



An Analysis of Survey on Deep Learning for Spatio - Temporal Data Mining

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What is Spatio-temporal data?

- Data that relates to both **space and time**.
- Spatio-Temporal Data Mining(**STDM**) refers to a technique that is used to discover patterns over time
- Used to extract **spatial knowledge** such as history of various cities over time, global warming patterns or predicting any natural calamities
- **Common applications:** All domains including biology, ecology and medicine to transportation and forestry

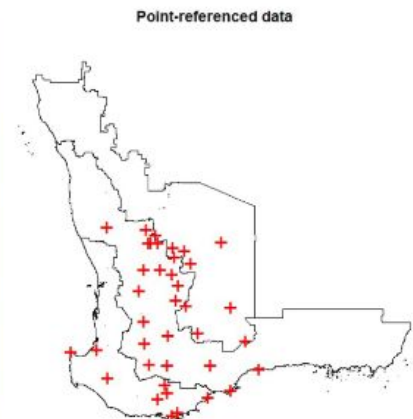
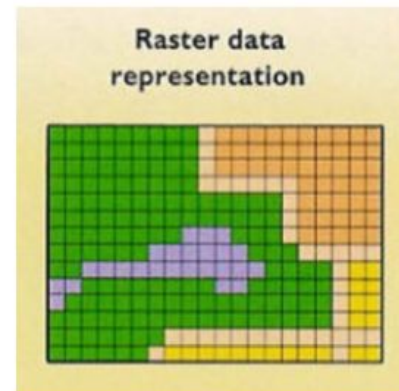
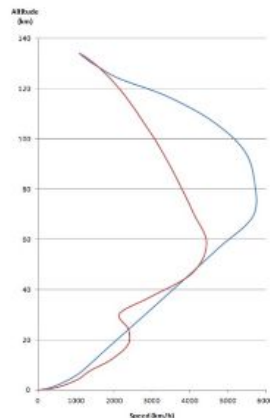
ST Data Example: *Before and after images captured showing destruction caused by flooding in Moffett, Oklahoma from the sky.*



Image Courtesy: insider.com

Data Types in Spatio-Temporal data

- Categorized by the way the data is fetched and by the way it is represented to the real world.
- Also based on the input type preferences of various deep learning models.
- Data categories:
 - Event data
 - Trajectory Data
 - Point Reference Data
 - Raster Data
 - Video



Why did Traditional data mining techniques Under perform on Spatio-temporal data?

- Models failed over traditional Graph and transactional data.
- An assumption was made about the spatio-temporal data which says that each data sample is independently generated.
- In reality, all the data in a spatio-temporal space that's generated continuously is highly correlated.
- Careful feature engineering along with sufficient domain expertise was needed.

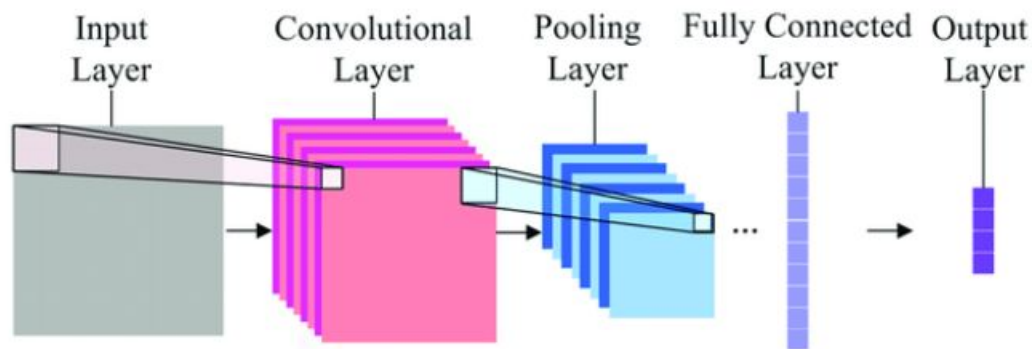
Deep Learning to the Rescue!

