Algorithms for Robust Information Embedding in Video: Progress Report 04/12/04

Professor Joseph A. O'Sullivan
Nicholas Fichtenbaum
Department of Electrical and Systems Engineering

Washington University in St. Louis

Center for Security Technologies

Agenda

- Review project history
- Information embedding approach
- Implementation discussions
  - QIM Mathematics
  - Directions for quantization
  - Artifacts and precision
- VEIL—WU interaction
  - distortion levels expected
  - further implementation issues
- Current timeline

Review Project History

- Jan. 5, 2004, Nick joins project
- Jan. 30, 2004 report
  - –Information Performance Constraints/Design Goals
  - – System Implementation Constraints/Design Goals
- Mar. 1, 2004 report
  - – System Design Framework: progress on block diagram implementations, understanding
  - – Information embedding strategy outlined
  - – Choices in applying principles: statistical analysis
    - DCT Coefficients
    - SVD Analysis

System Design Framework

- Information Performance Constraints/Design Goals
  - Priority: Robustness to keying, translation, DCT compression, transformations to and from high definition and to and from selected other standards conversions
  - Next: Robustness to scaling, rotation, playback rate changes
    - Comment: scaling may be hard, necessity may impact critical design paths
  - Establish target values for robustness
- System Implementation Constraints/Design Goals
  - Decoder implementable in real time using VEIL-developed hardware
  - Encoding in near real time using VEIL-developed hardware
  - Target hardware platforms include AD dual core Blackfin DSPs

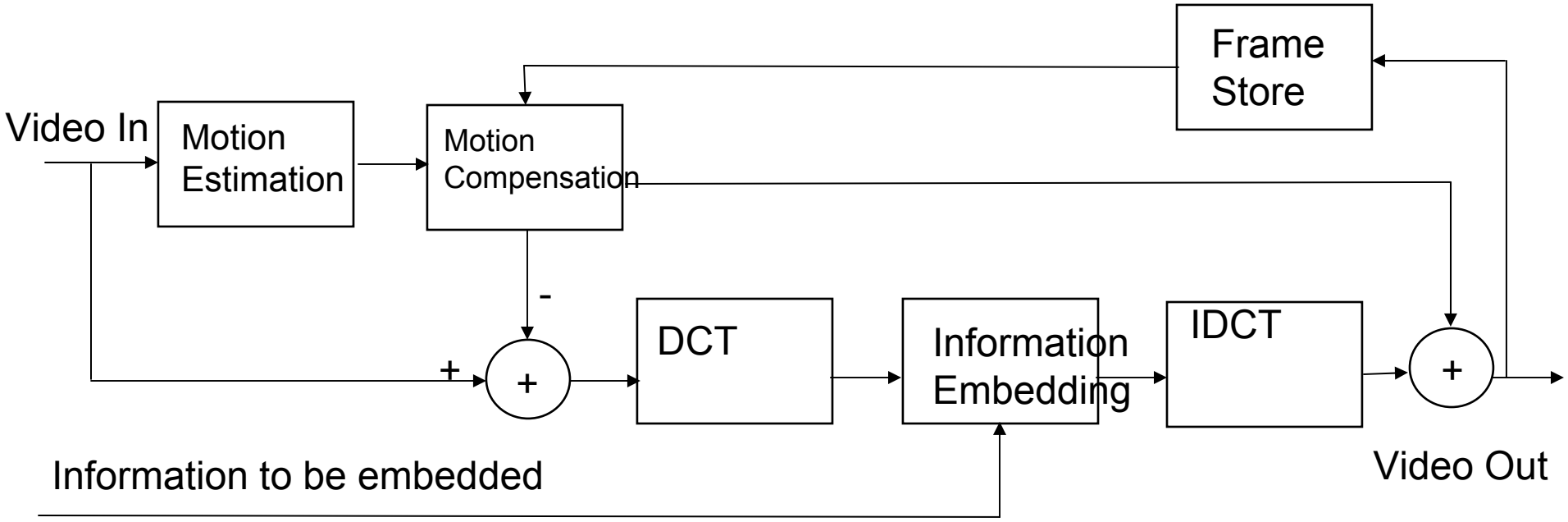
WU Approach to Algorithm Design

- Principles (Moulin-O'Sullivan, 1996-2003)
  - Use information-theoretic analysis to guide design
  - Extract independent random variables
  - Embed information in extracted variables
- Choices in Applying Principles
  - Extraction of random variables
    - necessarily approximate due to lack of underlying true distribution
    - based on parametric, semiparametric, or nonparametric principles
    - often have an invertible transform at the core
      - choice of transform: DCT, wavelet (further choices), Hough, Radon
    - motion compensation is typically semiparametric
    - 3D, 4D, nD mesh models are parametric
  - Embedding and extracting information
    - spread spectrum, QIM

