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Regularization-free Diffeomorphic Temporal Alignment Nets
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Multiple Video synchronization w/o a reference (work in progress)

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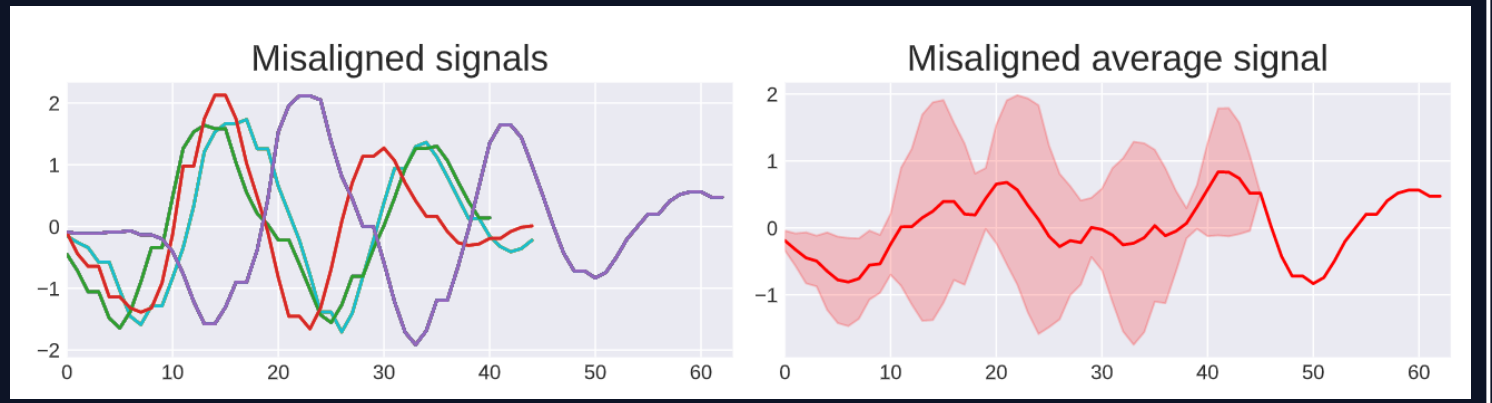
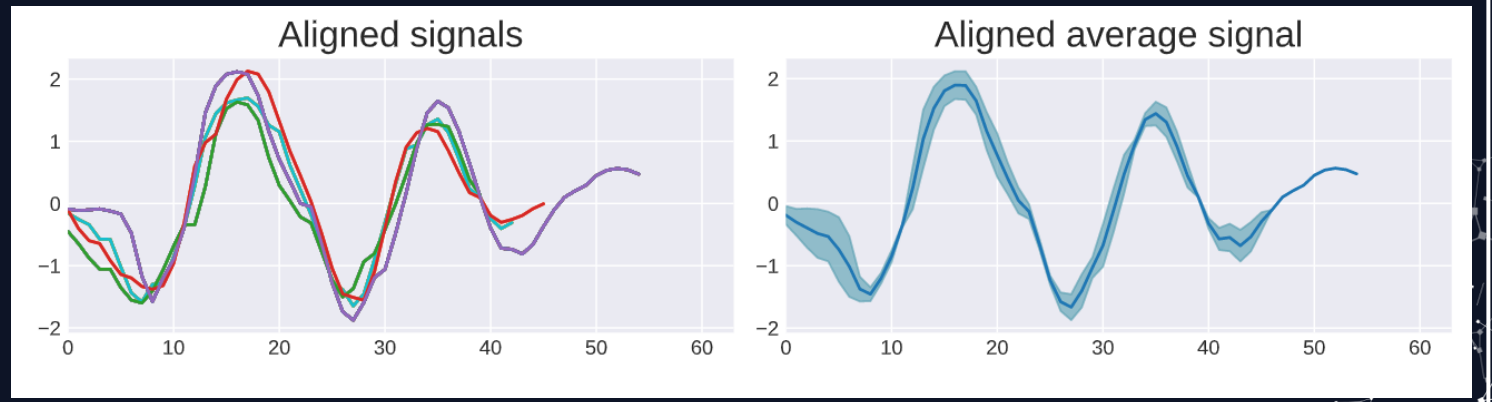
Problem Formulation – Time Series Joint Alignment

