Distributed Compressive Sensing: A Deep Learning Approach

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What is Distributed Compressive Sensing?

- Single Measurement Vector (SMV)

$$\boldsymbol{y} = \boldsymbol{A} * \boldsymbol{s}$$

- Multiple Measurement Vector (MMV)

$$\boldsymbol{Y} = \boldsymbol{A} * \boldsymbol{S}$$

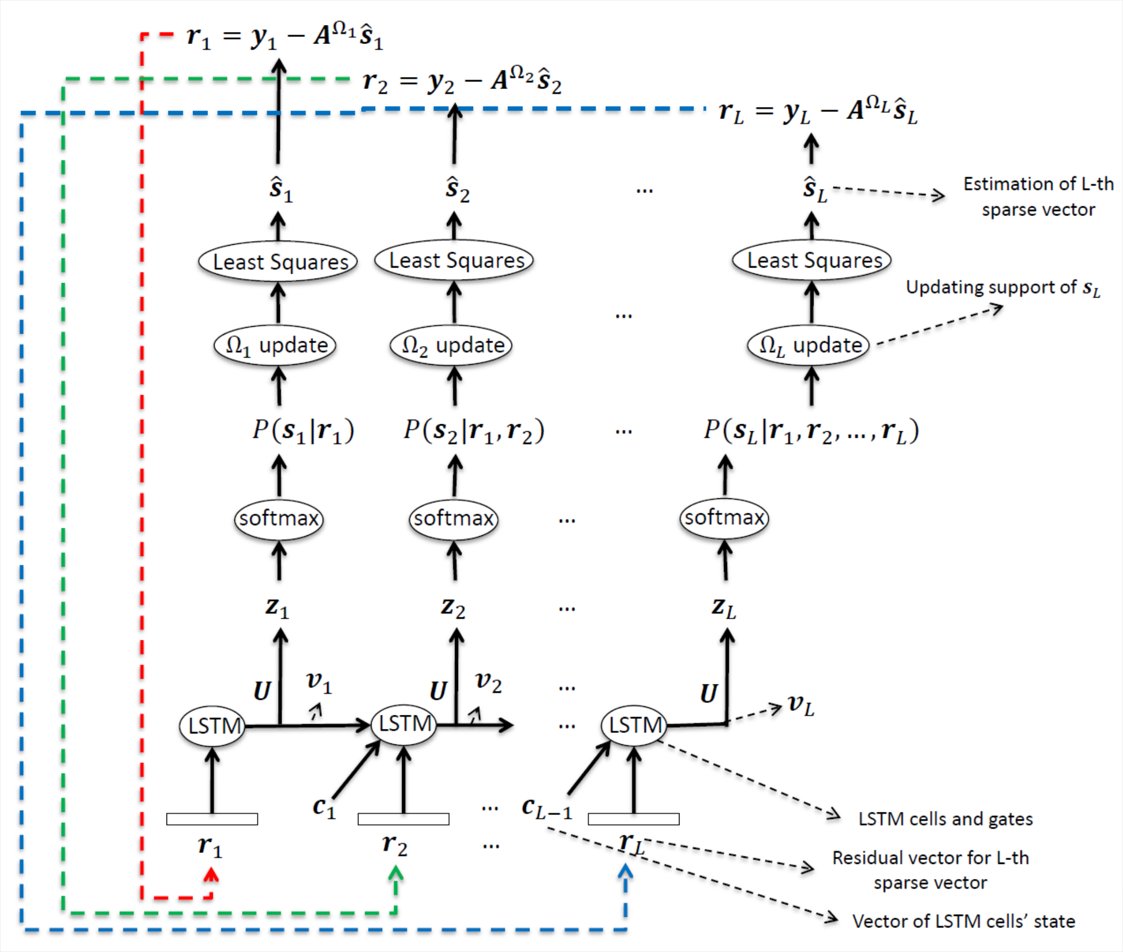
  - Jointly Sparse Vectors
    - Simultaneous Orthogonal Matching Pursuit (SOMP) – Greedy Method
    - Multitask Bayesian Compressive Sensing (MT-BCS) – Bayesian Method
    - Sparse Bayesian Learning (SBL) – Bayesian Method

