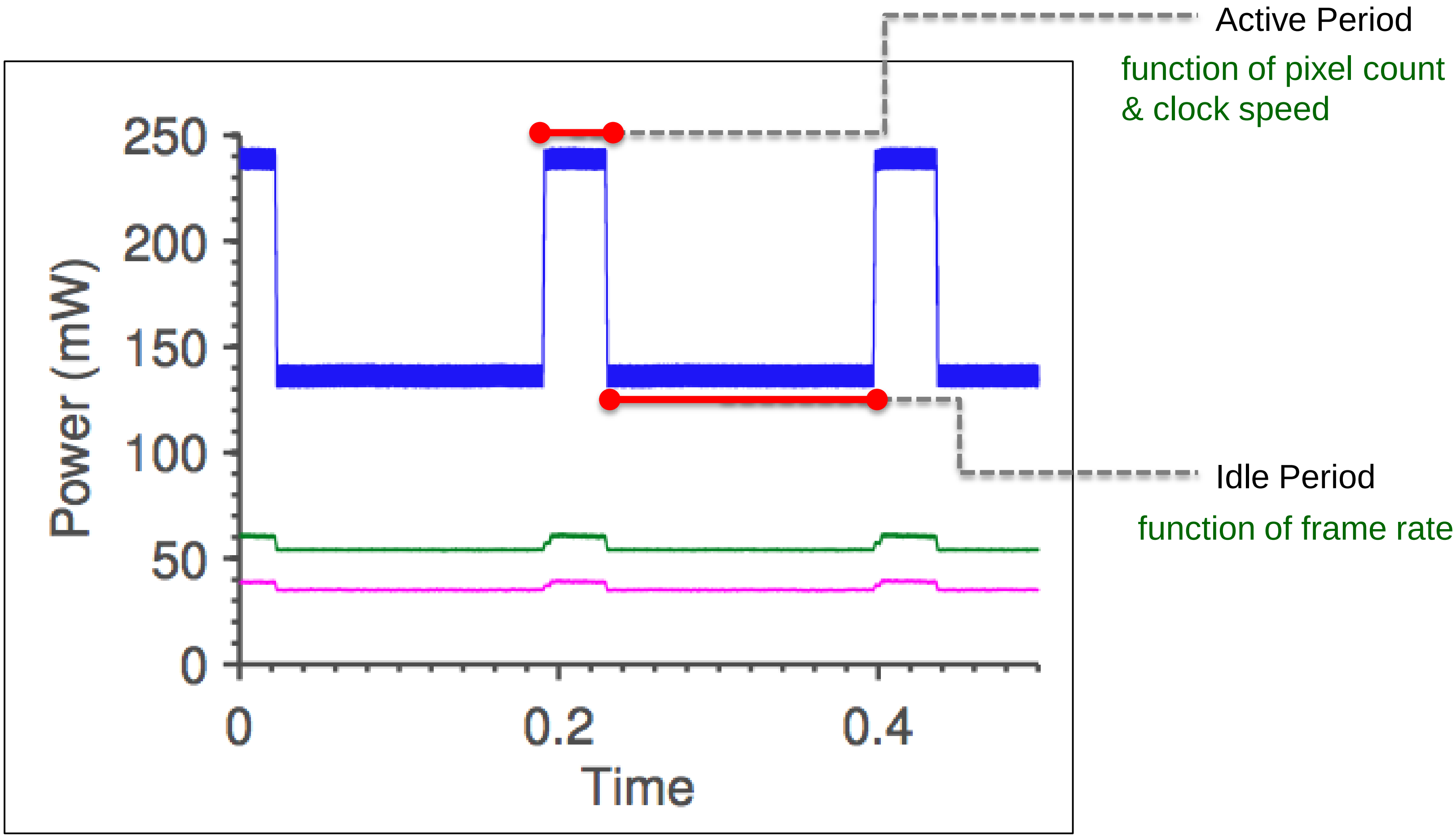
digging deeper (1 MP, 5 fps)