Problem: nonlinear misalignment of the data





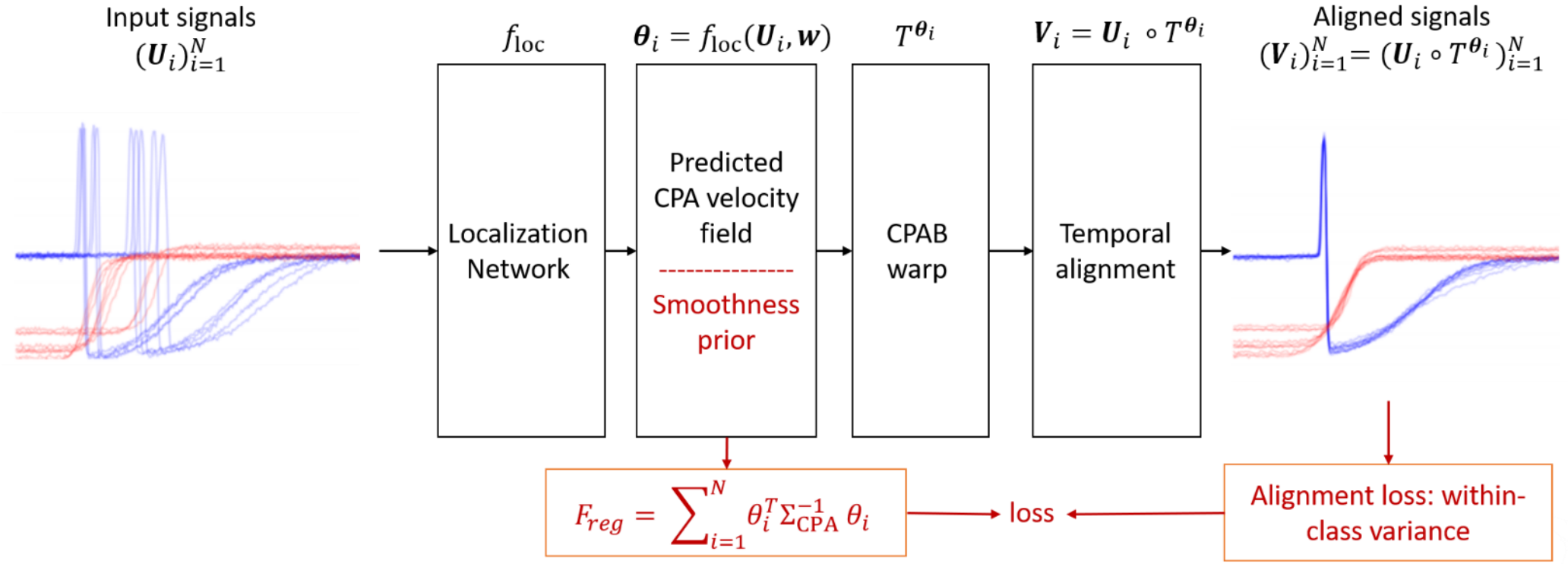
Regularization-free Diffeomorphic Temporal Alignment Nets

- Our proposed solution –

  Regularization-free Diffeomorphic Temporal Alignment Nets – RF-DTAN

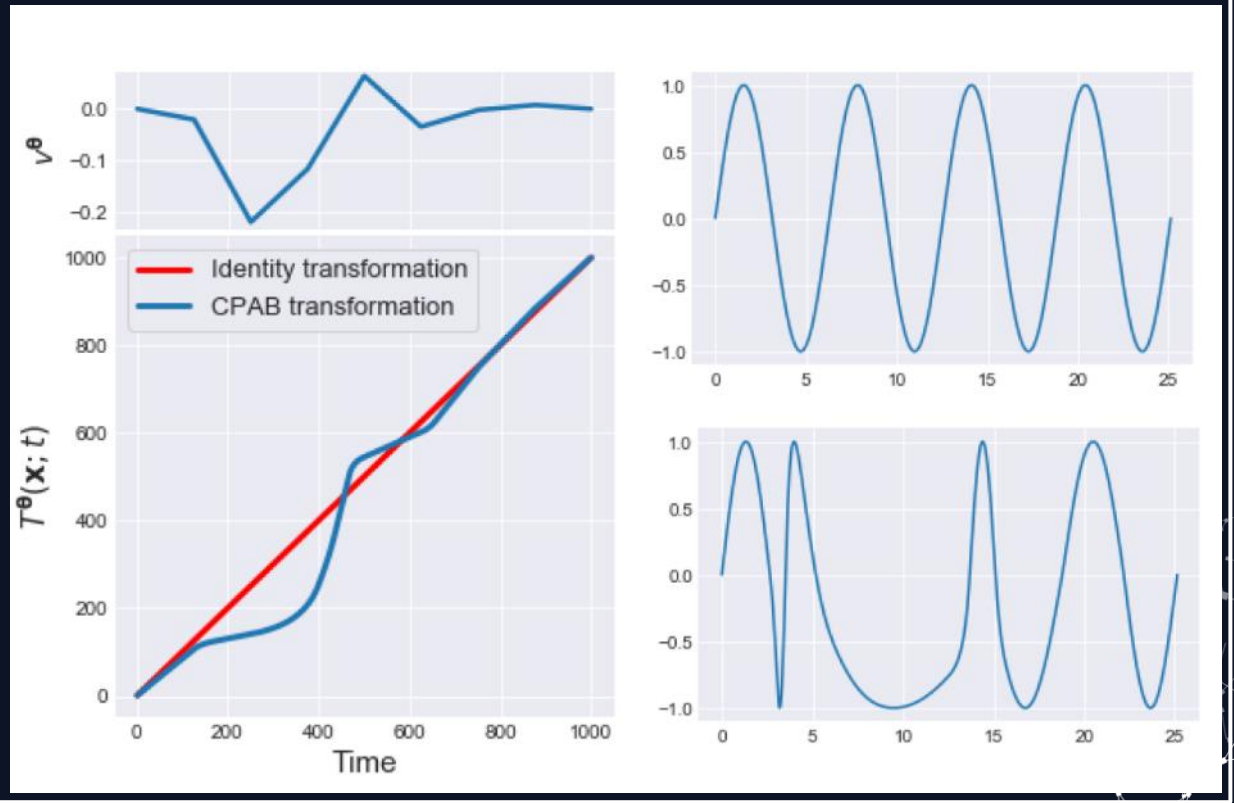
  - **Shapira Weber**, Eyal, Skafte Detlefsen, Shriki and Freifeld [**NeurIPS '19**]
  - Kaufman, Shapira Weber and Freifeld [**ICIP '21**]
  - **Shapira Weber** and Freifeld [**ICML '23**]

DTAN (2019)