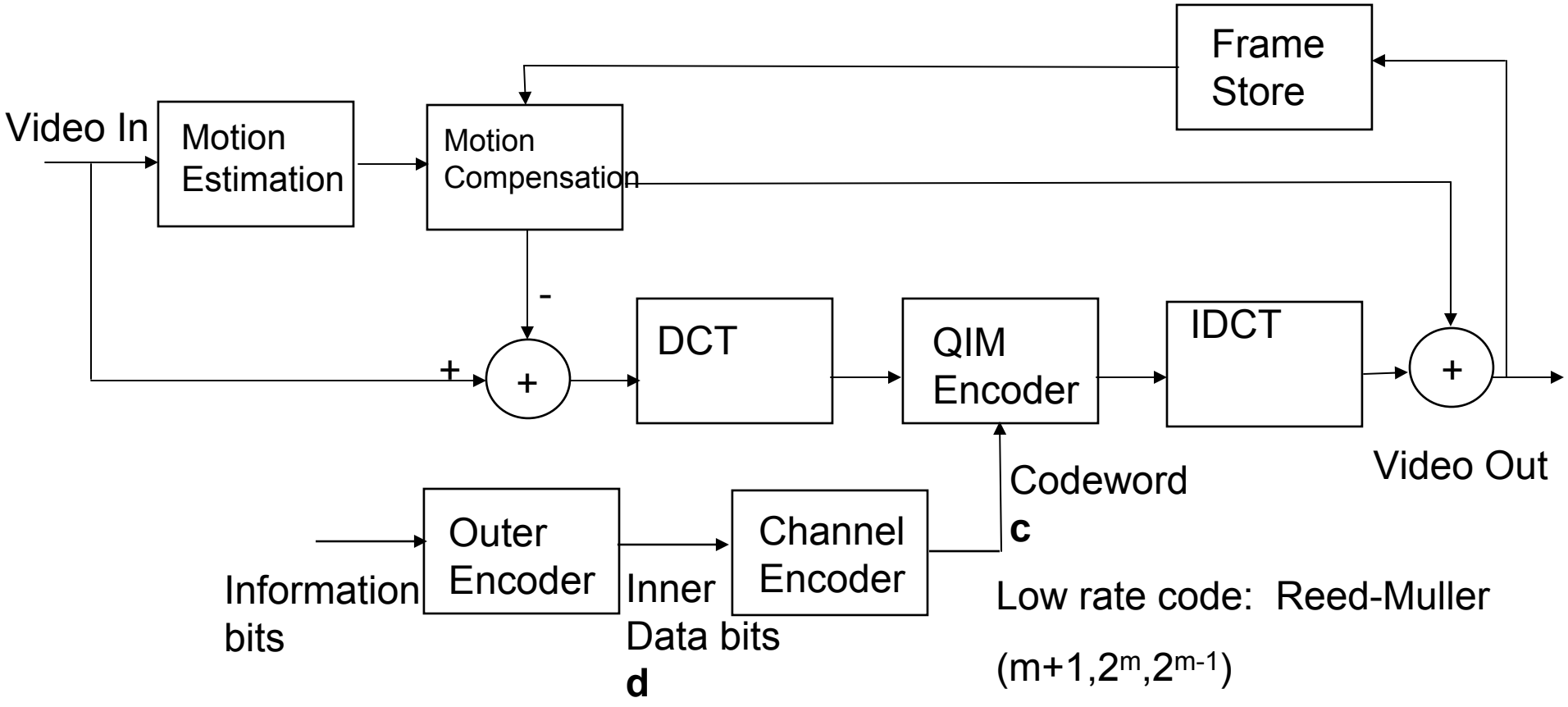
Extraction of Variables

- Singular Value Decomposition Analysis
  - DCT coefficient blocks
  - frame type dependence
  - Y-U-V separately or together
  - robustness to compression, noise, transformations

