Title

Energy-Efficient Image Communication for Wireless Sensor Networks

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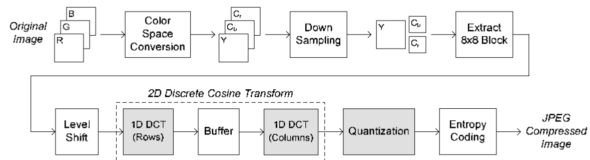
Introduction: Image Communication with Sensors

Image Communication

- Transmission of compressed images is believed to be more efficient than transmission of uncompressed images, however very little quantitative studies exist in the context of resource-constrained sensor platforms
- Traditional JPEG implementations used far greater precision than is necessary in light of the rounding occurring in the quantization process
- In contrast, we adopt an energy-aware approach to ensure JPEG computations utilize the minimum precision needed
- Using optimized JPEG implementations we examine detailed energy/speed tradeoffs between different transmission strategies

JPEG Compression



- We focus primarily on the optimization of the DCT and quantization steps, as these are lossy steps in JPEG compression and thus offer the largest opportunity for potential impact in terms of overall energy utilization by addressing precision issues

Problem Description: Efficient Mapping of JPEG into Sensor Platforms

DCT and Quantization Steps

- DCT and Quantization steps consist of large numbers of additions and multiplications involving real numbers
- Straightforward way of implementing such computations is to use floating-point, but processors used in sensors lack dedicated floating-point hardware
- Emulating floating-point via integer operations retains high precision but is extremely slow
- Floating-point accuracy is rarely required in embedded environments
  → processor cycles and memory wasted for computing overly precise results
- We implement the computations in fixed-point arithmetic with consideration of the precision needed and the native word-length of the processor

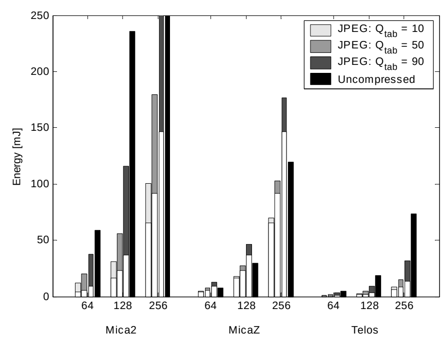
Proposed Solution: Precision Optimized JPEG

DCT & Quantization: IJG vs Proposed

	Method	Type	DCT [Cycles]	Quantization [Cycles]	Total [Cycles]	Code Size [Bytes]	Execution Time [ms]	Energy [μJ]	PSNR [dB] Bird	PSNR [dB] Camera	PSNR [dB] Goldhill
1	IJG	Float	580,106	244,840	824,946	5,964	103.12	2268.60	31.8	28.3	27.0
2		Slow	31,378	17,039	48,417	3,355	6.05	133.15	31.8	28.3	27.0
3		Fast	8,131	17,831	25,962	1,670	3.25	71.40	25.8	23.7	23.8
4	Proposed	Slow	21,172	17,192	38,364	3,524	4.80	105.50	31.8	28.3	27.0
5		Medium	20,718	2,810	23,528	3,318	2.94	64.73	31.3	28.0	26.6
6		Fast	8,768	2,385	11,153	2,662	1.39	30.67	30.6	27.5	26.1

- Comparison against the Independent JPEG Group (IJG) library for an 8x8 DCT and quantization on the ATmega128 processor used in the Cyclops platform
- Quality setting at Q_{tab} = 50 (standard JEPG quantization table)
- Proposed approach leads to better performances due to the custom precision approach

Image Communication Energy



Upper part: Communication

Lower part: Computation

Region of Interest Coding

(a) No ROI: $Q_{tab} = 87.5$

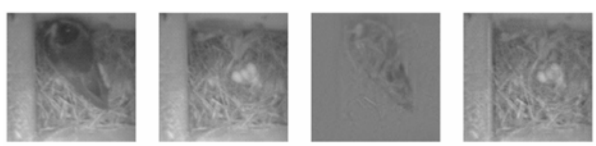
(b) No ROI: $Q_{tab} = 12.5$

(c) With ROI: $Q_{tab} = 87.5$ and $Q_{tab} = 12.5$

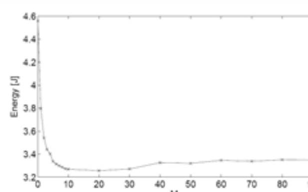
Scheme	$Q_{tab} = 87.5$	$Q_{tab} = 12.5$	ROI
Compression [mJ]	223.2	65.6	91.2
Transmission [mJ]	441.3	100.6	166.8
Total [mJ]	664.5	166.2	258.0

Successive Images

- Instead of transmitting each frame individually, exploit temporal dependencies between frames.
- Use inter-coded frames (I-frames) and difference-coded frames (D-frames)



(a) I-frame (b) Frame X (c) D-frame (d) Reconstructed X



(Number of D-frames per I-frame)