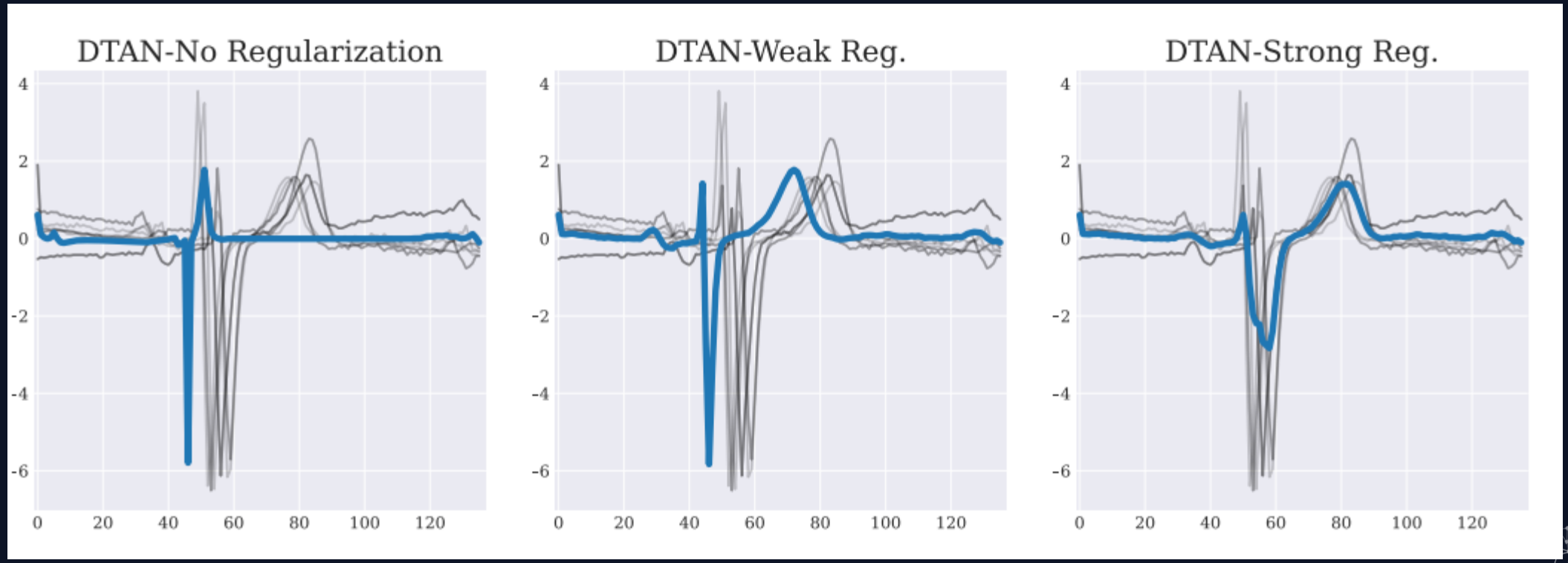

Input signals
$(\boldsymbol{U}_i)_{i=1}^N$
f_{loc}
$\boldsymbol{\theta}_i = f_{\text{loc}}(\boldsymbol{U}_i, \boldsymbol{w})$
$T^{\boldsymbol{\theta}_i}$
$\boldsymbol{V}_i = \boldsymbol{U}_i \circ T^{\boldsymbol{\theta}_i}$
Aligned signals
$(\boldsymbol{V}_i)_{i=1}^N = (\boldsymbol{U}_i \circ T^{\boldsymbol{\theta}_i})_{i=1}^N$
Localization Network
Predicted CPA velocity field
Smoothness prior
CPAB warp
Temporal alignment
$F_{reg} = \sum_{i=1}^{N} \theta_i^T \Sigma_{\text{CPA}}^{-1} \theta_i$
loss
Alignment loss: within-class variance

CPAB Warps

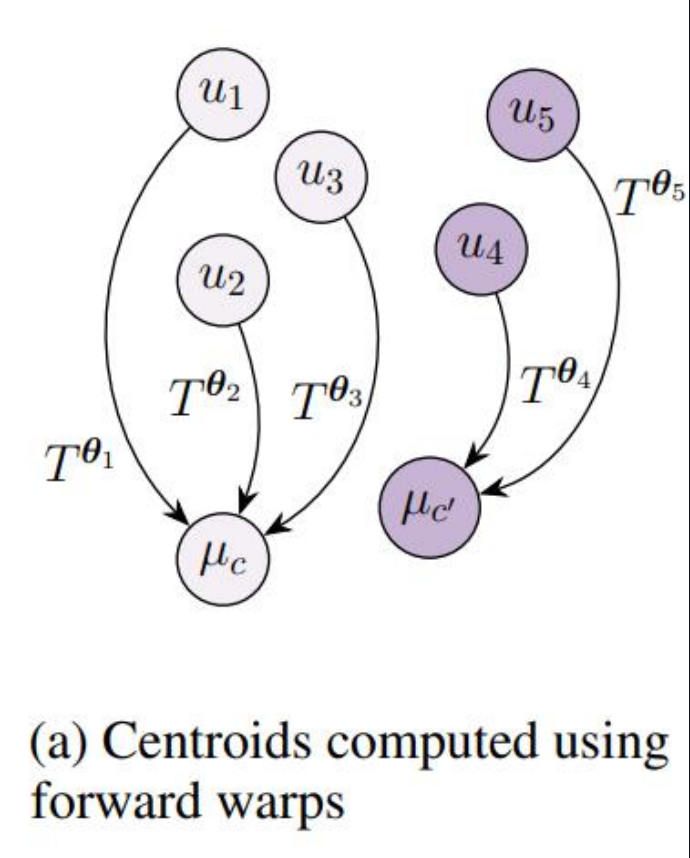
- CPAB warps [Freifeld et al., ICCV ’15 & PAMI ’17]
- Fast and has a closed form
- Parametric (and finite-dimensional)
- Highly-accurate & Expressive
- The gradient w.r.t. the parameters has a closed from and is fast to compute [Martinez ICML ’22].



