UNIVERSITY OF BUCHAREST

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**Dissertation Thesis**

**Spatial-Temporal Neural Networks for Traffic Prediction**

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Abstract

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# INTRODUCTION

# THEORY

## Traffic Flow

Traffic Flow represents the study of interaction between travelers of different types, including vehicles and pedestrians with infrastructure having the goal to create an optimal transport network with efficient and optimal traffic movement such that traffic congestion is reduced to a minimum.

Traffic networks are complex and nonlinear, depending on external factors such as current time of day/year, weather, and also on internal factors such as infrastructure, number of vehicles and their types or unexpected vehicle crashes. Due to the fact that traffic is based on human interaction, or rather individual reactions to other pedestrians or vehicles, the system does not follow any rules and is rather chaotic.

The traffic system is composed of roads/pavement on which the participants in traffic travel at a certain speed to reach their individual goal. The size can vary and is objective, it can range from a neighborhood to a countries entire traveling system. There are traffic systems which are unique to a single type vehicle, for example the railway system in which just the train travels. Traffic flow is focused on city sized traffic systems for cars, which exhibit the biggest congestion.

Participants in traffic are pedestrians and vehicles (bikes, motorbikes, cars or public transportation). Different types of vehicles can be more effective than others. An example is the underground metro system which is supervised by an entity, thus the participants travel restrictively to preserve the entire system efficiency and can take thousands of passengers. Another example is a car which can take up to a maximum of 5 passengers legally. Although a car can travel to any point but a metro system has predetermined stations.

The main variables that are considered in traffic flow theory are density (k, number of vehicles per unit of space), speed (v) and flow (q, number of vehicles per unit of time).

Speed is defined as the distance traveled per unit of time. Due to the high number of vehicles in a traffic system it is impractical to measure the speed of every vehicle, and the average speed is measured. There are 2 main definitions of speed.

The first one is time mean speed, which is the average speed of a vehicle over a period of time, is computed by measuring the distance traveled by a car over a certain reference point. This method is not accurate because the average speed of a vehicle over a wide range does not take into account the difference between the speeds of different vehicles.

m = Number of vehicles passing through a fixed point; = speed of vehicle i

The second method is called space mean speed. This method is measured over the entire segment. Consecutive recordings of passing vehicles over the entire segment are considered to track individual vehicle speed, after which the speed is calculated. It is considered more accurate than the first method

m = Number of vehicles passing through the roadway segment; = speed of vehicle i

Density represents the total number of vehicles per road segment. There are two types of densities: critical density and jam density. Critical density is considered to be the maximum density under free flow, while jam density is considered the maximum density under congestion. Density is measured as:

K = density, L = length of a roadway, = time, m = number of vehicles

Flow is represented as the total number of vehicles passing through a point given a time period. Headway is the inverse flow, which is represented by the time elapsed between the n-th vehicle passing a point and the next (n+1-th) vehicle. Flow is measured as:

q = flow, T= time interval, = point in space, m = number of vehicles

The goal of traffic flow analysis is to develop a model that will allow vehicles to reach their destinations within the shortest possible time. This is achieved in a four stages process:

* Generation – Calculate how many trips to be generated by the needs of the passengers.
* Distribution – Generate the path between starting point and stopping point based on what has been generated at step 1
* Modal Split/Mode Choice – Decide the distribution of different type of vehicles for the number of passengers.
* Route Assignment – Assign each vehicle its route such as the entire system has a minimum travelling time.

## Machine Learning

Machine Learning is a subset of Artificial Intelligence which creates and develop software which is able to learn and improve from data over a period of time exposed to data (experience) without being explicitly programmed. This method is used for tasks which are mathematically impossible to program iteratively. For example, it is impossible to explicitly program a function which can classify cats and dogs. The process of learning starts with observing data, experience (time observing data) and instruction in order to look for patterns in data for better future decisions. The goal is to let the software learn without human intervention.

There are three categories which divide machine learning algorithms based on the task and based on the nature of our data:

* Supervised learning: Our data is presented with a label and our task is to predict the correct label. An example is classifying an animal inside a photo as a cat or a dog. Our image contains a correct label and the objective is to predict which animal is inside the photo.
* Unsupervised learning: Our data has no label and the task is to structure the data to find similarities or patterns in the given data and label it for future unknown data.
* Reinforcement learning: There exists a dynamic environment with a goal to perform. As the problem space is explored the program receives positive or negative feedback based on its current decision such that positive behavior is reinforced. Self-driving vehicles are an example.

One of the algorithms used in Supervised learning are called Artificial Neural Networks (ANN’s). They are simply called neural networks (NN’s). Neural Networks are a method based on the anatomy of the nervous system and the brain. These networks are based on the electrical activity of the nervous system [1].

The base element of the neural networks is a neuron, which is based on the fundamental unit of the brain with the same name, which receives an input, multiplies it by a weight, adds a bias and the returns the result for further processing by a software or another neuron. Normally the neurons are placed in a layer, with the output from the previous layer being the input of the previous layer, thus simulating the synaptic connections of the brain [1].

After computation a scalar function is used to aggregate a layer into a single input value. Once it is calculated a transfer function, or activation function is used to calculate the output of the layer. A few examples are Linear, ReLU (Rectified Linear Unit) or Sigmoid activation. The Linear function is typically used as the last activation function for regression type tasks such as price prediction. while Sigmoid is used for non-linear classification type tasks such as dogs vs. cats.

### Deep Learning

## Long Short-Term Memory

## Graph Convolutional Networks

# RELATED WORK

# METHODOLOGY & EXPERIMENTS

## