Output: Estimated signal tensor $\hat{\Theta} \in \mathbb{R}^{d_1 \times \cdots \times d_K}$. 1: for $\pi \in \mathcal{H} = \{-1, \dots, -\frac{1}{H}, 0, \frac{1}{H}, \dots, 1\}$ do Estimate sign tensor $\operatorname{sgn}(\tilde{\mathcal{Z}}_{\pi})$ by performing weighted classification using sub-algorithm. 3: end for 4: Return estimated tensor $\hat{\Theta} = \frac{1}{2H+1} \sum_{\pi \in \mathcal{H}} \operatorname{sgn}(\mathcal{Z}_{\pi})$.

Sub-algorithm: Sign tensor estimation using weighted classification

12:

13: end while

Algorithm 1 Nonparametric tensor completion **Input:** Noisy and incomplete data tensor \mathcal{Y}_{Ω} , rank r.

Input: Noisy and incomplete data tensor \mathcal{Y}_{Ω} , rank r, target level π .

Output: Sign tensor
$$\operatorname{sgn}(\mathcal{Z}) \in \{-1,1\}^{d_1 \times \cdots \times d_K}$$
 as the estimation of $\operatorname{sgn}(\Theta - \pi)$.

5: Random initialization of tensor factors
$$A_k = [a_1^{(k)}, \dots, a_r^{(k)}] \in \mathbb{R}^{d_k \times r}$$
 for all $k \in [K]$.

Random initialization of tensor factors
$$m{A}_k = [m{a}_1^{(k)}, \dots, m{a}_r^{(k)}] \in \mathbb{R}^{d_k}$$

Normalize columns of
$$A_k$$
 to have unit-norm for $k \in [K-1]$, and a

6: Normalize columns of
$$A_k$$
 to have unit-norm for $k \in [K-1]$, and absorb the scales into the columns of A_K .

Update $\mathcal{Z} \leftarrow \sum_{s \in [r]} a_s^{(1)} \otimes \cdots \otimes a_s^{(K)}$, and $A_K \leftarrow A_K / \|\mathcal{Z}\|_F$.

Normalize columns of
$$A_k$$
 to have unit-norm for $k \in [K-1]$, and absorb the scales into the columns while not convergence do

7: while not convergence do
8: for
$$k = 1, ..., K$$
 do

for
$$k = 1, ..., K$$
 do

Undate A_k while holding others fixed: $A_k \leftarrow \arg\min_{A \in \mathbb{R}^d \times \mathbb{R}} \sum_{\sigma} (\mathcal{V}(\omega) - \pi) F(\mathcal{Z}(\omega) \operatorname{sgn}(\mathcal{V}(\omega) - \pi)$

8: **for**
$$k = 1, ..., K$$
 do
9: Update \mathbf{A}_k while holding others fixed: $\mathbf{A}_k \leftarrow \arg\min_{\mathbf{A}_k \in \mathbb{R}^{d_k \times r}} \sum_{\omega \in \Omega} (\mathcal{Y}(\omega) - \pi) F(\mathcal{Z}(\omega) \operatorname{sgn}(\mathcal{Y}(\omega) - \pi)),$

9: Update
$$A_k$$
 while holding others fixed: $A_k \leftarrow \arg\min_{A_k \in \mathbb{R}^{d_k \times r}} \sum_{\omega \in \Omega} (\mathcal{Y}(\omega) - \pi) F(\mathcal{Z}(\omega) \operatorname{sgn}(\mathcal{Y}(\omega) - \pi))$
where $F(\cdot)$ is the large-margin loss and $\mathcal{Z} = \sum_{\alpha \in \Omega} \mathbf{g}^{(1)} \otimes \ldots \otimes \mathbf{g}^{(K)}$

9: Update
$$A_k$$
 while holding others fixed: $A_k \leftarrow \arg \min_{A_k \in \mathbb{R}^{d_k \times r}} \sum_{\omega \in \Omega} (\mathcal{Y}(\omega) - \pi) F(\mathcal{Z}(\omega) \operatorname{sgn}(\mathcal{Y}(\omega) - \pi)$ where $F(\cdot)$ is the large-margin loss, and $\mathcal{Z} = \sum_{s \in [r]} a_s^{(1)} \otimes \cdots \otimes a_s^{(K)}$.

where
$$F(\cdot)$$
 is the large-margin loss, and $\mathcal{Z} = \sum_{s \in [r]} \boldsymbol{a}_s^{(1)} \otimes \cdots \otimes \boldsymbol{a}_s^{(K)}$.

where
$$F(\cdot)$$
 is the large-margin loss, and $\mathcal{Z} = \sum_{s \in [r]} \boldsymbol{a}_s^{(r)} \otimes \cdots \otimes \boldsymbol{a}_s^{(r)}$.

10: **end for**

where
$$F(\cdot)$$
 is the rarge-margin loss, and $\mathcal{L} = \sum_{s \in [r]} \boldsymbol{u}_s \otimes \cdots \otimes \boldsymbol{u}_s$.

10: **end for**

10: end for

Normalize columns of
$$A$$
, to have unit norm for $k \in [K-1]$ and absorb the scales into the columns of A .

11: Normalize columns of
$$A_k$$
 to have unit-norm for $k \in [K-1]$, and absorb the scales into the columns of A

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Normalize columns of
$$A_k$$
 to have unit-norm for $k \in [K-1]$, and absorb the scales into the columns of A_k