Regularization



DTAN (2019)

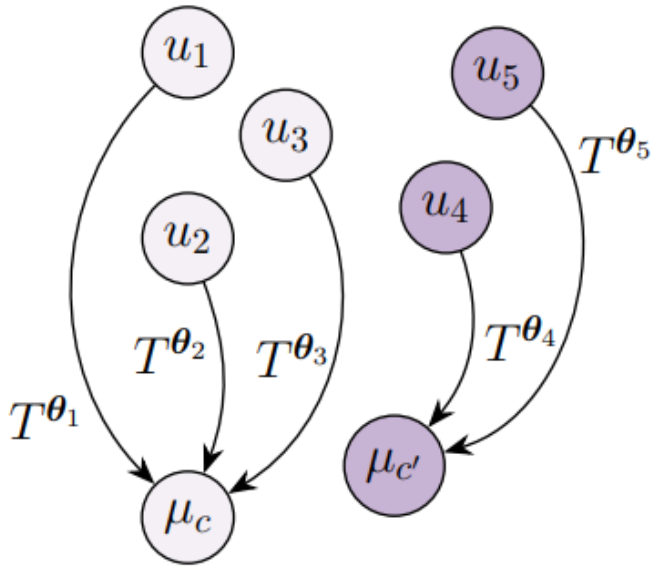


(a) Centroids computed using forward warps

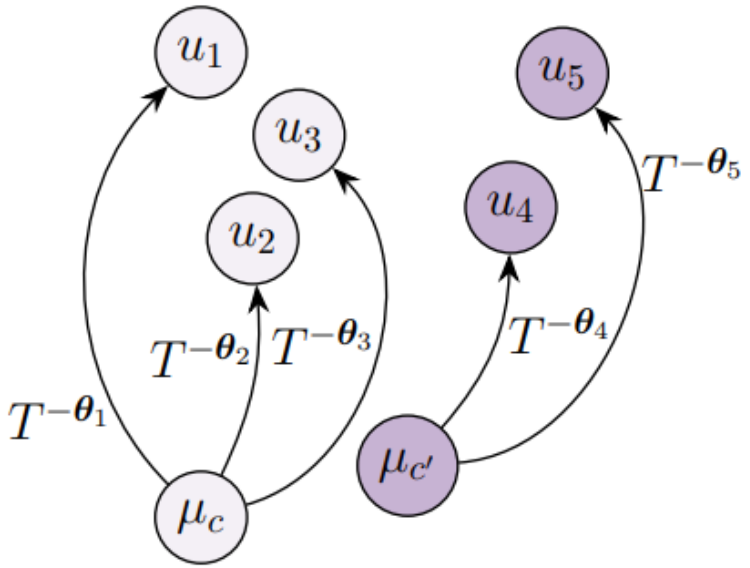
$$F_{data} = \sum_{k=1}^{K} \frac{1}{N_k} \sum_{i:y_i=k} \left\| u_i \circ T^{\theta_i} - \mu_k \right\|_{\ell 2}^2$$

$F_{reg} = \theta_i^T \Sigma_{\mathrm{CPA}}^{-1} \theta_i$, has 2 hyper-parameters (HP)

Regularization-free DTAN (ICML 2023)



(a) Centroids computed using forward warps



(b) The ICAE loss computed using backward warps

$$F_{ICAE} =$$

$$\sum_{k=1}^{K} \frac{1}{N_k} \sum_{i:y_i=k} \left\| \mu_k \circ T^{\theta_i} - u_i \right\|_{\ell 2}^2$$

Inverse Consistency Averaging Error (ICAE)

