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SPARSE AUDIO CODING VIA TARGETED DITHERING AND COMBINATORIAL DECODING

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Presentation Outline

- Introduction: Transform domain coding
- Proposed solution overview
- Encoder side: Subframe decomposition
- Encoder side: Targeted dithering
- Encoder side: Choice of filler vectors
- Encoder side: Header information
- Decoder side: Combinatorial decoding
- Practical results and future work

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Introduction

- Sparse signal coding context
- Transform domain representation of audio
- From input signal $\mathbf{n}$, obtain $\mathbf{x} = \psi(\mathbf{n})$
- With appropriate transformation, most elements in $\mathbf{x}$ have negligible perceptual value and can be zeroed.

Inherent problem in transform coding

- Transmission of sparse vectors:
  - Quantized active/non-negligible **values**
  - Their **position** in the sparse vector
- Problem: potentially large overhead required to encode the positions
- Some solutions: RLE, Huffman-coding of position vectors, etc.
- We propose an alternative solution

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Proposed solution overview

- Embed some position information in quantized values
- Adjust quantized values so as to minimize some function of both values and positions
- Perceptually controlled adjustment
- Decoder progresses through reduced set of possible positions, and verifies which one minimizes the known function

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Subframe decomposition

- Further decompose into small non-overlapping frames
- Reduce set of possibilities for decoder
- Compromise required (not too small!): each subframe needs a header, and smaller frames mean less room for transparent adjustments!

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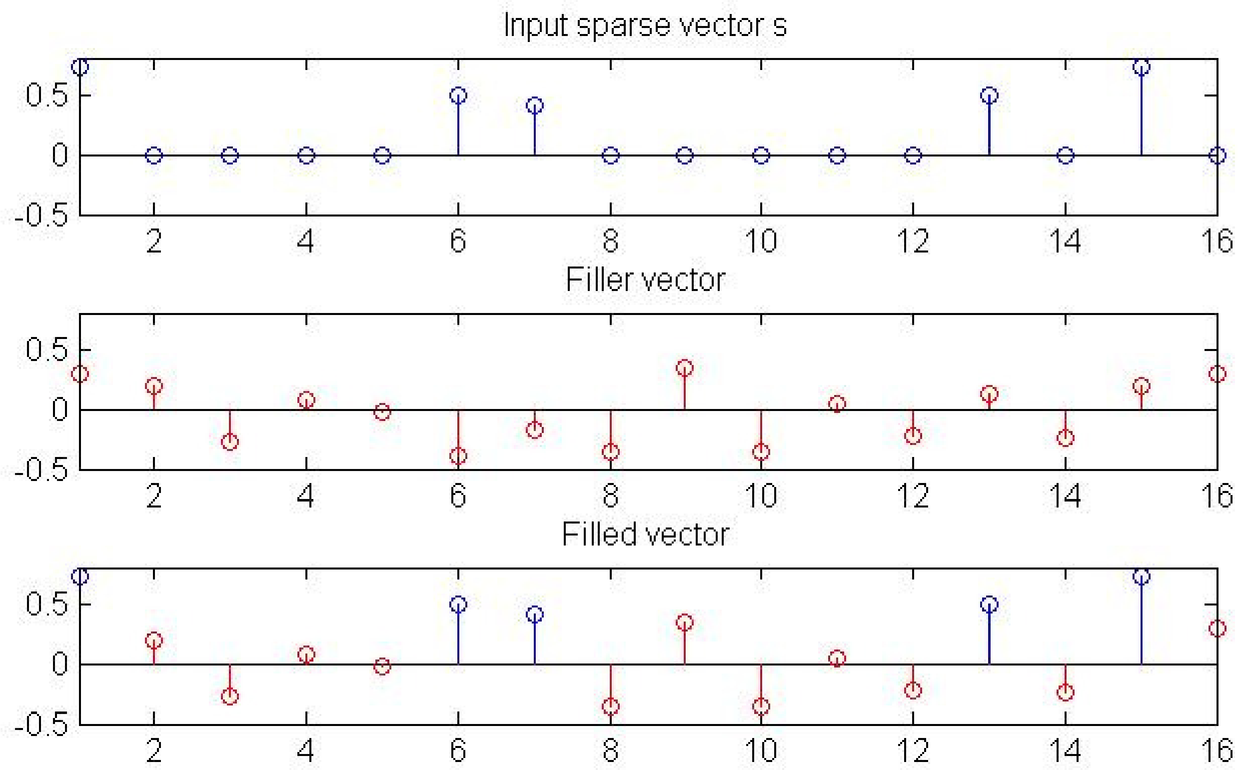
Targeted dithering stage

- Obtain the quantized sparse input
- Using a fixed, unquantized filler vector, define vector $\mathbf{v}$



$\mathbf{v}$ consists of the red dots on the bottom graph. It essentially completes $\mathbf{s}_q$ with values from the filler vector

Targeted dithering stage

- Denote by T a certain target number
- We can then define a targeting function:

$$f(\mathbf{s}_q, \mathbf{v}) = T + e$$

designed such that e is small

- Goal: adjust $\mathbf{s}_q$ such that e is minimized

- E.g.:

$$f(\mathbf{s}_q, \mathbf{v}) = \sum_n (\mathbf{s}_q(n) + \mathbf{v}(n))$$
$$T = [f(\mathbf{s}_q, \mathbf{v})]$$