WU Embedding Block Diagram



Information Embedding Detail



Low rate code: Reed-Muller

$(m+1,2^m,2^{m-1})$

Ex: (13,2048,1024)

Correct 511 errors

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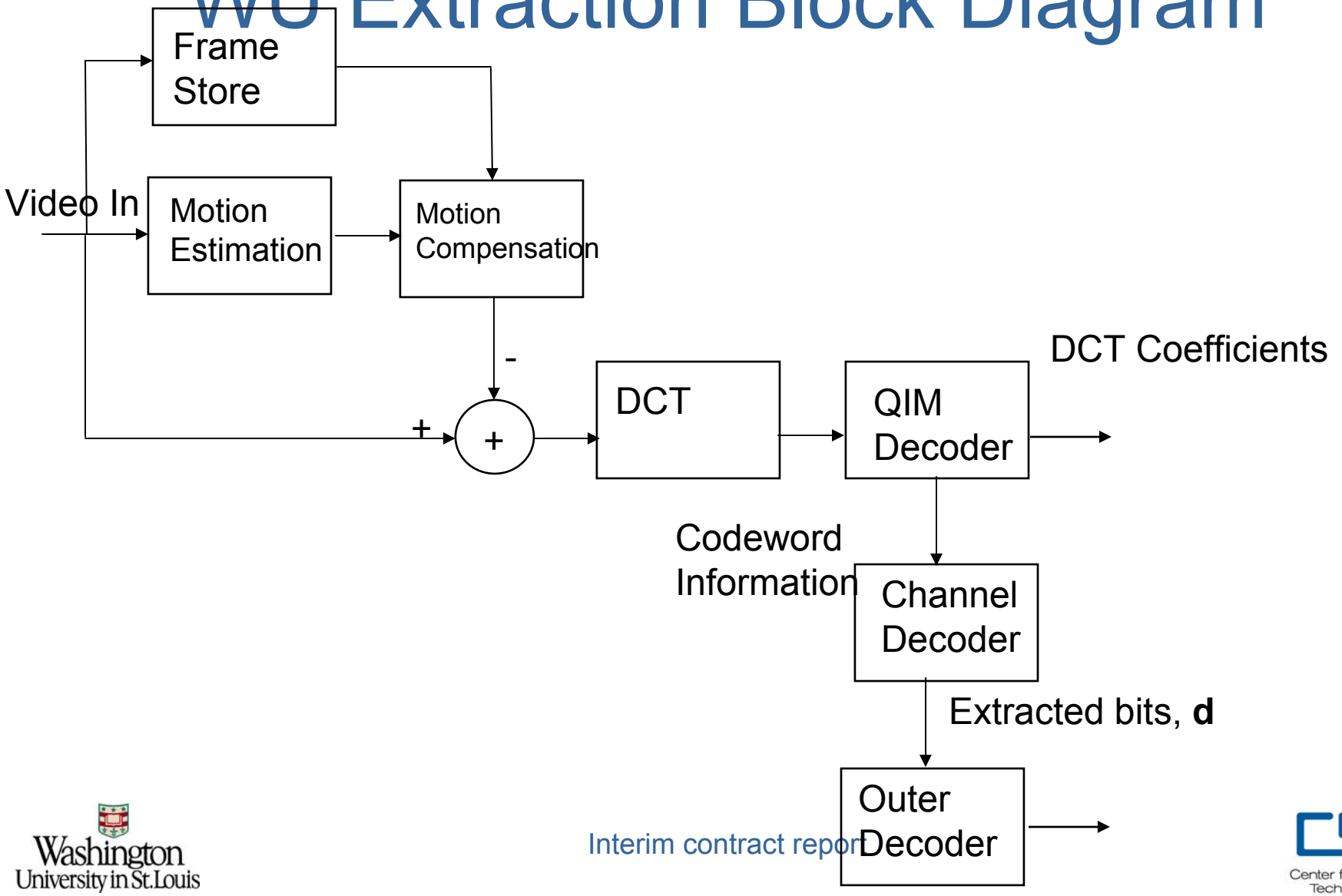
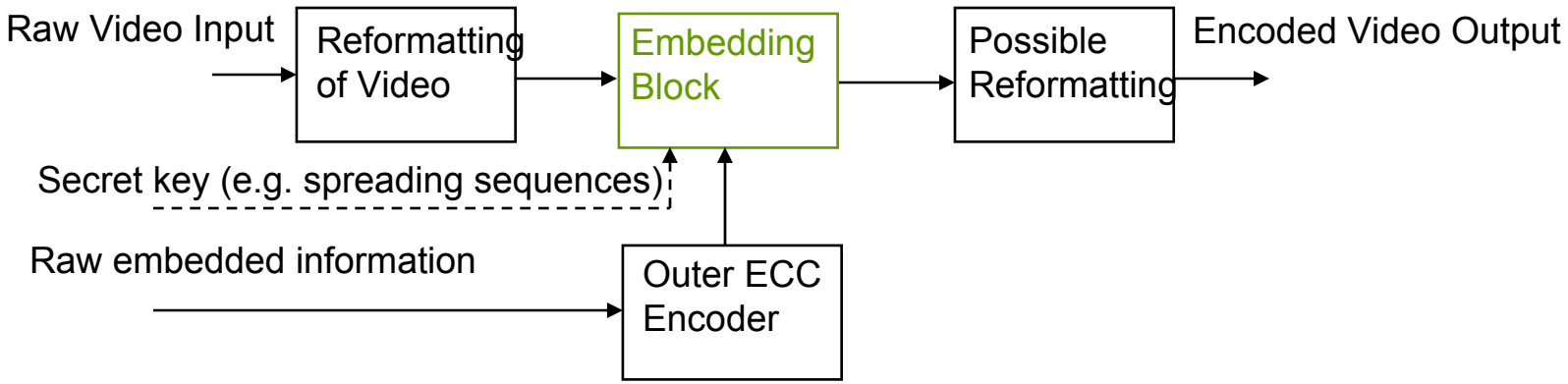
Current Instantiation of WU Extraction Block Diagram

