Estimate the Lost Phasor Measurement Unit Data Using Alternating Direction Multipliers Method

Mang Liao, Di Shi, Zhe Yu, Wendong Zhu, Zhiwei Wang, and Yingmeng Xiang, Apr. 2018

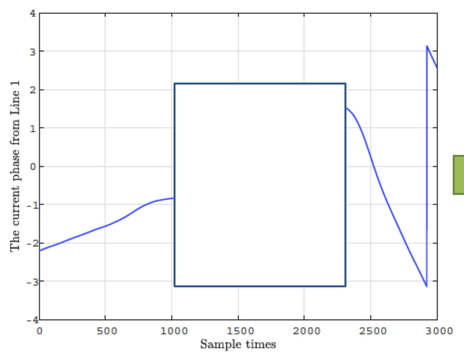
Objective:

- Present an algorithm for recovering missing PMU data
  - Less computational time and complexity
  - Avoid estimating uncertain factor
- Provide a strategy of reshaping the matrix for estimating the measurements which missing from all PMU channels

Technical Approach:

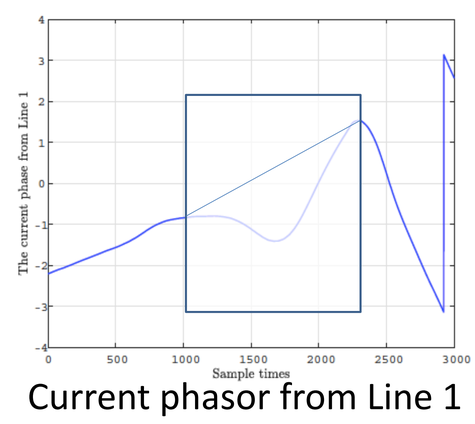
time & space correlations → Low rank

One PMU channel: the same sampling instant → PMU data



Current phasor from Line 1

linear interpolation? ✗



Current phasor from Line 1

The optimal problem:

$$\min_{X \ R^{n_1 \ n_2}} rank(\hat{X})$$

$$s.t.\left(\hat{X} \quad M\right)\odot I_S = 0$$

$$\boldsymbol{X} = \boldsymbol{A}^{\mathrm{T}}\boldsymbol{B}$$

The optimal problem:

$$\min_{\boldsymbol{A},\boldsymbol{B}} = \frac{1}{2}\left(\left\|\boldsymbol{A}\right\|_F^2 + \left\|\boldsymbol{B}\right\|_F^2\right)$$

$$s.t.\left(\boldsymbol{A}^{\mathrm{T}}\boldsymbol{B} \quad \boldsymbol{M}\right)\odot \boldsymbol{I}_s = 0$$

$$M = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \\ m_{31} & m_{32} \\ m_{41} & m_{42} \\ 0 & 0 \\ m_{61} & m_{62} \end{bmatrix}$$

✗ recover

reshape → $n^* = 3$

$$M_{re} = \begin{bmatrix} m_{11} & m_{31} & 0 & m_{12} & m_{32} & 0 \\ m_{21} & m_{41} & m_{61} & m_{22} & m_{42} & m_{62} \end{bmatrix}$$

✓ recover

ALS algorithm

$$a_i = \left(\sum_{j:[I_s]_{ij}=0} b_j b_j^{\mathrm{T}} + \lambda I_r\right)^{-1}\left(\sum_{j:[I_s]_{ij}} [X]_{ij} b_j\right), i = 1, \ldots, n_1$$

$$b_j = \left(\sum_{i:[I_s]_{ij}=0} a_i a_i^{\mathrm{T}} + \lambda I_r\right)^{-1}\left(\sum_{i:[I_s]_{ij}} [X]_{ij} a_i\right), j = 1, \ldots, n_2$$

- Reduce the computational complexity
- Avoid the influence of uncertain factor into the performance