$$E_{frame} = P_{active}T_{active} + P_{idle}T_{idle}$$

reduce power by reducing pixel readout time

one pixel is read out per clock period

$$E_{frame} = P_{active} T_{active} + P_{idle} T_{idle}$$

reduce this

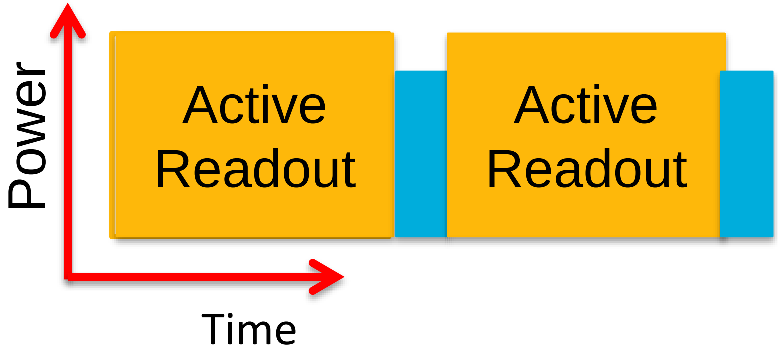
$$T_{active} = \frac{N}{f}$$

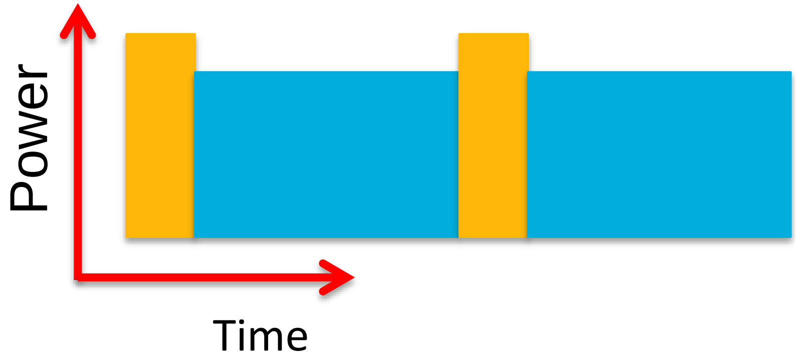
Number of Pixels
divided by
Clock Frequency

reducing pixel count (N)

Region-of-Interest
(Windowing)

Scaled Resolution
(Pixel Skipping)