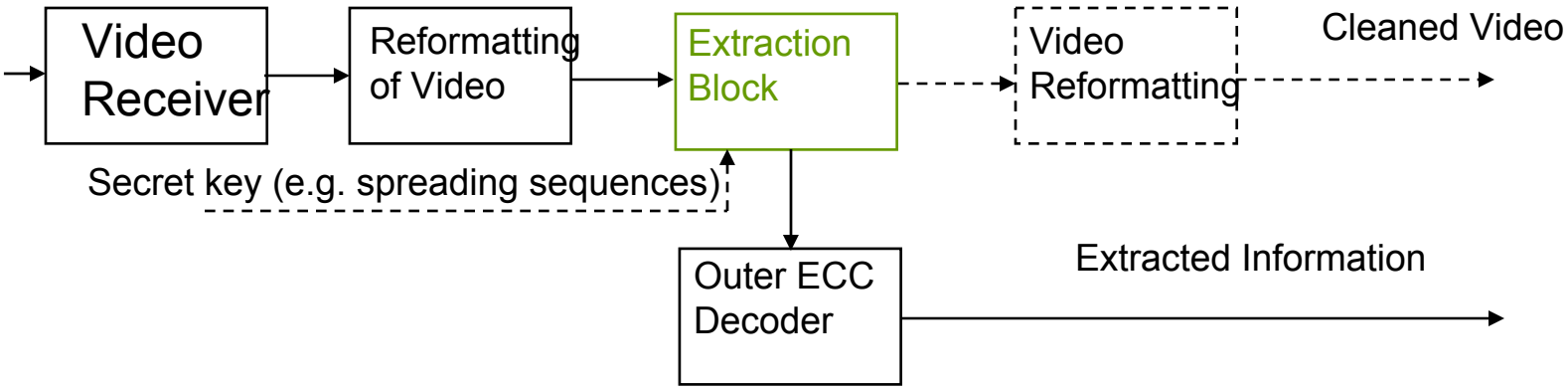


Further Embedding System Design



Comment: proposed embedding block from previous slide

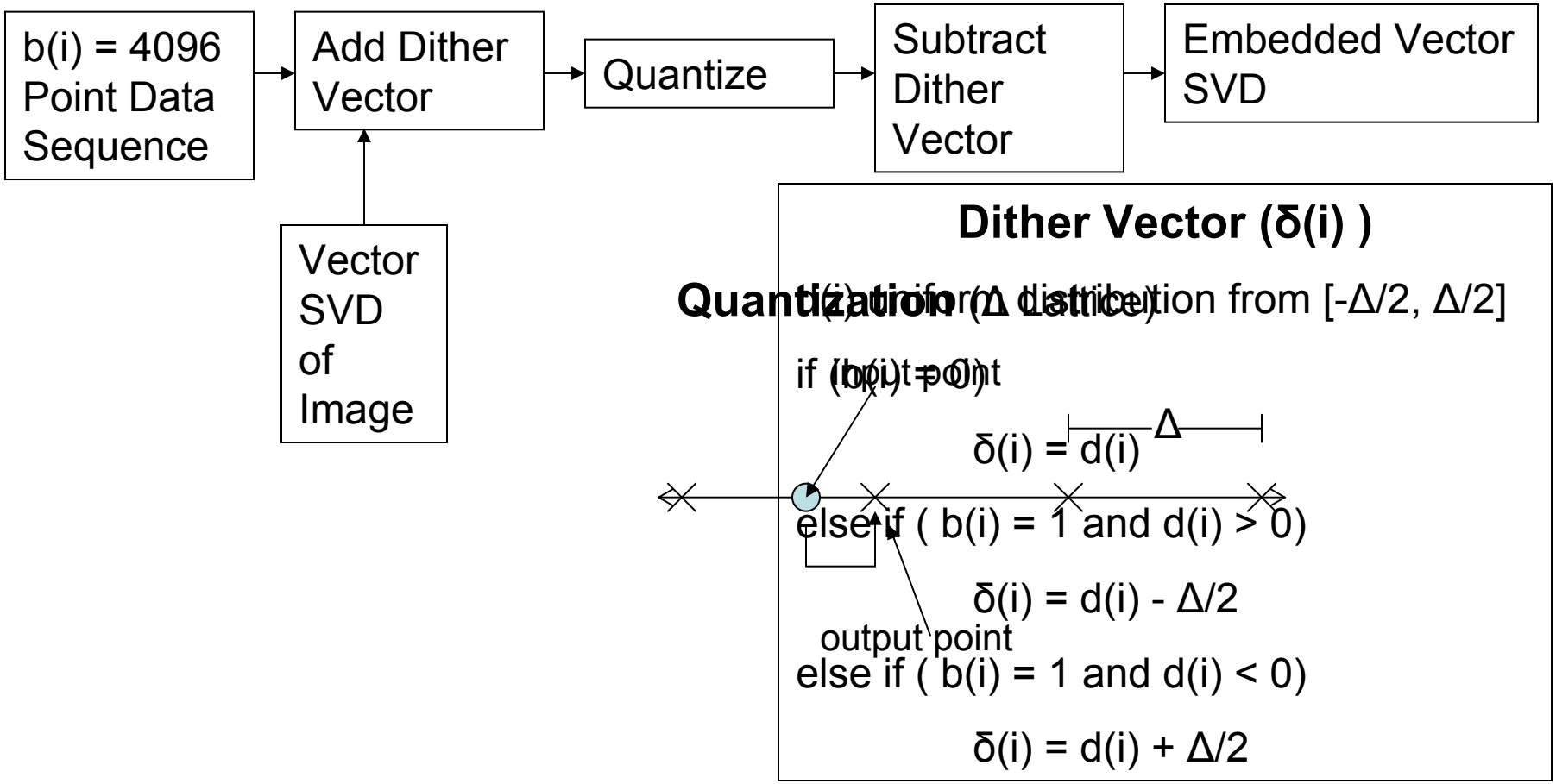
Further Extraction System Design



Comments:

