

SINGAPORE MANAGEMENT



Robust Sleep Staging over Incomplete Multimodal Physiological Signals via Contrastive Imagination

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Overall framework

Missing rate: $\rho = 1 - \frac{1}{N \cdot M} \sum_{i=1}^{N} \sum_{j=1}^{M} Z_i^j$ At least one mode is kept in one instance





■ SMCCL									$\mathbf{U} = \{\{u_i^j\}_{i=1}^R\}_{j=1}^R, u_i^j = \begin{cases} 1, & \bar{y}_i^j = \dot{y}_i^j \\ 0, & \bar{u}^j \neq \dot{w}^j \end{cases} \mathbf{V} = \{\{v_i^j\}_{i=1}^R\}_{j=1}^R, v_i^j = \begin{cases} 1, & \bar{s}_i^j = \dot{y}_i^j \\ 0, & \bar{s}_i^j = \dot{y}_i^j \end{cases}$								$\bar{s}_i^j = \dot{s}_i^j$							
Lab	$\int_{1}^{el} \mathbf{Y} = \begin{bmatrix} 0\\1\\2 \end{bmatrix}$	0 0 1 1 2 2				$\mathbf{S} = \begin{bmatrix} 0\\0\\0\\0 \end{bmatrix}$	1 2 1 2 1 2	Modality matrix	у								5	(·	$0, y_i \neq 0$	y_i		5	ί	$s_i \neq s_i$
latten	+ Replicate	ŧ					Flatten	+ Replic	ate						w	$I = \mathbf{U} \odot \mathbf{V} +$	$(1-\Theta)(\mathbf{II} - \mathbf{II})$	$\odot \mathbf{V} + 0$	$\Theta(\mathbf{V} - \mathbf{U})$	\mathbf{V}		1 5	M = I($(\phi^k; \phi^i)$
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1	1 1 1	1.1	1 1	1 11	0 0	0 0	0 0	0 0 0	x 1							the 1th level	the 2th level		the 3th level			$M-1 \leftarrow$	i=1 H	$(\phi^{\kappa}, \phi^{i})$
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Contra	stive mask calculation	Forma	da (11)	Con	trastive m	ask tion	Form	ila (11)							П	(\$)<					$\iint p(x, y)$	$y)\ln\frac{1}{p(x,y)}dxdy$	y	
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MCTA

 $(N*L, C, D) \rightarrow (N, L, C*D/S)$





Quantitative results

Table 1: Performance comparison for complete and incomplete modalities in randomly partially missing case. Here "incomplete" means the maximum missing rate.

Datasets	Methods		Complete	2	Incomplete			
Dunieto		Acc	MF1	K	Acc	MF1	K	
	FeatConcat	0.825	0.761	0.771	0.497	0.429	0.285	
	MultitaskCNN [8]	0.835	0.753	0.775	0.589	0.506	0.449	
	SalientSleepNet [23]	0.872	0.827	0.827	0.634	0.565	0.485	
Sleep-EDF-20	MM-Net [1]	0.867	0.817	0.822	0.570	0.493	0.432	
8	TransSleep [16]	0.864	0.819	0.821	0.594	0.521	0.457	
	XSleepNet [10]	0.864	0.809	0.819	0.623	0.560	0.478	
	CIMSleepNet	0.867	0.821	0.824	0.853	0.801	0.805	
	FeatConcat	0.788	0.726	0.717	0.526	0.471	0.392	
	MultitaskCNN [8]	0.795	0.727	0.722	0.613	0.535	0.453	
	SalientSleepNet [23]	0.843	0.794	0.791	0.722	0.643	0.625	
Sleep-EDF-78	MM-Net [11]	0.845	0.796	0.794	0.706	0.628	0.597	
22	TransSleep [16]	0.846	0.797	0.795	0.738	0.654	0.637	
	XSleepNet [10]	0.838	0.776	0.779	0.697	0.622	0.583	
	CIMSleepNet	0.849	0.799	0.797	0.830	0.772	0.775	
	FeatConcat	0.745	0.731	0.672	0.502	0.445	0.336	
	MultitaskCNN [8]	0.774	0.763	0.705	0.643	0.630	0.533	
SVUH-UCD	TransSleep [16]	0.794	0.782	0.732	0.725	0.698	0.636	
	XSleepNet [10]	0.783	0.761	0.725	0.708	0.689	0.615	
	CIMSleepNet	0.801	0.794	0.751	0.788	0.777	0.726	
	FeatConcat	0.700	0.464	0.237	0.477	0.243	0.011	
MUD	MLP [24]	0.723	0.529	0.306	0.610	0.348	0.035	
MHK	DeepCNN [9]	0.759	0.615	0.421	0.616	0.354	0.039	
	CIMSleepNet	0.729	0.553	0.348	0.701	0.466	0.240	

Table 2: Performance comparison in completely missing case.

Test Modalities	Methods	Acc	MF1	K
EEG	CoRe-Sleep [26]	0.882	0.808	0.834
	CIMSleepNet	0.891	0.817	0.845
EOG	CoRe-Sleep [26] CIMSleepNet	0.853	0.753 0.760	0.792 0.798
EEG+EOG	CoRe-Sleep [26]	0.895	0.823	0.853
	CIMSleepNet	0.903	0.828	0.862

3 Experiment

Quantitative results

- As the missing rate increases, the performance of other methods begins to decline significantly.
- CIMSleepNet exhibits amore stable trend.





Qualitative results





Ablation studies

MAIM	SMCCL	MCTA	Acc	MF1	K	Model Size (MB)	GFLOPs
			0.497	0.429	0.285	2.344	0.069
\checkmark			0.771	0.704	0.672	5.767	0.096
	\checkmark		0.786	0.726	0.699	8.458	0.071
		1	0.694	0.629	0.536	30.272	2.206
\checkmark	~		0.810	0.756	0.759	4.412	0.097
\checkmark		1	0.829	0.778	0.777	33.696	2.876
	\checkmark	1	0.834	0.786	0.784	36.386	2.246
\checkmark	~	1	0.853	0.801	0.805	37.678	2.902

Table 3: Ablation study of CIMSleepNet on Sleep-EDF-20. " \checkmark " indicates the use of this component. MCTA indicates the Transformer equipped with MCTA. The context length of single inference is 25.

Table 4: Ablation study of Transformer equipped with MCTA on Sleep-EDF-20.

Methods	Acc	MF1	K
Intra-GRU	0.827	0.775	0.772
Inter-GRU	0.835	0.780	0.787
Intra & Inter-GRU	0.839	0.788	0.791
Intra-Transformer	0.813	0.770	0.765
Inter-Transformer	0.837	0.789	0.793
Intra & Inter-Transformer	0.845	0.795	0.797
Transformer with MCTA	0.853	0.801	0.805



Other analysis





- We try to challenge multimodal ASS under incomplete modalities by proposing CIMSleepNet.
- MAIM reconstructs missing modality data by establishing interactions among modalities, which allows for the provision of complete modality data support for subsequent components.
- SMCCL ingeniously leverages semantic information and modal information to subdivide similarity into three levels, thereby simulating real data distribution.
- MCTA mechanism accomplishes comprehensive temporal context modeling, further improving the expressive ability of latent temporal representations.



Thank You For Your Attention!