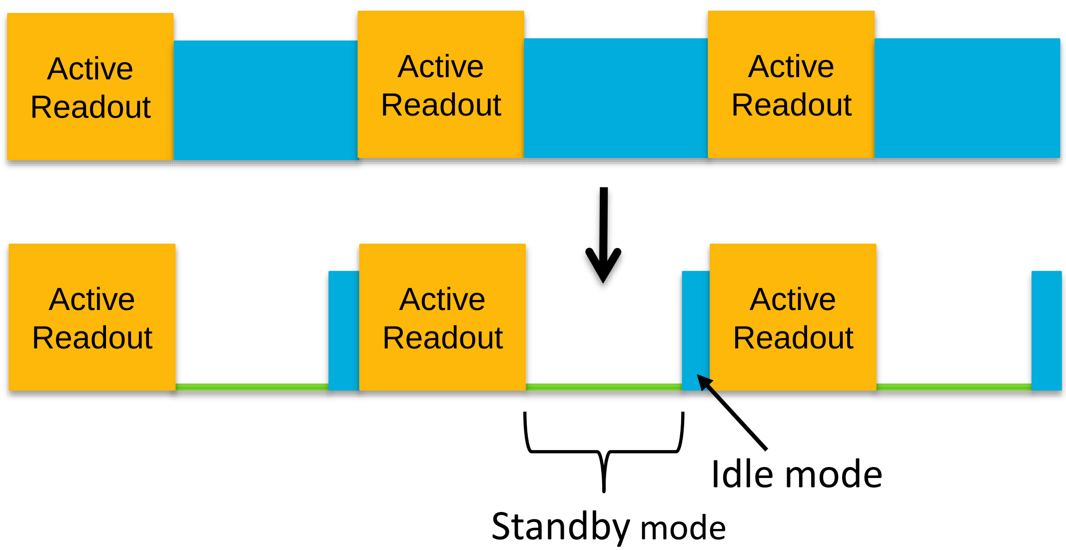




reduce power by aggressive use of standby

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

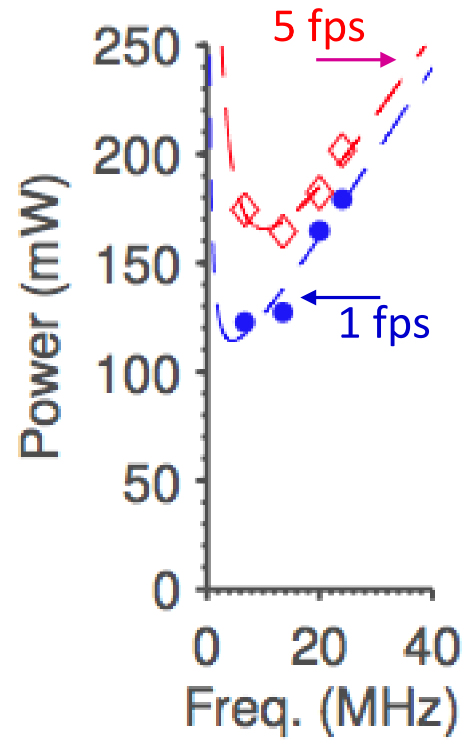
$$T_{active} = \frac{N}{f}$$

Adjust this

Tradeoff

frequency ↑ Power ↑

frequency ↑ T_{active} ↓



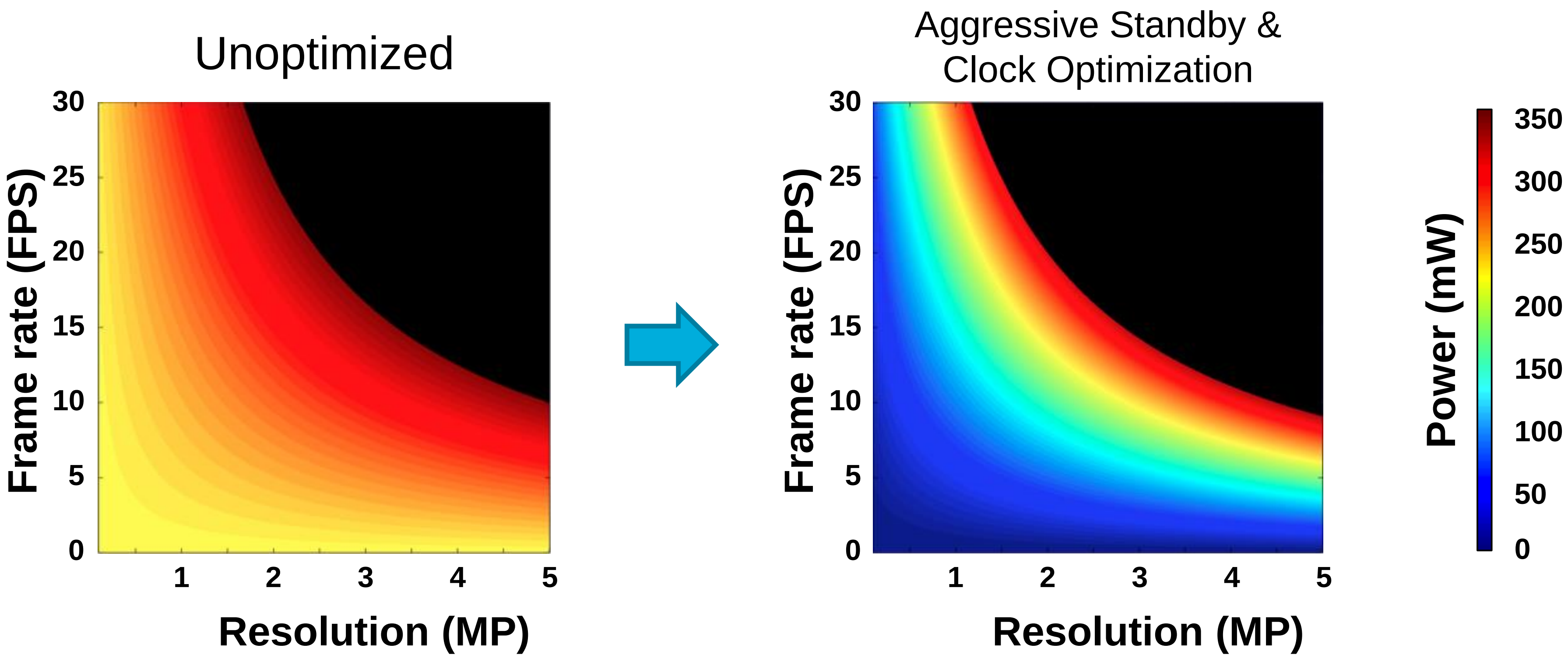
RULE OF THUMB

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

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



impact on vision algorithms

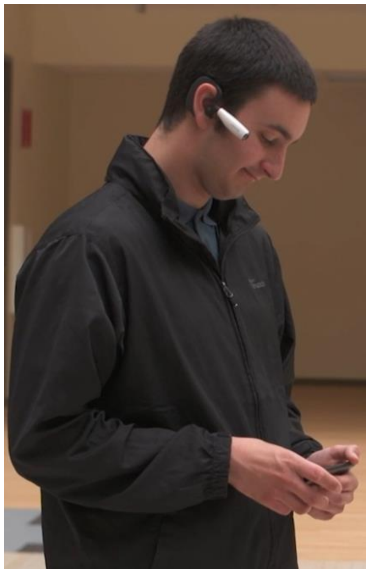
Image registration

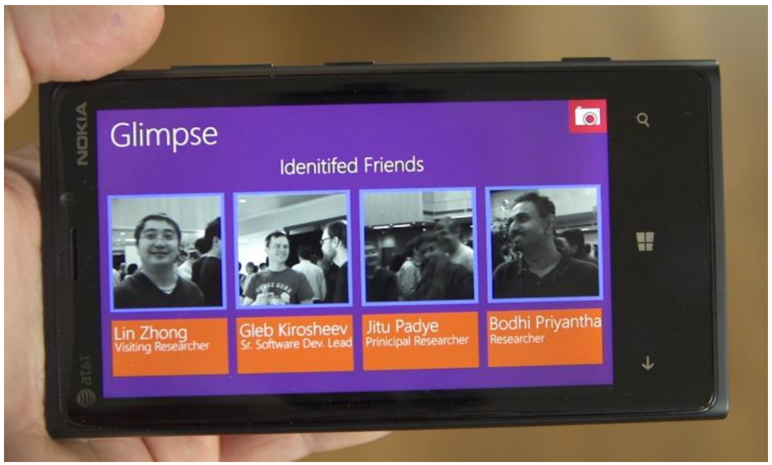
Person Detection

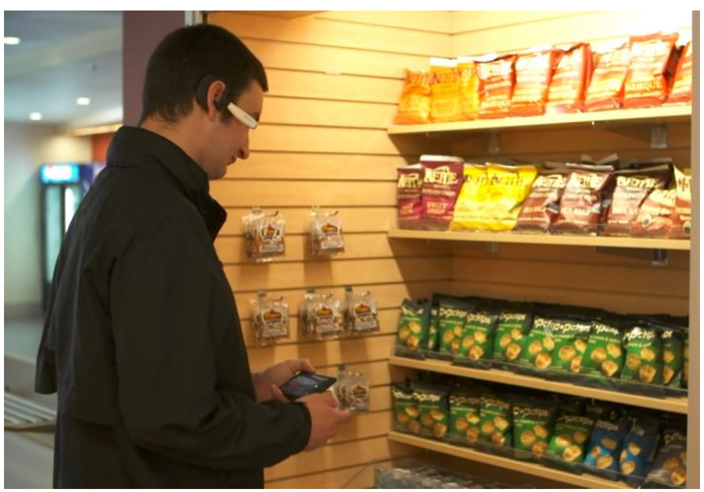
480 x 270

	Image Registration Success	Person Detection Success	Actual Power Reduction with software assist	Estimated Power Reduction with hardware assist
Full Resolution (129600 pixels)	99.9%	94.4%	51%	84%
Frame Rate- 3 FPS	**95.7%**	83.3%	**95%**	98%
30% Window (63504 pixels)	96.5%	77.8%	63%	91%
Subsampled by 2 (32400 pixels)	91.8%	72.2%	71%	94%

MSR’s Glimpse project





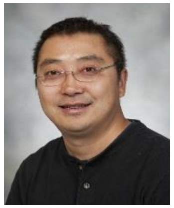


collaborators & references

Robert

Bodhi

Matthai



Lin

R. LeKamWa, B. Priyantha, M. Philipose, L. Zhong, P. Bahl, **Energy Characterization and Optimization of Image Sensing Towards Continuous Mobile Vision**, Proceedings of ACM MobiSys 2013, Taipei, Taiwan, June 26-29, 2013

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Thanks!