Advantageous features of deep learning:

- Automatic feature representation and learning
- Powerful Function Approximation

Preparatory deep learning models and what they do?

- Convolutional Neural Network(CNN)

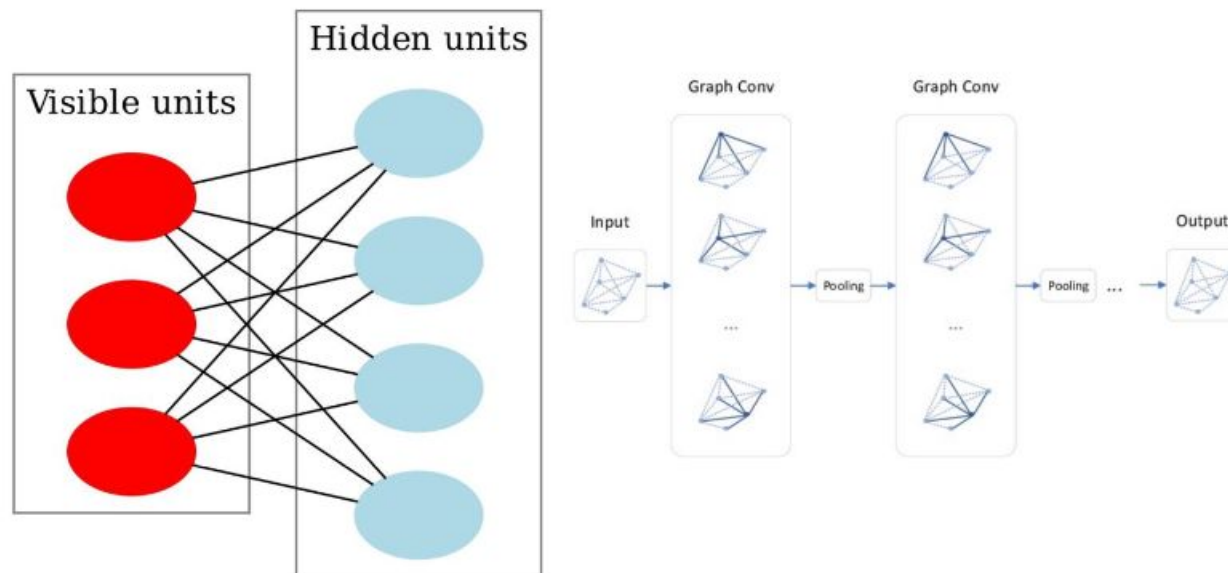


- **Restricted Boltzmann Machines(RBM)**

- A two layer stochastic neural network which is primarily used for feature learning has two layers- visible and hidden.

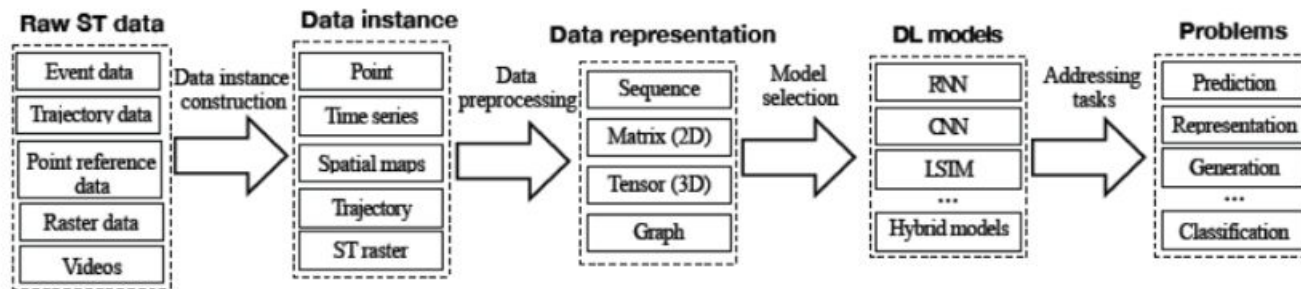
- **GraphCNN**

- Not only the convolution happens but also applies it to the neighbors of each node in the graph. This is followed by pooling and stacking of multiple convoluted layers.