  - Only Dependent Vectors (New approach called LSTM-CS)

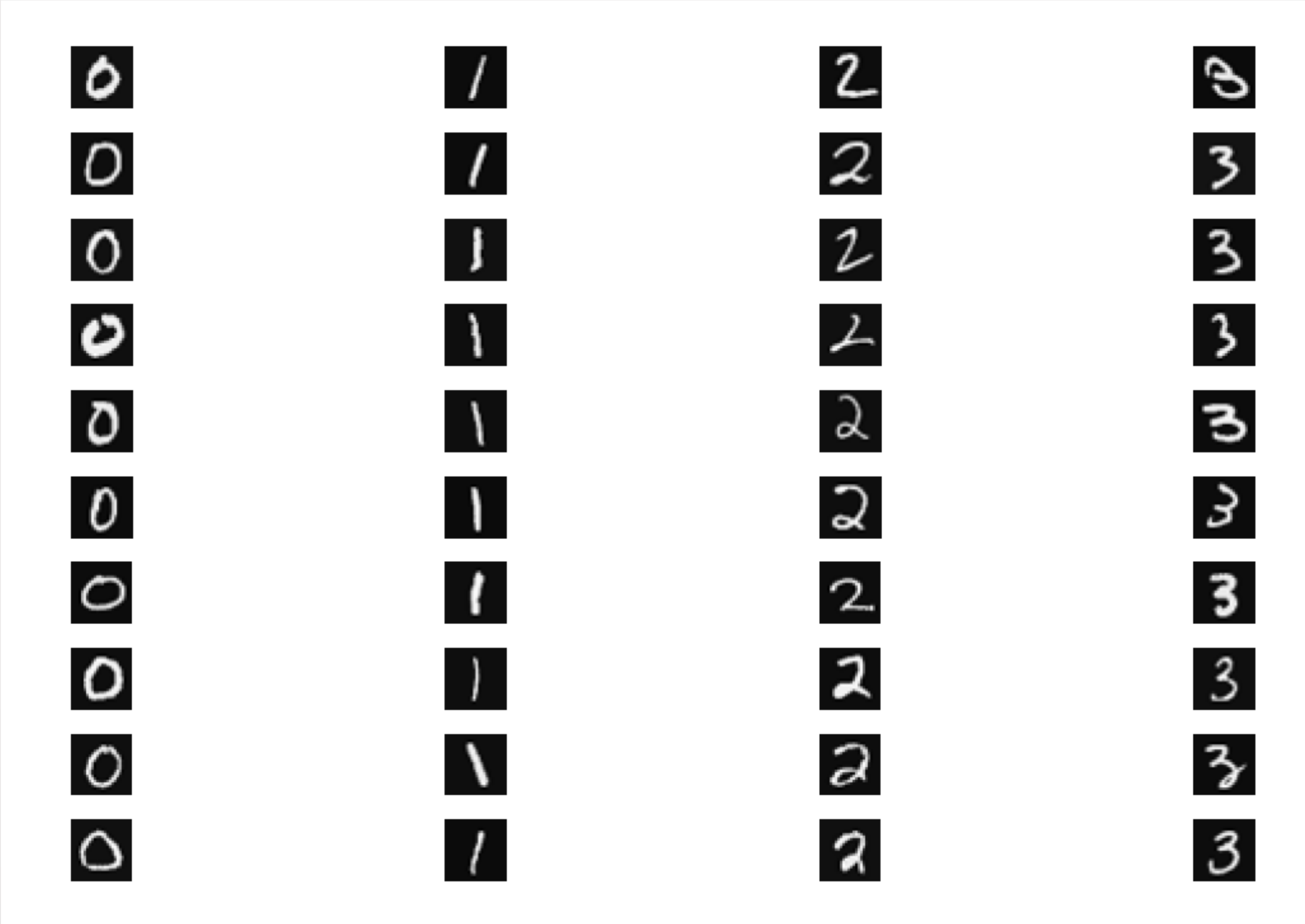
The New Approach!

