Distributed Video Compression for Smart Visual Sensors

Nikos Deligiannis
Wireless Multimedia Sensor Networks

- Wireless Lightweight Multimedia Applications:
  - *Wireless visual surveillance sensors* ([Little Sister Project](#))
Wireless Lightweight Multimedia Applications:
- Wireless visual surveillance sensors
- Wearable/On-body visual sensors
- **In-body Sensors** *(Wireless capsule endoscopy)*

Video Compression Requirements:
- Low complexity encoding
- High compression performance
- Scalability
- Communication error resilience

©Given Imaging
Traditional Predictive Coding

Traditional Predictive Video Coding (H.26x, MPEG)
- Redundancies exploited at the encoder
  - Motion Compensated Prediction
- Characteristics
  - High compression performance
  - Complex encoder – Simple decoder
  - Downlink model (Broadcast Scenario)
Distributed Video Coding

- Redundancies exploited at the decoder
  - Motion/Disparity Estimation at the decoder
- Characteristics
  - Simple encoder – Complex decoder
  - Error Resilience
  - Good compression performance
  - Uplink model (Multi-terminal Communication Scenario)
  - **No need for communication between the sensors**
Mono-View Distributed Video Coding

**High-level Architecture**

- **DCT** → **Q** → **SW Enc.**
- **SW Dec.** → **Q⁻¹** → **IDCT**
- **Correlation Channel** → **Side Information**

**Intra Coding**
Stereo / Multi-View DVC

**High-level Principle**

Key frame  WZ frame

Key frame  WZ frame
Efficient Intra-Frame Coding

**Low-Resolution Image Sensors**

- Current DVC Systems
  - H.263+ or H.264/AVC Intra
- Proposed Designated System:

```
  video input  ->  optional mirror padding  +  transform (2x2, 4x4 or 8x8)  ->  quantization  ->  entropy encoding (Huffman or CAVLC)  ->  bitstream
          |                                                                         |     intra prediction                                                |
          |                                                                         |     inverse transform (2x2, 4x4 or 8x8)                            |
          |                                                                         |     inverse quantization                                            |
```
Efficient Intra-Frame Coding

**Low-Resolution Image Sensors**
Efficient Intra-Frame Coding

**Low-Resolution Image Sensors**

Compared to H.264/AVC Intra:
Vast Reduction in Encoding Execution Time
Distributed Video Coding
**High-level Architecture**

**Intra Coding**

**SW Enc.**

DCT → Q → SW Enc.

**WZ Enc.**

SW Dec. → Q⁻¹ → IDCT

Correlation Channel

Side Information

**WZ Dec.**

Intra Coding
SI Generation at the Decoder
** Motion-Compensated Interpolation **
The EDVC system:
✓ The hash can act as SI predictor
✓ Modified OBMEC with HPS
SI Generation in EDVC
** OBMEC with HPS **

- Lanczos-3 Interpolation Filter
- Reliability Screening
- MSE-optimal Motion Compensation
Compression Results
** Endoscopic Sequences **

“Endoscopy Test Video 2”, 480x320, GOP2, 30Hz

43.3% Bjøntegaard Rate Savings

Proposed DVC with HPS

TDWZ
Compression Results
** Endoscopic Sequences **

H.264/AVC Intra (790kbps, 37.9dB)  Proposed EDVC (800kbps, 39.2dB)

EDVC advantages:
- High compression performance
- Low encoding complexity (~56% less than H.264/AVC Intra)
- Scalable coding
Compression Performance of HDVC

Foreman Sequence, QCIF, 15Hz, GOP8

31.4% Bjøntegaard Rate Savings
System Architecture
**Codeword Formation and Side Info Refinement**

![System Architecture Diagram]

- **DCT**
- **Q**
- **SW Enc.**
- **SW Dec.**
- **Buffer**
- **Q⁻¹**
- **IDCT**
- **Successively Refined Correlation Estimation**
- **Side Information (OBMEC/SAD)**

Partially Decoded Frame
Proposed Distributed Video Coding

**Results on Low-Resolution Sensor Data**

Uncompressed Data Rate $\sim 290$ kbps
Proposed Distributed Video Coding

**Results on Low-Resolution Sensor Data**

Uncompressed Data Rate  ~  316 kbps
Architecture with Encoder Rate Control

**Feedback Channel Removal**

- DCT → Q → SW Enc.
- SW Dec. → Buffer → Q⁻¹ → IDCT

- Coarse Side Info
- Rate Allocation
- Mode Decision (Intra/Skip/WZ)
- Arithmetic Entropy Enc.
- Enc. Rate Control
- Successively Refined Correlation Estimation
- Mode Signal.
- Entropy Enc⁻¹
- DCT
- Side Information
- SW Enc.

WZ Enc.

WZ Dec.
Architecture with Encoder Rate Control

**Performance Evaluation**

- Better Rate-Distortion Performance
- No Encoder Syndrome Buffering
- No FB channel Latency

Vs. feedback-based benchmark (DISCOVER)

- Foreman QCIF GOP4
- Soccer QCIF GOP4

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Conclusions

➢ Novel DVC architectures
  • Visual Sensor Applications
  • Significant gains over prior art
➢ Novel Intra-Frame Codec
➢ Novel SI generation methods
➢ Novel Encoder-Rate Control Mechanism


Selected Publications
Conference Papers


7. F. Verbist, N. Deligiannis, M. Jacobs, J. Barbarien, P. Schelkens, and A. Munteanu, "A statistical approach to create side information in distributed video coding," in *ACM/IEEE International Conference on Distributed Smart Cameras*, ICDCS’11, Ghent, Belgium, August 2011. (*This paper received the ACM/IEEE ICDSC’11 Best Paper Award*).