Targeted dithering

- Why would we do this?
- Suppose that $\mathbf{s}_q$ has been adjusted and e is minimized
- The K quantized and adjusted values are sent to the decoder
- With *only* these K values, the decoder can go through the set of possible positions and stop whenever the following is smaller than an established threshold ϵ :

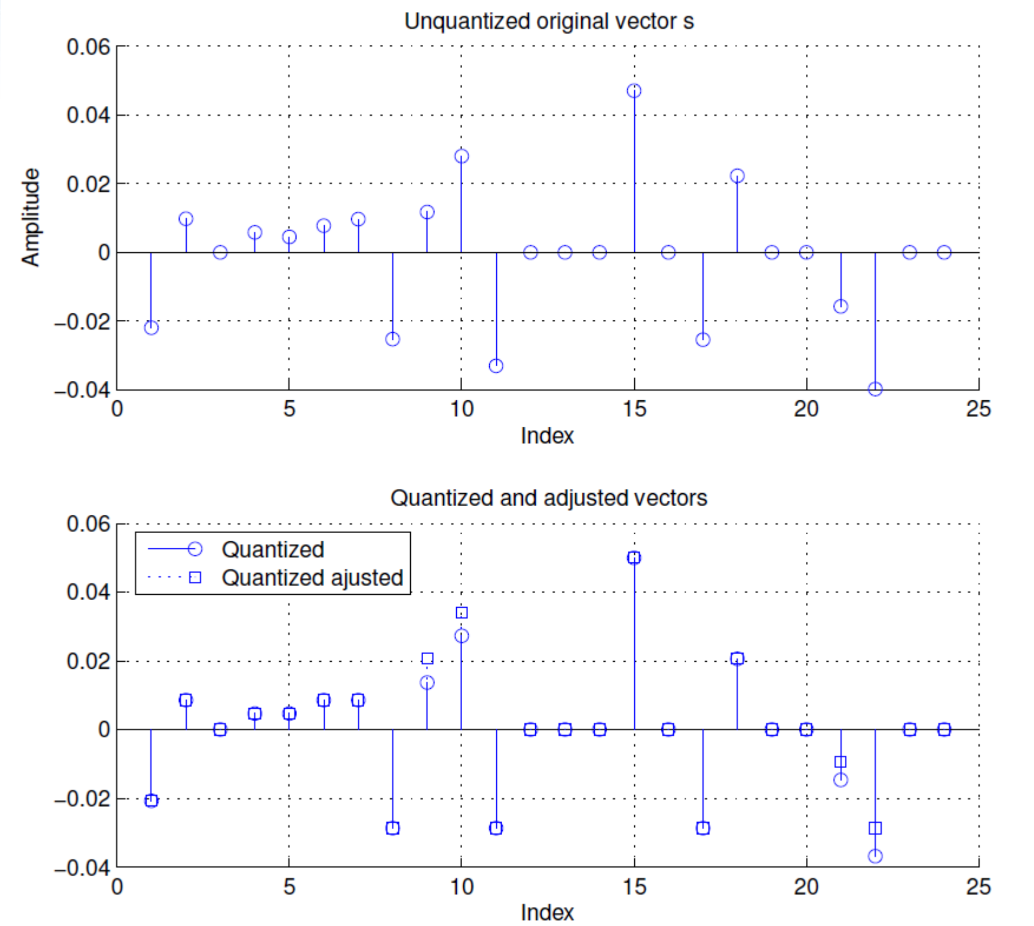
$$e = f(\mathbf{s}_q, \mathbf{v}) - [f(\mathbf{s}_q, \mathbf{v})] \leq \epsilon$$

Performing the adjustment

- The problem can be cast as a binary integer program, i.e., a constrained minimization with binary variables
- Efficient branch-and-bound can be used
- The solution minimizes the required adjustments
- The problem is feasible for at least one choice of threshold

Example of targeted dithering

- Example: $\boxed{\epsilon = 5 \times 10^{-5},\ T = 2}$



$$f(\mathbf{s}_q, \mathbf{v}) \simeq 2.28987$$

$$f(\mathbf{s}_q, \mathbf{v}) \simeq 1.99997$$

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Choice of filler vectors

- Choice of targeting function and filler vector is important
- Need smallest possible epsilon with the smallest amount of changes
- Also, should yield significantly different function values for incorrect positioning
- Open problem, but a few findings in the paper
  - Adaptive filler vectors
  - Zero-mean Gaussian, smaller variance than input signal yields operational solution
  - Bank of filler vectors

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Header information

- If everything goes “as planned”, all that is needed is the number of active elements
- Encoder can easily verify whether everything will go well for the decoder
- If not: header can provide additional hints, e.g.:
  - Exponent of the error
  - Target integer
  - Rough amount of trials required (can save time!)
  - Etc.

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Combinatorial decoding

- Decoder is very simple in essence
- For each subframe:
  - Read header to get number of active elements (and any other “hint”)
  - Decode the amplitudes
  - Go through a list of position vector candidates. For each possibility, extract filler vector and test targeting function
- List exhaustion scheme, required amount of trials, and other details derived in the paper

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Practical results

- Paper contains a detailed operational codec
- Bit allocation scheme, “tricks” to reduce amount of trials required, and to ensure success of targeted dithering
- Preliminary tests: good quality for 44.1 kHz sampling rate at about 50 kbps.
- Adjusted vs. unadjusted: example with 6 bits per coefficient and nearly undistinguishable results
- Drawback: significantly slower and more demanding than available state-of-the-art audio codecs

Questions?

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