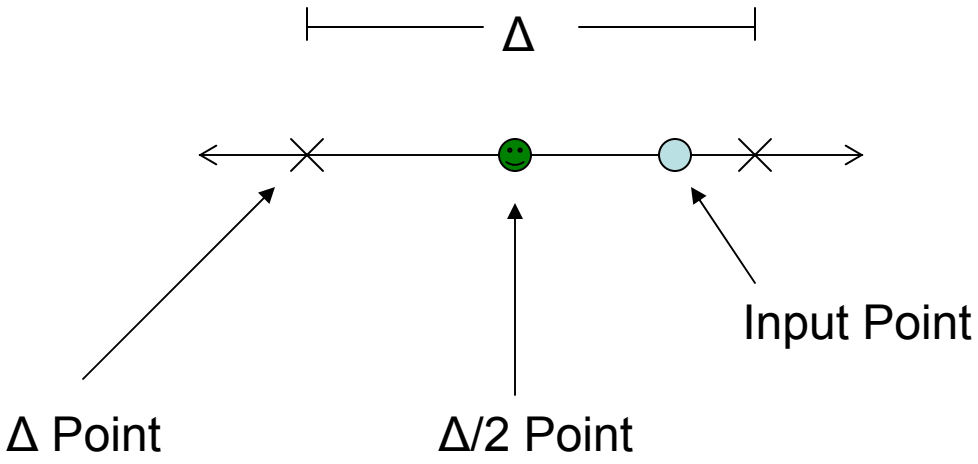
- proposed extraction block earlier
- dashed blocks are optional

Embedding


b(i) = 4096 Point Data Sequence
Add Dither Vector
Quantize
Subtract Dither Vector
Embedded Vector SVD
Vector SVD of Image
Dither Vector (δ(i))
δ(i) uniform distribution from [-Δ/2, Δ/2]
