MPTSNet: Integrating Multiscale Periodic Local Patterns and Global Dependencies for Multivariate Time Series Classification

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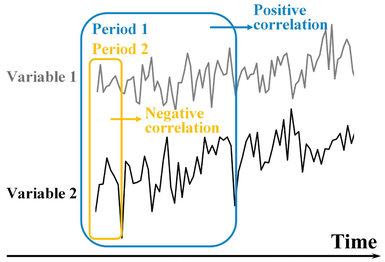
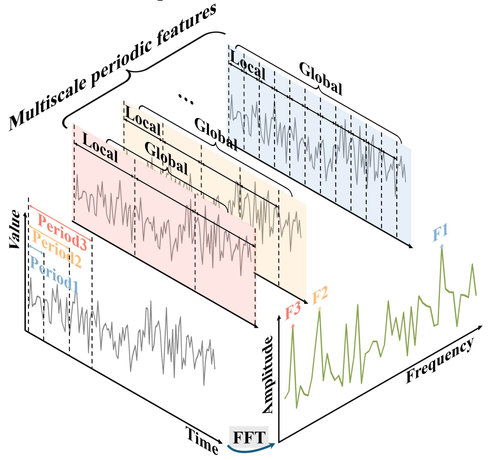
Concept

Challenges: (1) TS possesses periodic characteristics; (2) Variable correlations vary across periodic scales.



Our core idea: FFT decomposition reveals local & global features across different periodic scales.

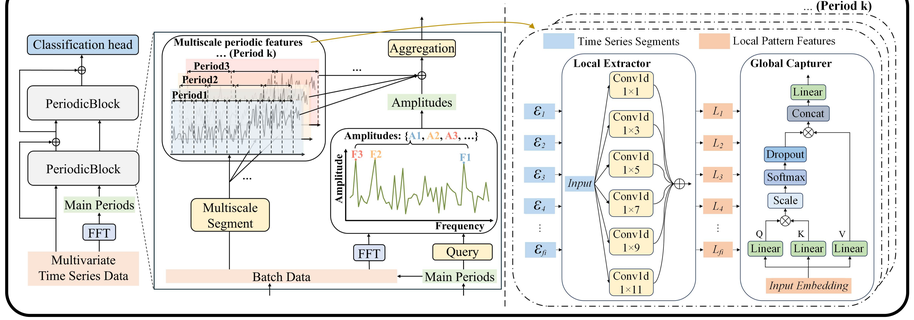


We solve challenges by two fundamental properties of MTS: multi-periodicity and complex variable correlations.

Implementation

Our code is publicly available!

Method



General Time Series Frameworks

Data/Model	LSTNet *SIG'18*	LSSL *ICLR'22*	FEDf. *ICLR'22*	Flowf. *ICLR'22*	SCINet *NIPS'22*	Dlinear *AAAI'23*	PatchTST *ICLR'23*	MICN *ICLR'23*	TimesNet *ICLR'23*	Crossf. *ICLR'23*	M.TCN *ICLR'24*	Ours
EthanolConcentration	39.9	31.1	31.2	33.8	34.4	36.2	32.8	35.3	35.7	38.0	36.3	**43.3**
FaceDetection	65.7	66.7	66.0	67.6	68.9	68.0	68.3	65.2	68.6	68.7	**70.8**	69.8
Handwriting	25.8	24.6	28.0	33.8	23.6	27.0	29.6	25.5	32.1	28.8	30.6	**34.4**
Heartbeat	77.1	72.7	73.7	77.6	77.5	75.1	74.9	74.7	**78.0**	77.6	77.2	75.6
JapaneseVowels	98.1	98.4	98.4	98.9	96.0	96.2	97.5	94.6	98.4	**99.1**	98.8	98.6
PEMS-SF	86.7	86.1	80.9	86.0	83.8	75.1	89.3	85.5	89.6	85.9	89.1	**94.2**
SelfRegulationSCP1	84.0	90.8	88.7	92.5	92.5	87.3	90.7	86.0	91.8	92.1	**93.4**	92.8
SelfRegulationSCP2	52.8	52.2	54.4	56.1	57.2	50.5	57.8	53.6	57.2	58.3	**60.3**	57.2
SpokenArabicDigits	**100**	**100**	**100**	98.8	98.1	81.4	98.3	97.1	99.0	97.9	98.7	99.5
UWaveGestureLibrary	87.8	85.9	85.3	86.6	85.1	82.1	85.8	82.8	85.3	85.3	86.7	**88.1**
Ours 1-to-1-Wins	3	4	9	3	3	8	1	10	5	7	5	-
Ours 1-to-1-Draws	1	2	0	1	0	0	0	0	1	0	0	-
Ours 1-to-1-Losses	6	4	1	6	7	2	9	0	4	3	5	-
Avg. accuracy (↑)	71.8	70.9	70.7	73.2	71.7	67.9	72.5	70.0	73.6	73.2	74.2	**75.4**
Avg. rank (↓)	6	7.5	7.6	4.6	6.7	8.6	6.1	9.2	4.1	4.5	3	**2.4**

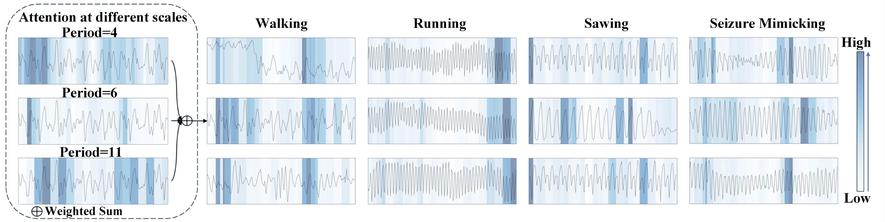
Contributions

- Propose the novel **MPTSNet framework** to capture local patterns and global dependencies through multiscale periodic decomposition.
- Demonstrate **enhanced interpretability** by integrating multiscale attention maps, revealing key temporal patterns across periodic scales.
- Achieve **SOTA performance** on UEA benchmark datasets surpassing 21 advanced methods in MTSC tasks.