ADMM for PMU data recovery

Initialize A^0, B^0, w^0 and $k = 0$, and determine the values , , $k_{\max}$

Do:

$$A^{k+1} = B^k\left(w^k \odot I_S\right)^T \quad B^k\left(\left((A^k)^T B^k \quad M\right)\odot I_S\right)^T$$

$$B^{k+1} = A^{k+1}\left(w^k \odot I_S\right) \quad A^{k+1}\left(\left((A^{k+1})^T B^k \quad M\right)\odot I_S\right)$$

$$w^{k+1} = w^k + \left(\left((A^{k+1})^T B^{k+1} \quad M\right)\odot I_S\right)$$

$$k = k + 1$$

Until: the stopping criterion $\left\|\left(A^{k+1}\right)^T B^{k+1} \quad \left(A^k\right)^T B^k\right\| <$ or $k > k_{\max}$

Cut-Column Reshaping Method

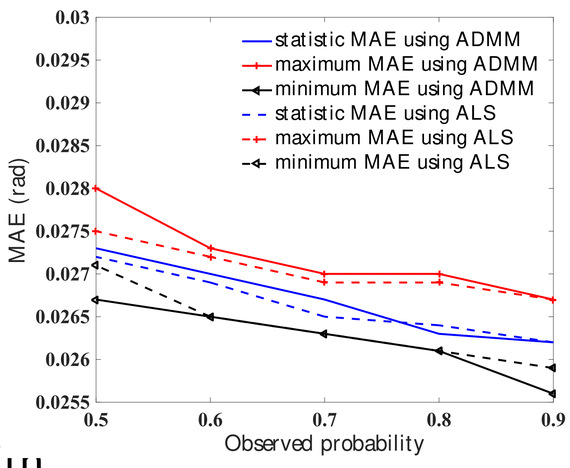
(1) Check whether any row of the observed n_1-by-n_2 matrix ***M*** owns all missing elements.

(2) If yes, let n* be the maximum divisor of n_1, which satisfies

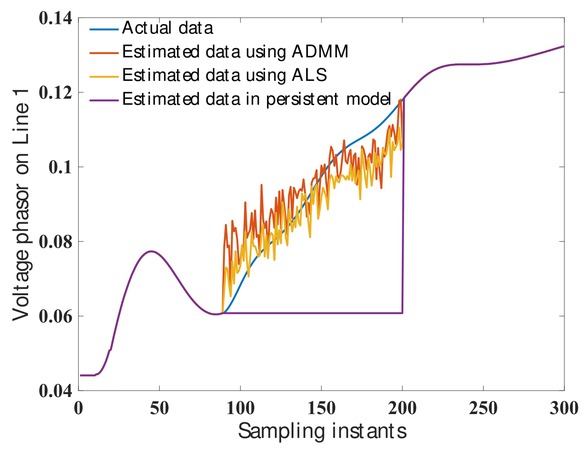
(3) Separate each column of ***M*** into n* shorter columns with n_1/n^* length. The original n_1-by-n_2 matrix is reshaped into a n_1/n^*-by-$n_2 n^*$ matrix

Accomplishments:

	# iteration	time	Sensitivity
ALS	50	>7s	less
ADMM	100	<1s	more



With missing data from all the channels MAEs using ADMM and ALS against different observed data probabilities, respectively.



Comparison of the estimated measurements using ADMM, ALS, and persistent model. The blue line shows the actual measurements.

Next Steps:

- Recovering continuous several rows of the observed matrix with all missing elements
- Testing the proposal using actual PMU data.

Potential Impact:

Data missing in wide-area network → challenges → Data recovery and state estimation for wide-area monitoring and control using PMU data → algorithms → ADMM for recovering the missing PMU data with less time → produce → Recover missing PMU data for real-time applications

STATE GRID GEIRI NORTH AMERICA 全球能源互联网美国研究院

NC STATE UNIVERSITY

FREEDM SYSTEMS CENTER