Quantization (Δ Lattice)
if (b(i) = 0)
δ(i) = d(i)
Δ
else if (b(i) = 1 and d(i) > 0)
δ(i) = d(i) - Δ/2
output point
else if (b(i) = 1 and d(i) < 0)
δ(i) = d(i) + Δ/2

Extraction

Quantization (Δ Lattice)



Decision

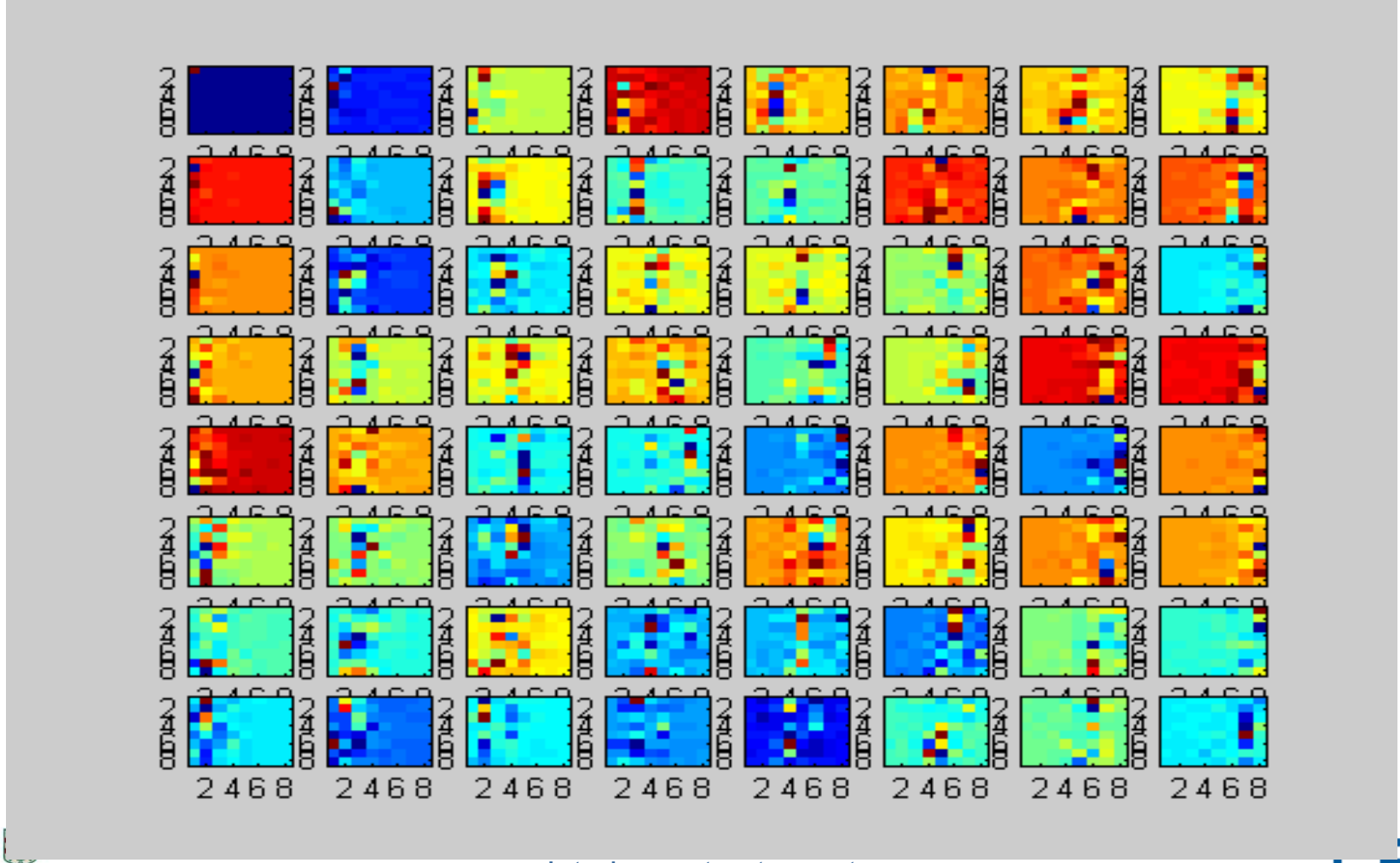
If (Input is closest to a Δ Point)

