

# TS-Rep: Self-supervised time series representation learning for robot sensor data

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## Highlights

TS-Rep learns a rich representation from the multimodal time series sensor data in robotics.

### TS-Rep

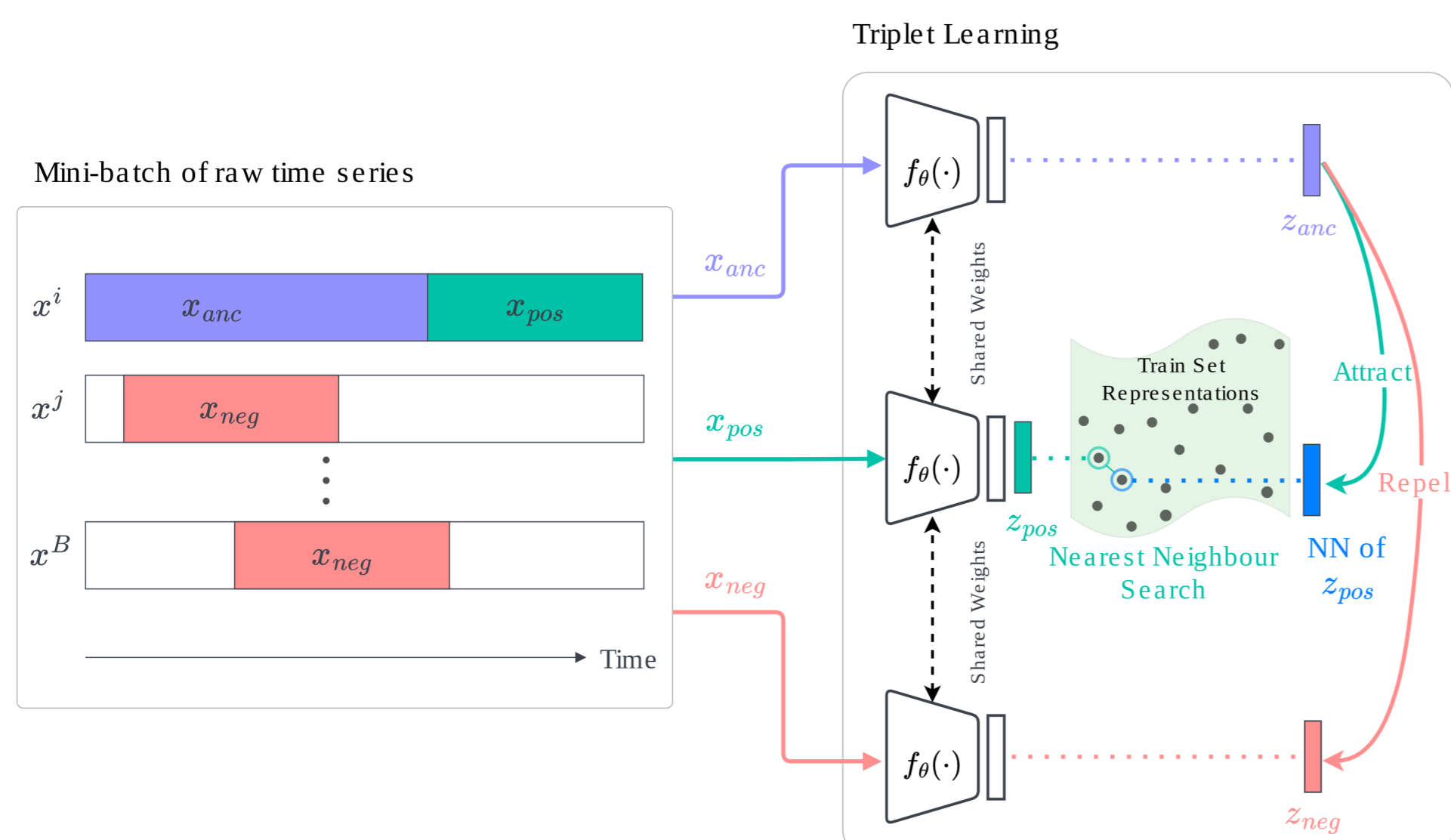
- learned representations have instances from the same class grouped together i.e., clusterability
- outperforms or performs closed to existing methods on anomaly detection and classification tasks
- on terrain classification outperforms unsupervised methods and performs closed to the supervised approaches.
- is on average fastest method to train and ~8 times faster than T-Loss, on which our approach is based on.

## Methodology

We present TS-Rep, a representation learning method that uses,

- Causal Dilated CNN Encoder
- Triplet loss
- Time-based negative sampling and,
- Positive sampling using nearest neighbour

### Method Overview



TS-Rep overview: Anchor ( $x_{anc}$ ), Positive ( $x_{pos}$ ) and Negatives ( $x_{neg}$ ) sampling (left). Triplet loss brings  $z_{anc}$  closer to the nearest neighbour of  $z_{pos}$  while pushing apart  $z_{neg}$  (right).