1. Find the most probable entries for each vector $\boldsymbol{s}_i$ in order to find its' support set.
   - Using a Recurrent Neural Network (RNN) with Long Short-Term Memory(LSTM) cells and a softmax layer on top of it.
   - The model parameters are found by minimizing a cross entropy cost function and using the known probabilities of the training data. Therefore, they are calculated only one time.
2. Find the value of this non-zero entries.
   - Solving a least squares problem.

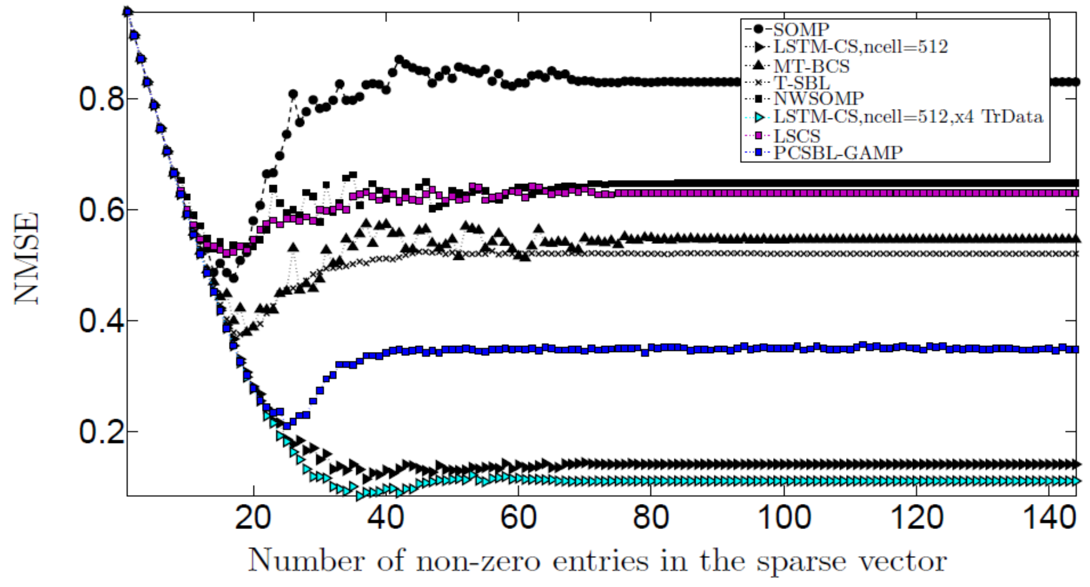
Block Diagram of the Proposed Method

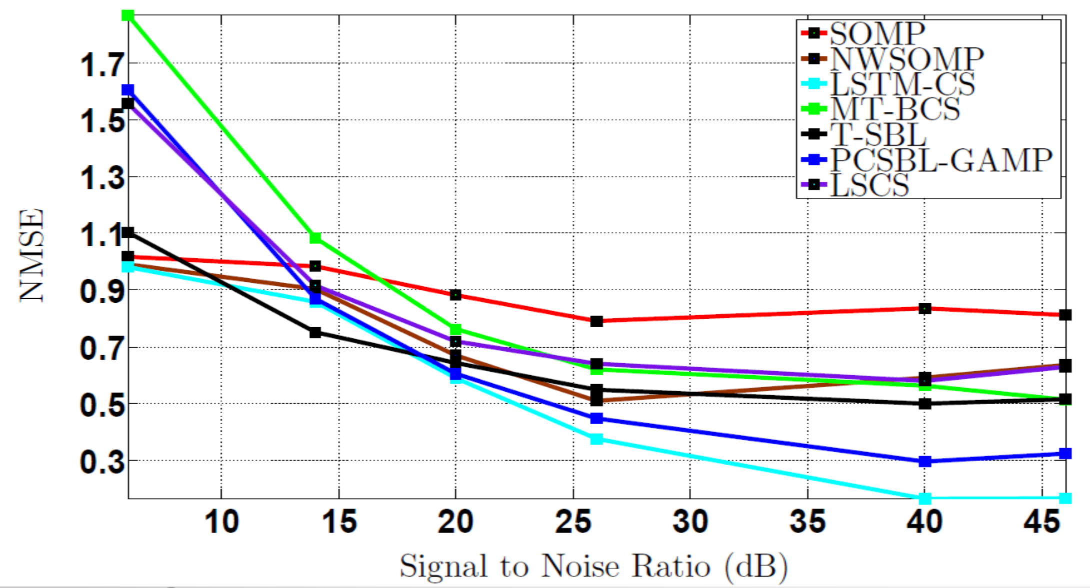


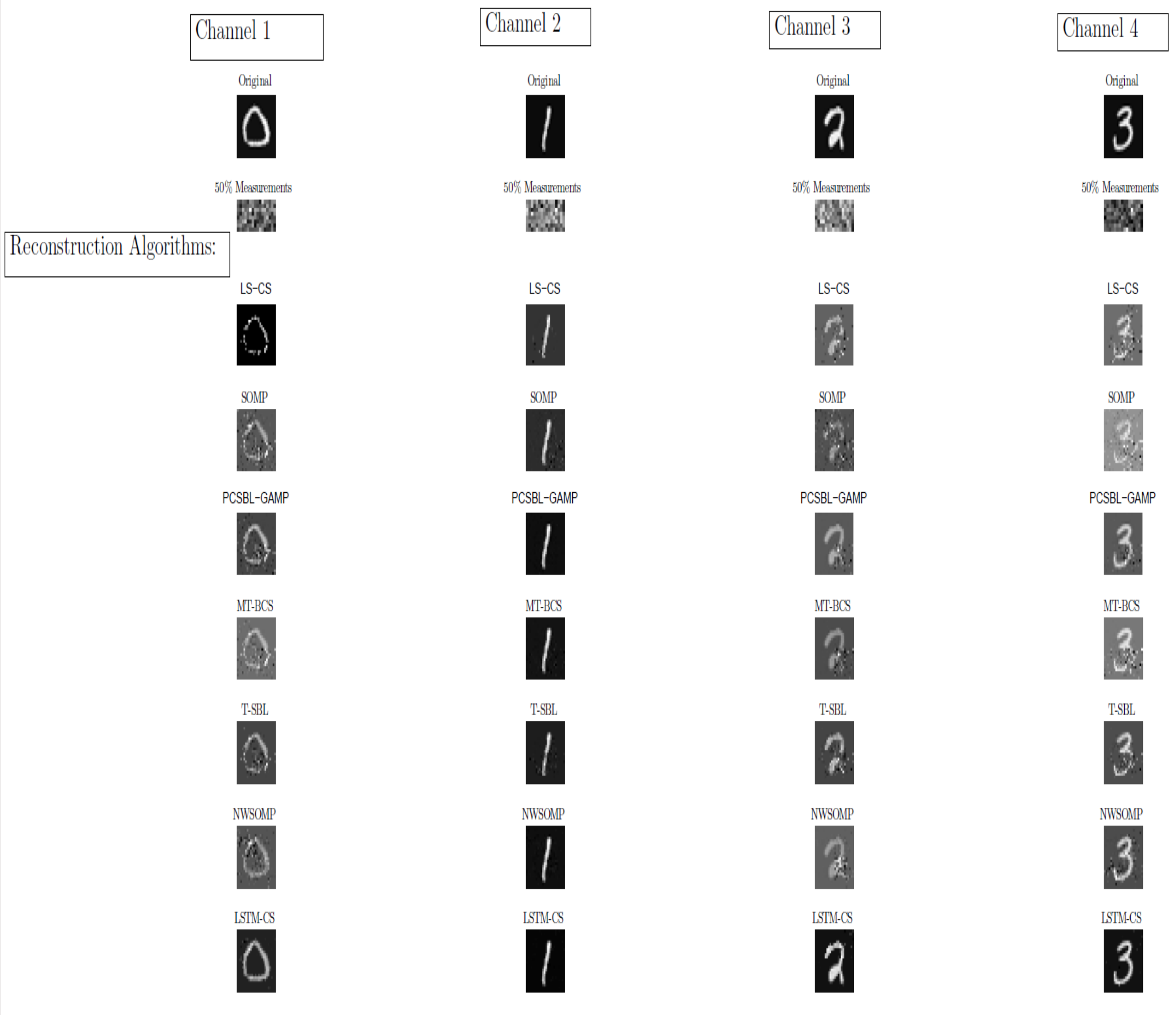
MNIST Dataset



Results: MNIST Dataset







Conclusions

- The proposed method does not rely on the commonly used joint sparsity assumption.

- The proposed method outperforms the general MMV baseline SOMP and a number of Bayesian model based methods.

- Nor multiple layers of LSTM neither advanced deep learning methods for training used, which can improve the performance of the method.

- Proof of concept that deep learning methods can improve the performance of the MMV solvers significantly.

Thank you very much for your attention!

Any Questions?

Agenda

- What is Distributed Compressive Sensing?
- The New Approach!
- Block Diagram of the Proposed Method
- Research Questions
- MNIST Dataset
- Results: MNIST Dataset
- Natural Images Dataset
- Results: Natural Images Dataset
- Conclusions

LSTM-CS Algorithm

Algorithm 1 Distributed Compressive Sensing using Long Short-Term Memory (LSTM-CS)

Inputs: CS measurement matrix $\mathbf{A} \in \Re^{M \times N}$; matrix of measurements $\mathbf{Y} \in \Re^{M \times L}$; minimum ℓ_2 norm of residual matrix "$resMin$" as stopping criterion; Trained "$lstm$" model

Output: Matrix of sparse vectors $\hat{\mathbf{S}} \in \Re^{N \times L}$

Initialization: $\hat{\mathbf{S}} = 0$; $j = 1$; $i = 1$; $\Omega = \emptyset$; $\mathbf{R} = \mathbf{Y}$.