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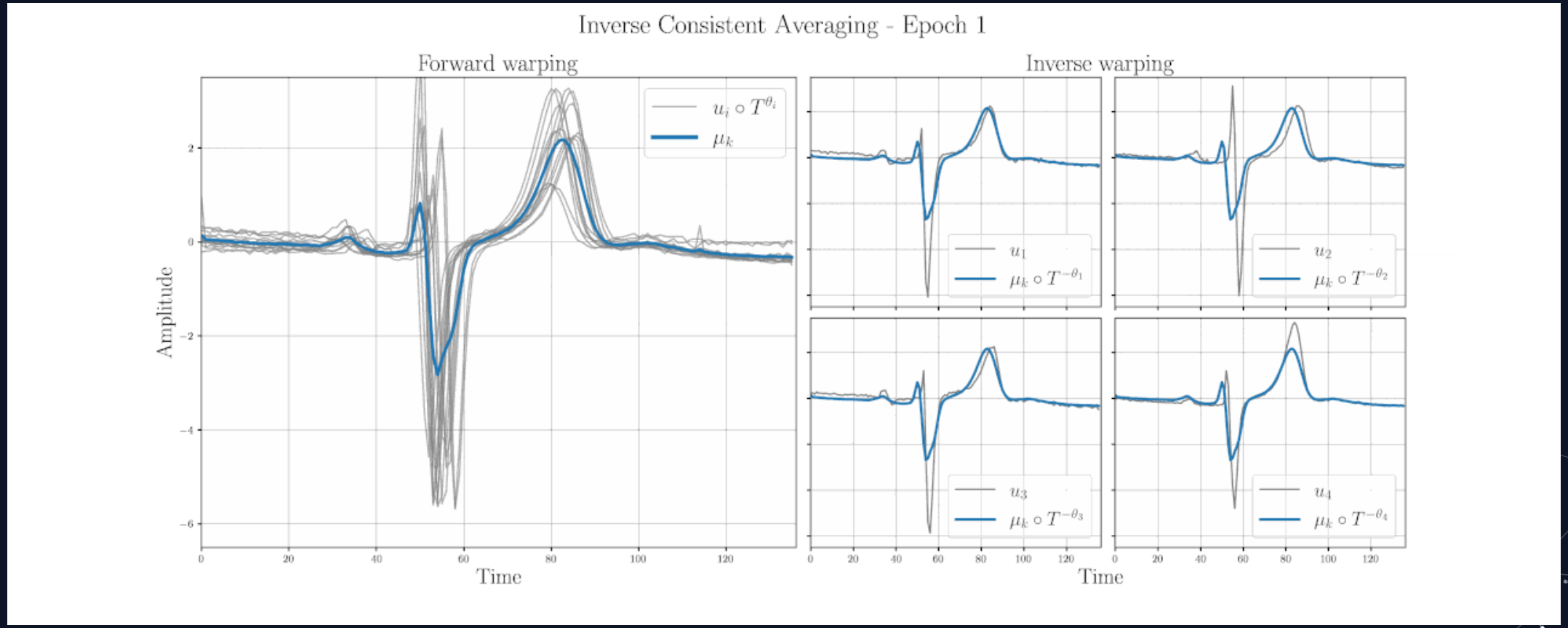
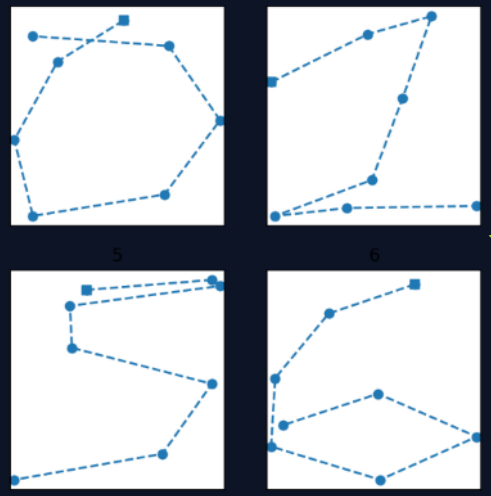
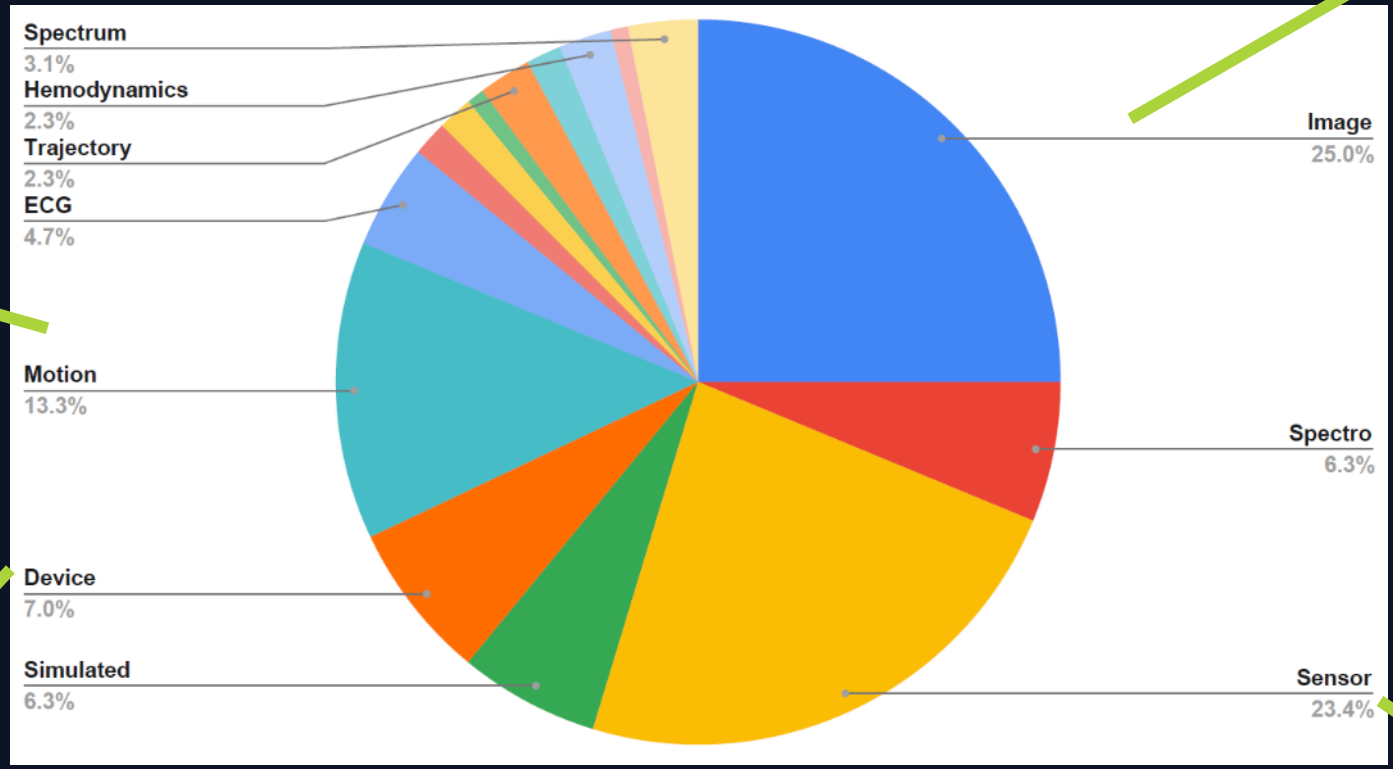
Training