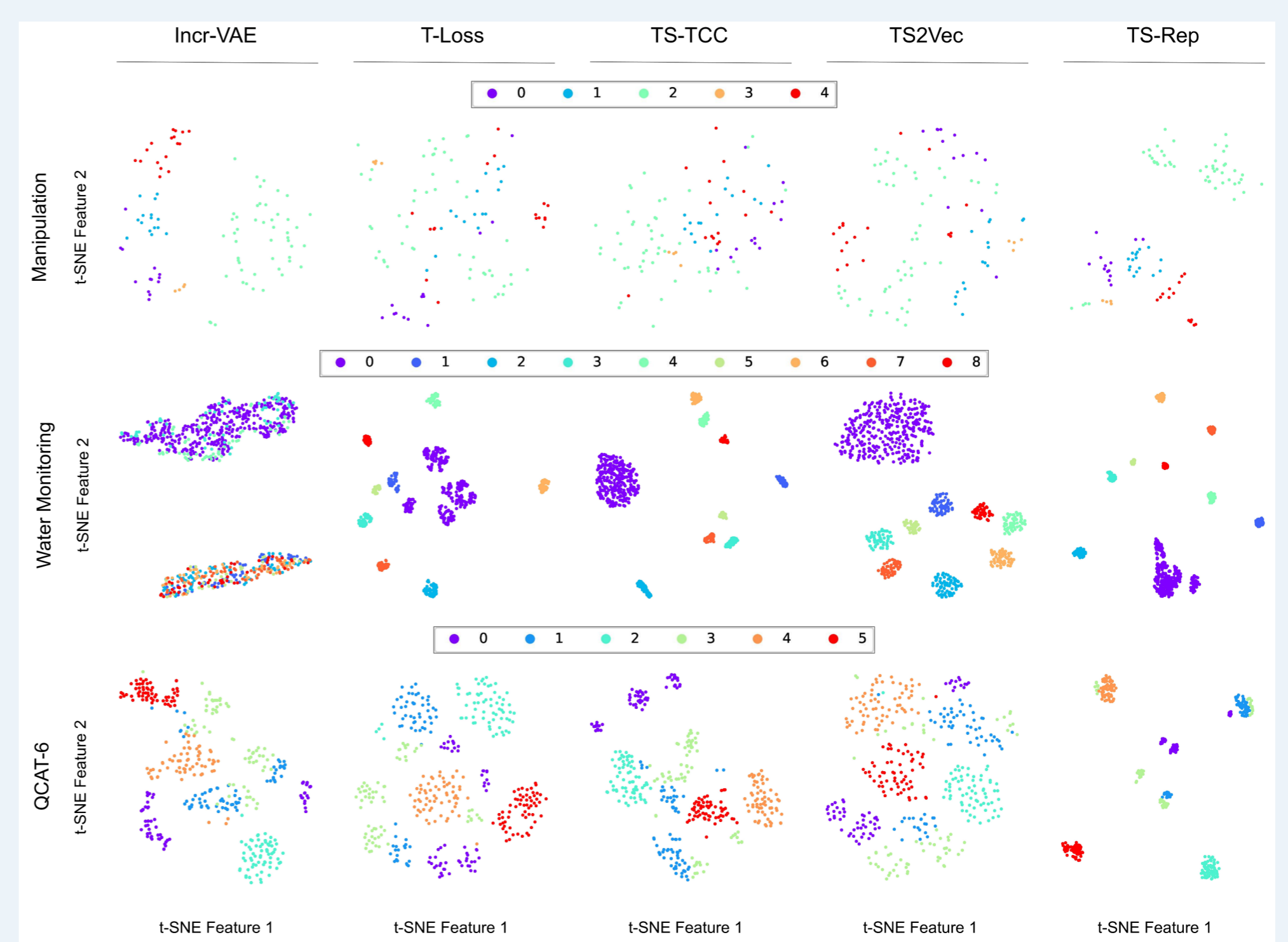
### Triplet Loss

$$\mathcal{L}_{triplet} = \frac{1}{B} \sum_{i=1}^B \left[ -\log\left(\sigma\left((z_{anc}^i)^T NN(z_{pos}^i, S)\right)\right) - \sum_{j=1; j \neq i}^B \log\left(\sigma\left(- (z_{anc}^i)^T (z_{neg}^j)\right)\right) \right]$$