Output = 0

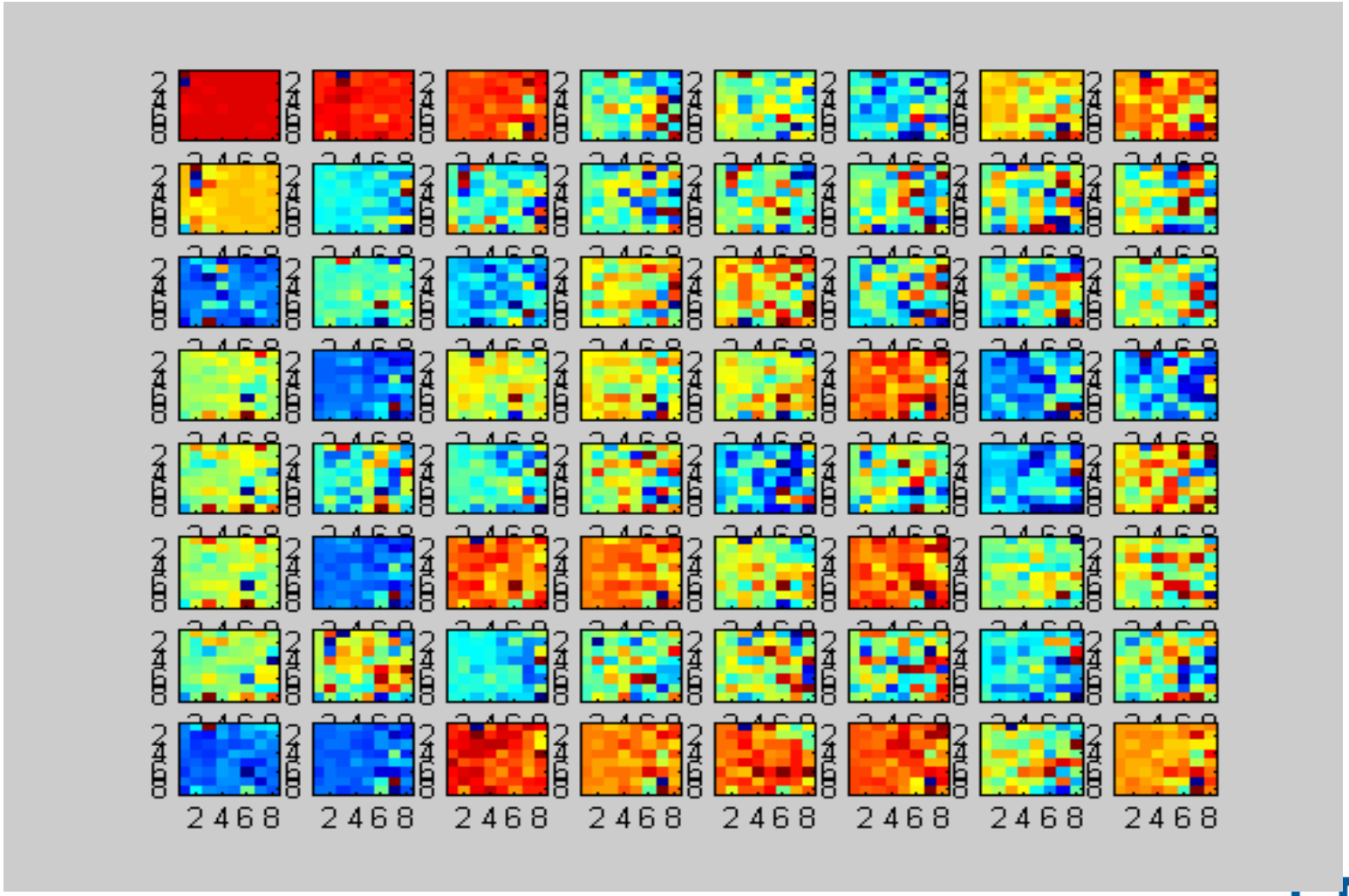
If (Input is closest to a Δ/2 Point)