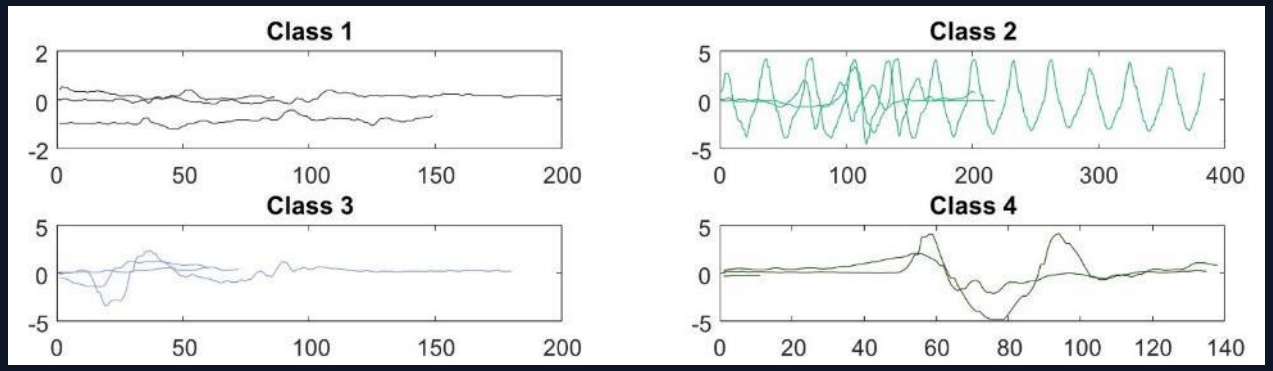


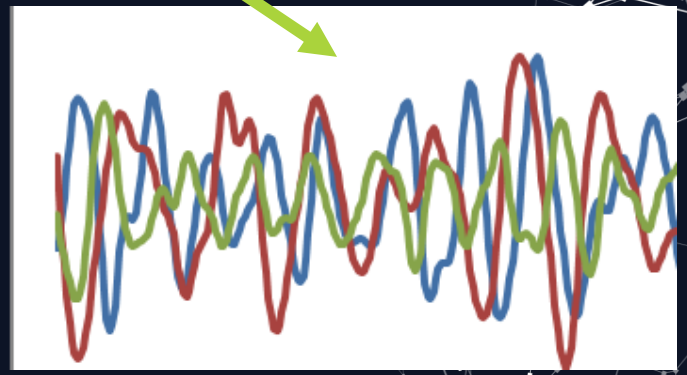
Results

UCR Archive – 128 datasets [Dau et al. 2019]









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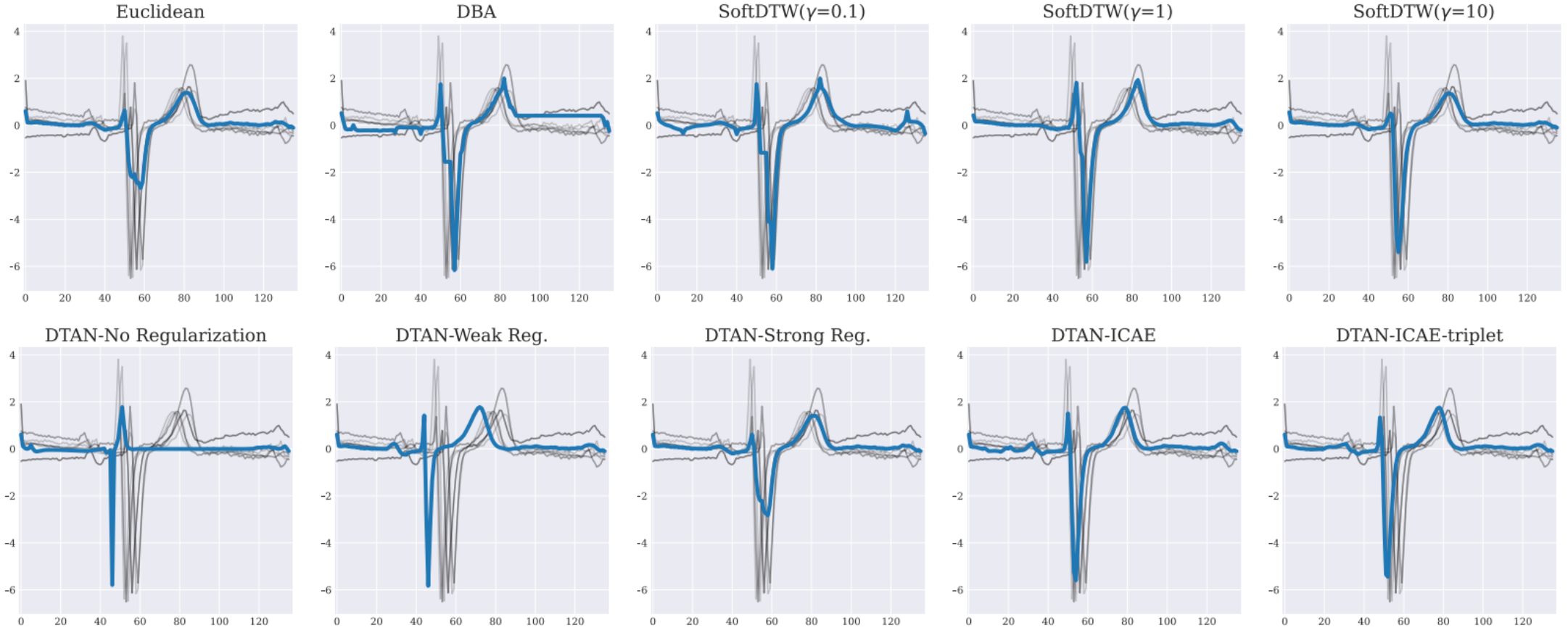