## Experiments

### Clusterability

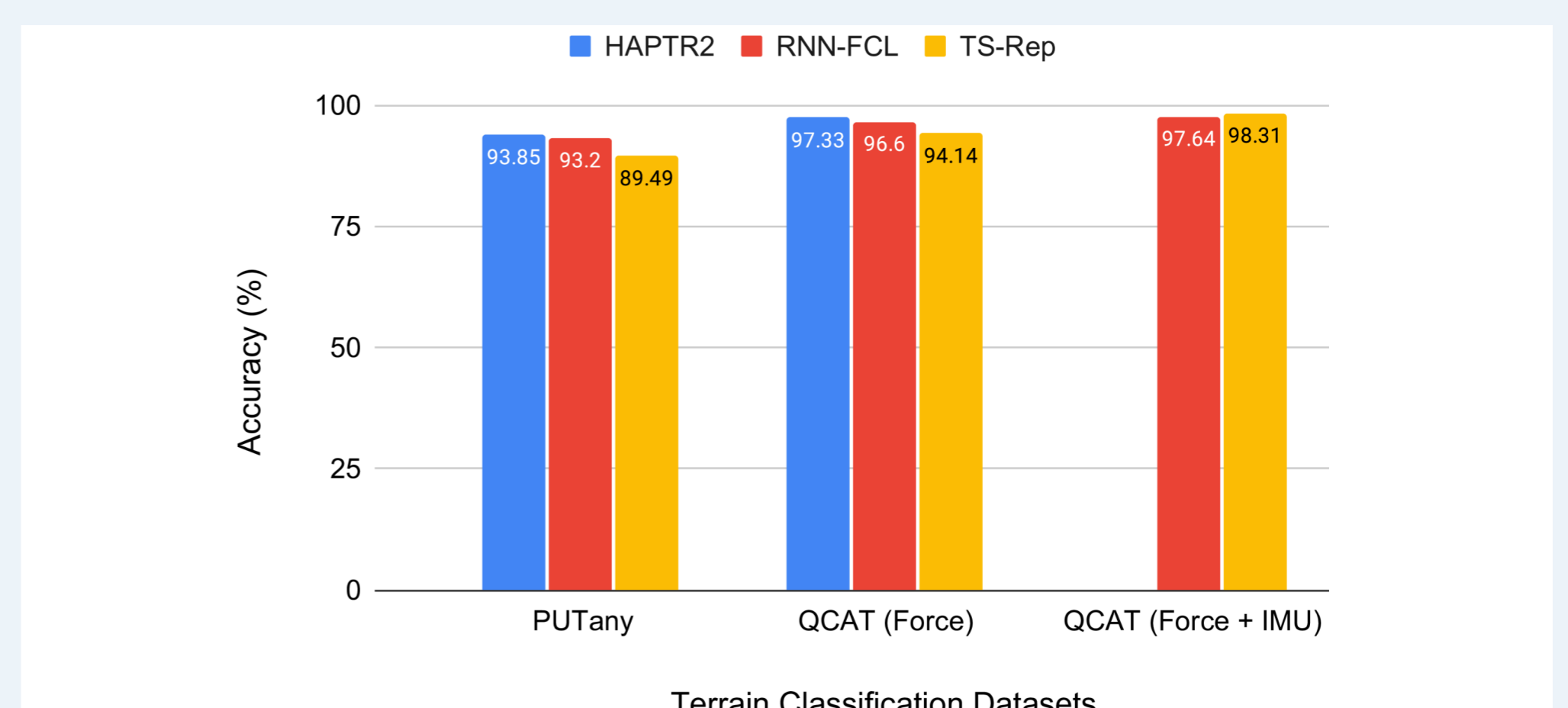
	Manipulation			Water Monitoring Robot			QCAT-6		
	NMI ↑	Silhouette ↑	DBI ↓	NMI ↑	Silhouette ↑	DBI ↓	NMI ↑	Silhouette ↑	DBI ↓
Incr-VAE	0.70	0.26	1.39	0.19	0.22	1.44	0.65	0.16	2.14
T-Loss	0.45	0.11	2.34	0.84	0.25	1.72	0.72	0.11	2.75
TS-TCC	0.20	0.17	1.70	0.97	0.67	0.83	0.65	0.15	2.01
TS2Vec	0.34	0.11	2.14	0.80	0.11	2.27	0.48	0.07	2.75
<b>TS-Rep</b>	<b>0.65</b>	<b>0.31</b>	<b>1.26</b>	<b>1.00</b>	<b>0.70</b>	<b>0.50</b>	<b>0.80</b>	<b>0.41</b>	<b>1.10</b>



### Anomaly Detection

	Manipulation			Water Monitoring Robot			QCAT-6		
	F1 ↑	AUROC ↑	FPR-95%-TPR ↓	F1 ↑	AUROC ↑	FPR-95%-TPR ↓	F1 ↑	AUROC ↑	FPR-95%-TPR ↓
Incr-VAE	0.83	0.99	0.02	0.33	0.80	0.56	0.99	1.00	0.01
T-Loss	0.77	0.90	0.37	1.00	1.00	0.00	1.00	1.00	0.00
TS-TCC	0.39	0.58	0.69	1.00	1.00	0.00	0.92	0.97	0.10
TS2Vec	0.76	0.75	0.50	0.99	1.00	0.00	0.96	0.98	0.09
<b>TS-Rep</b>	<b>0.81</b>	<b>0.85</b>	<b>0.33</b>	<b>1.00</b>	<b>1.00</b>	<b>0.00</b>	<b>0.98</b>	<b>1.00</b>	<b>0.01</b>

### Terrain Classification



For more information please visit our project page at [pratiksomaiya.in/projects/TS-Rep](http://pratiksomaiya.in/projects/TS-Rep)  
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