Output = 1

Component SVD



Vector SVD



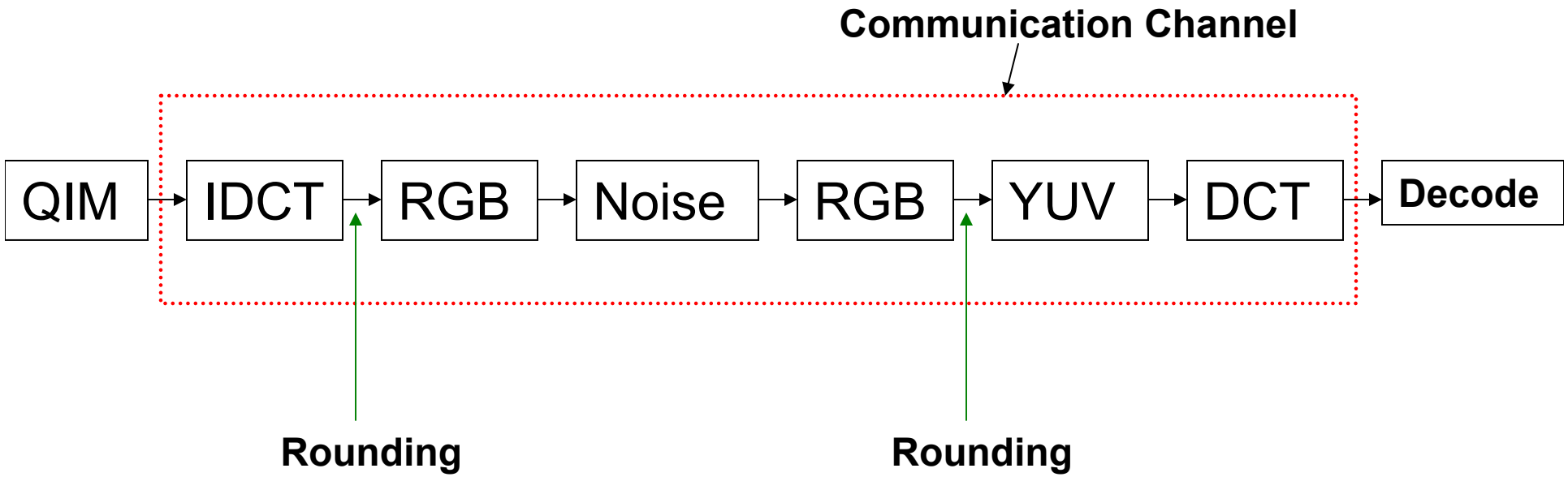
$\Delta = .006$

Δ = .0003

YUV → RGB Conversions

- [6,2,18] ([Y,U,V]) → [27,-5,10]([R,G,B])
- [27,0,10]([R,G,B]) →[9,0,16]([Y,U,V])
- [R,G,B] must be between [0,255]

Information Flow Model



Timeline

- Demonstration of information embedding/extraction blocks: April 12
- Data for analysis of transmission statistics:
  - Video before/after transmission
  - Assistance with reformatting data analysis
- Demonstration of MPEG blocks together with information embedding/extraction blocks: April 30
- Review of patents