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Results

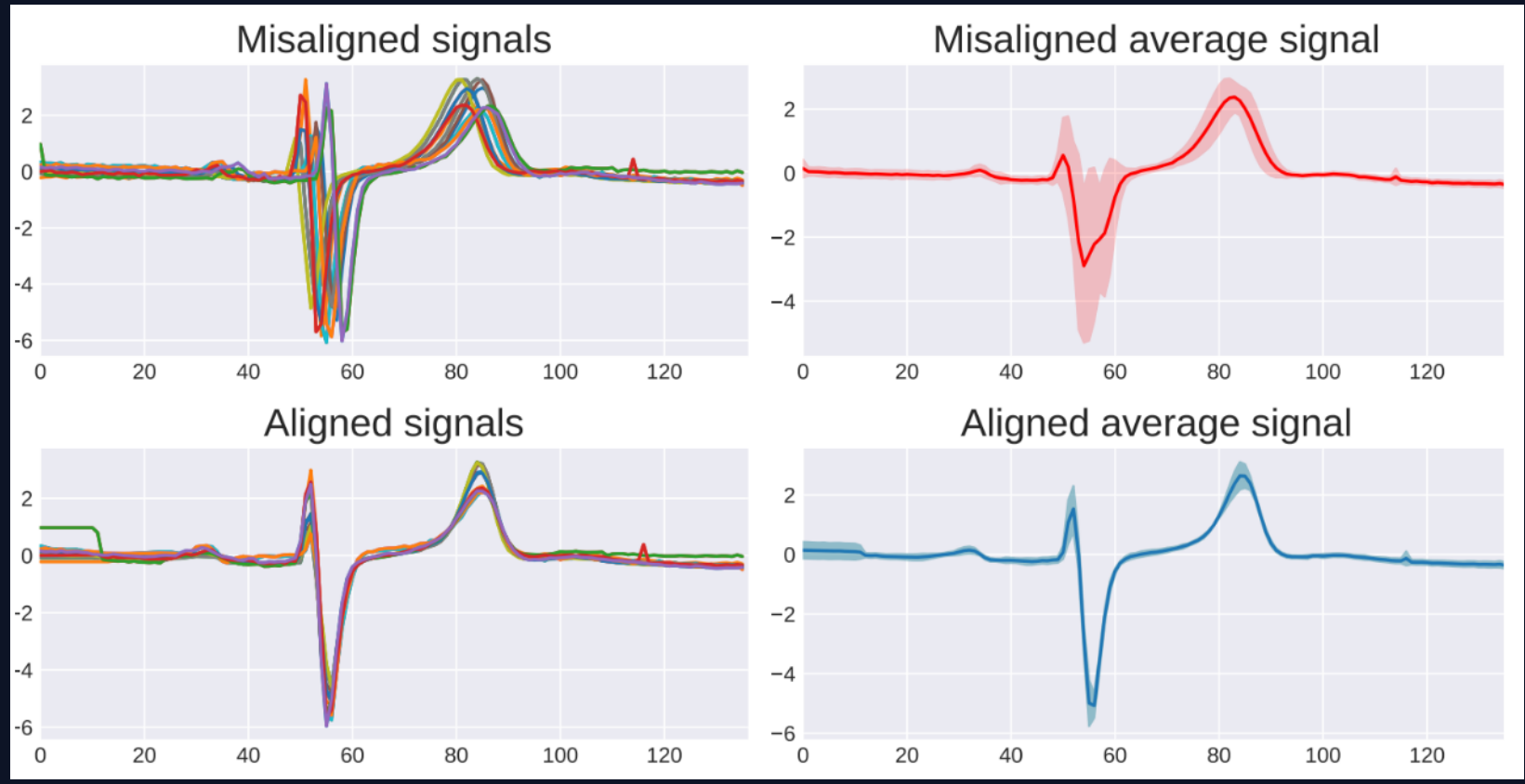

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Table 2. Nearest Centroid Classification Accuracy.