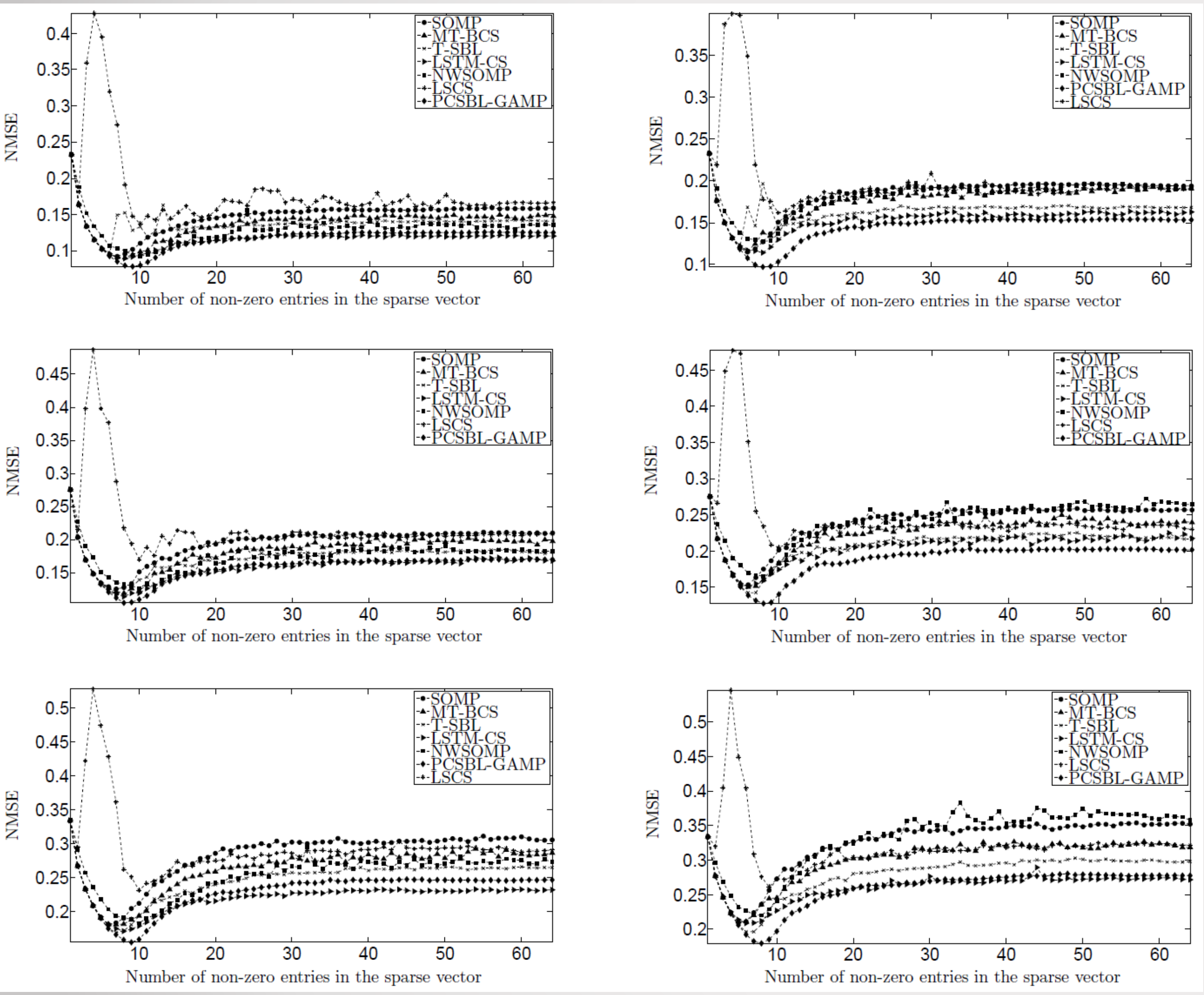
procedure LSTM-CS($\mathbf{A}, \mathbf{Y}, lstm$)
    while $i \leq N$ or $\|\mathbf{R}\|_2 \leq resMin$ **do**
        $i \leftarrow i + 1$
        for $j = 1 \rightarrow L$ **do**
            $\mathbf{R}(:, j)_i \leftarrow \frac{\mathbf{R}(:,j)_{i-1}}{max(|\mathbf{R}(:,j)_{i-1}|)}$
            $\mathbf{v}_j \leftarrow lstm(\mathbf{R}(:, j)_i, \mathbf{v}_{j-1}, \mathbf{c}_{j-1})$ ▷ LSTM
            $\mathbf{z}_j \leftarrow \mathbf{U}\mathbf{v}_j$
            $\mathbf{c} \leftarrow softmax(\mathbf{z}_j)$
            $idx \leftarrow Support(max(\mathbf{c}))$
            $\Omega_i \leftarrow \Omega_{i-1} \cup idx$
            $\hat{\mathbf{S}}^{\Omega_i}(:, j) \leftarrow (\mathbf{A}^{\Omega_i})^{\dagger}\mathbf{Y}(:, j)$ ▷ Least Squares
            $\hat{\mathbf{S}}^{\Omega_i^C}(:, j) \leftarrow 0$
            $\mathbf{R}(:, j)_i \leftarrow \mathbf{Y}(:, j) - \mathbf{A}^{\Omega_i}\hat{\mathbf{S}}^{\Omega_i}(:, j)$
        end for
    end while
end procedure

Research Questions

- How is the performance of different reconstruction algorithms for the MMV problem, including the proposed method, when different channels, i.e., different columns in S, have different sparsity patterns?
- Does the proposed method perform well enough when there is correlation among different sparse vectors? E.g., when sparse vectors are DCT or Wavelet transform of different blocks of an image?
- How fast is the proposed method compared to other reconstruction algorithms for the MMV problem?
- How robust is the proposed method to noise?

Natural Images Dataset

Results: Natural Images Dataset



Left:
- Rows: buildings, cows, flowers
- Columns: DCT Transform, Wavelet Transform

Bottom:
- DCT Transform, buildings