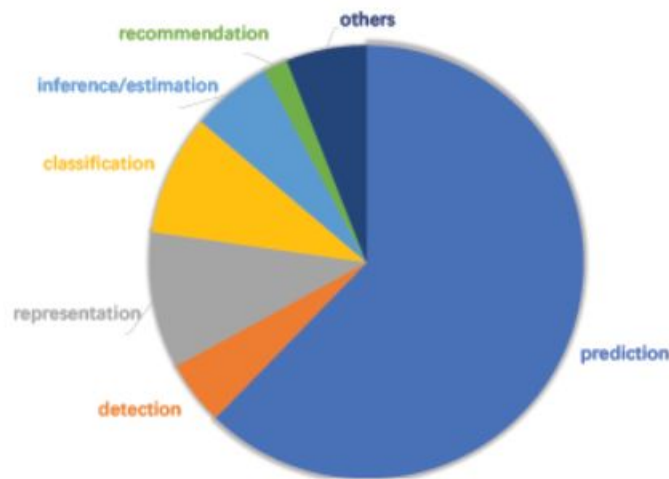
Senzhang Wang's Framework on how to handle STDM Data:

- This framework is a pipeline of data instance construction, representation, model selection and design.



- The data formats of raw data instances are changed and made suitable to apply to various Deep Learning models.
- With this data in hand, models like RNN and LSTM, which are good at handling sequence data or the CNN are applied to perform tasks like prediction, classification or learning.

How are various STDN problems addressed using the robust Deep Learning Models?



Inference:

As we see, **Prediction** is the largest problem category.

The approach of Predictive Learning:

Spatial Data Instance Type	Approach of Predictive Learning
Points	<ul style="list-style-type: none">- Points are merged in temporal/spatial space to apply models- Ex: ST-ResNet model to predict crime over Los Angeles Area- transformed the point crime data into heatmaps and used CNN.
Time Series	<ul style="list-style-type: none">- Used in traffic control prediction- Used autoencoders to learn features from traffic flow time-series data.- Proposed Deep Belief Networks(DBN) to predict future traffic flow- RNN and LSTM are also widely used to predict the speed of a traffic segment
Spatial maps	<ul style="list-style-type: none">- These are represented as image-like matrices.- Hence can be processed with CNN for predictive learning- Ex: UrbanFlow; a real-time crowd forecasting system was built with the crowd flow spatial maps as input.
Trajectories	<ul style="list-style-type: none">- Can be represented as a sequence of locations.- Hence, only RNN's and CNN's can process trajectory data.- Ex: Urban Human Mobility prediction system was built which can predict where a person will go next in the city by learning a few past trajectory data.- Collision-Free LSTM was built for this by adding an extra pooling layer to share the hidden locations of neighbouring pedestrians.
Spatio-temporal raster	<ul style="list-style-type: none">- Can be represented as matrices(2D) or tensors(3D).- 2D-CNN or 3D-CNN is applied with a combination of RNN.- Ex: 3D-SCN; a CNN was built for storm prediction, growth and advection from the 3D radar data.

Real-time Applications :

- Transportation
- On-Demand Services
- Location Based Social Network(LBSN)
- Climate & Weather
- Neuroscience

References

- *Survey Author: Senzchang Wang, jiannong Cao, IEEE*
- *Article Link: <https://arxiv.org/abs/1906.04928>*
- *Medium Article Link:
<https://medium.com/@srisruthi.chilukuri/deep-learning-for-spatio-temporal-data-mining-analysis-166eff7152ca>*

Thank you!