METHOD	OBJECTIVE	NCC_{median}	NCC_{best}	#CONFIGS	#DATASETS	#EXPERIMENTS
PART 1: ALLOWING HP SEARCH (PREVIOUSLY-REPORTED RESULTS)						
EUCLIDEAN	*N/A*	-	0.611	1	84	84
DBA	DTW	-	0.657	1	84	84
SOFTDTW	SOFTDTW	-	0.703	9	84	756
SOFTDTW	SOFTDTW-DIV	-	0.708	9	84	756
$DTAN_{libcpab}$	WCSS + REG	-	0.705	12	84	1008
RESNET-TW	WCSS + REG	-	0.711	20	84	1680
$DTAN_{DIFW}$	WCSS + REG	-	**0.749**	96	84	8064
PART 2: SINGLE HP CONFIGURATION IN ALL DATASETS (SAME UCR DATASETS AS REPORTED BY OTHER WORKS ABOVE)						
$DTAN_{DIFW}$	WCSS + REG	0.604	0.607	1	84	84
$DTAN_{DIFW}$	$\mathcal{L}_{ICAE}$ (OURS)	0.665	0.694	1	84	84
$DTAN_{DIFW}$	$\mathcal{L}_{ICAE-triplet}$ (OURS)	**0.707**	**0.739**	1	84	84
PART 3: SINGLE HP CONFIGURATION IN ALL DATASETS (INCLUDING ADDITIONAL NEWER FIXED-LENGTH UCR DATASETS)						
$DTAN_{DIFW}$	WCSS	0.609	0.65	1	117	117
$DTAN_{DIFW}$	WCSS + REG	0.603	0.605	1	117	117
$DTAN_{DIFW}$	$\mathcal{L}_{ICAE}$ (OURS)	0.656	0.686	1	117	117
$DTAN_{DIFW}$	$\mathcal{L}_{ICAE-triplet}$ (OURS)	**0.709**	**0.741**	1	117	117
PART 4: SINGLE HP CONFIGURATION IN ALL DATASETS (FULL UPDATED UCR ARCHIVE, INCLUDING VARIABLE-LENGTH DATASETS)						
$DTAN_{DIFW}$	$\mathcal{L}_{ICAE}$ (OURS)	0.623	0.653	1	128	128
$DTAN_{DIFW}$	$\mathcal{L}_{ICAE-triplet}$ (OURS)	**0.67**	**0.701**	1	128	128

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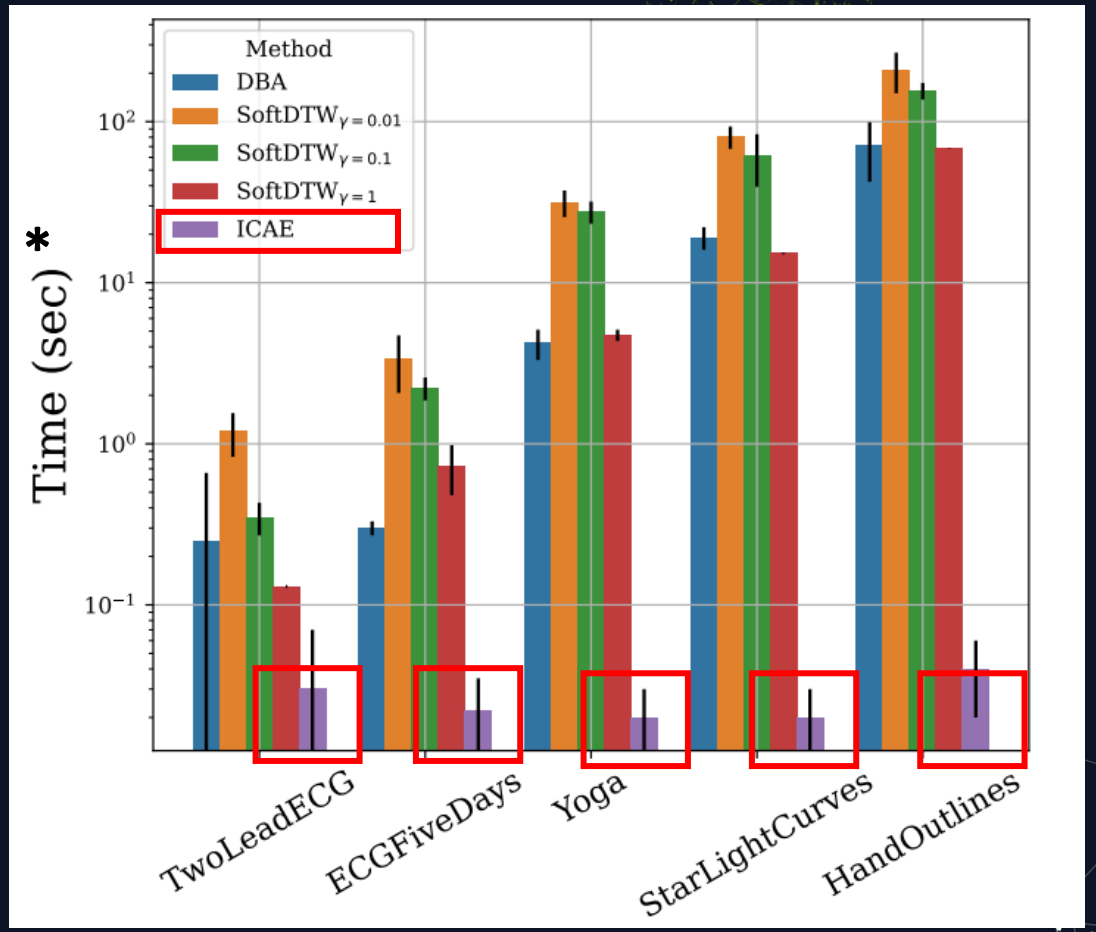
Barycenter computation during inference



*Log-scaled

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Conclusion

- Goal: A system that jointly aligns a large time-series ensemble.
- Problem #1: temporal misalignment confounds statistical analysis.
- Problem #2: regularization is class/dataset-specific and requires extensive HP tunning.
- Our proposed solution: Regularization-free DTAN, variable-length alignment [ICML ’23]
- Our code is publicly available at: https://github.com/BGU-CS-VIL/RF-DTAN

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