MTSC-dedicated Models

Data/Model	EDI	DTWI	DTWD	W.+MUSE *arxiv'17*	M.-FCN *Neur.'19*	TapNet *AAAI'20*	ShapeNet *AAAI'21*	OS-CNN *ICLR'22*	MOS-CNN *ICLR'22*	TodyNet *Info.'24*	Ours
ArticularyWordRecognition	97.0	98.0	98.7	99.0	97.3	98.7	98.7	98.8	**99.1**	98.7	97.7
AtrialFibrillation	26.7	26.7	20.0	33.3	26.7	33.3	40.0	23.3	18.3	46.7	**53.3**
BasicMotions	67.5	**100**	97.5	**100**	95.0	**100**	**100**	**100**	**100**	**100**	**100**
Cricket	94.4	98.6	**100**	**100**	91.7	95.8	98.6	99.3	99.0	**100**	94.4
DuckDuckGeese	27.5	55.0	60.0	57.5	67.5	57.5	**72.5**	54.0	61.5	58.0	68.0
Epilepsy	66.7	97.8	96.4	**100**	76.1	97.1	98.7	98.0	99.6	97.1	97.1
EthanolConcentration	29.3	30.4	32.3	13.3	37.3	32.3	31.2	24.0	41.5	35.0	**43.3**
ERing	13.3	13.3	13.3	43.0	13.3	13.3	13.3	88.1	91.5	91.5	**94.4**
FaceDetection	51.9	51.3	52.9	54.5	54.5	55.6	60.2	57.5	59.7	62.7	**69.8**
FingerMovements	55.0	52.0	53.0	49.0	58.0	53.0	58.9	56.8	56.8	**67.6**	64.0
HandMovementDirection	27.9	30.6	23.1	36.5	36.5	37.8	33.8	44.3	36.1	**64.9**	63.5
Handwriting	37.1	50.9	60.7	60.5	28.6	35.7	45.1	**66.8**	**67.7**	43.6	34.4
Heartbeat	62.0	65.9	71.7	72.7	66.3	75.1	**75.6**	48.9	60.4	**75.6**	**75.6**
Libras	83.3	89.4	87.2	87.8	85.6	85.0	85.6	95.0	**96.5**	85.0	87.2
LSST	45.6	57.5	55.1	59.0	37.3	56.8	59.0	41.3	52.1	**61.5**	60.4
MotorImagery	51.0	39.0	50.0	50.0	51.0	59.0	61.0	53.5	51.5	64.0	**65.0**
NATOPS	86.0	85.0	88.3	87.0	88.9	93.9	88.3	96.8	95.1	**97.2**	94.4
PenDigits	97.3	93.9	97.7	94.8	97.8	98.0	97.7	98.5	98.3	98.7	**98.9**
PEMS-SF	70.5	73.4	71.1	N/A	69.9	75.1	75.1	76.0	76.4	78.0	**94.2**
PhonemeSpectra	10.4	15.1	15.1	19.0	11.0	17.5	29.8	29.9	29.5	**30.9**	14.4
RacketSports	86.8	84.2	80.3	**93.4**	80.3	86.8	88.2	87.7	92.9	80.3	87.5
SelfRegulationSCP1	77.1	76.5	77.5	71.0	87.4	65.2	78.2	83.5	82.9	89.8	**92.8**
SelfRegulationSCP2	48.3	53.3	53.9	46.0	47.2	55.0	**57.8**	53.2	51.0	55.0	57.2
StandWalkJump	20.0	33.3	20.0	33.3	6.7	40.0	**53.3**	38.3	38.3	46.7	**53.3**
UWaveGestureLibrary	88.1	86.9	90.3	91.6	89.1	89.4	90.6	**92.7**	92.6	85.0	88.1
Ours 1-to-1-Wins	15	13	14	10	19	18	12	12	15	14	-
Ours 1-to-1-Draws	2	2	2	2	1	4	1	3	2	3	-
Ours 1-to-1-Losses	8	10	9	13	5	3	12	10	8	8	-
Avg. accuracy (↑)	56.8	62.3	62.6	62.1	60.0	64.3	67.6	68.2	69.9	72.6	**74.0**
Avg. rank (↓)	7.52	6.48	5.8	5.36	6.4	5.24	3.84	4.28	3.8	3.16	**3.12**

Enhanced Interpretability



Multiscale attention visualization: Attention maps across different periodic scales (left).
Weighted aggregation: Combines attention maps using amplitude-based weights (right).
Class-specific patterns: Identifies distinct temporal patterns for different classes, enhancing the model interpretability and decision transparency.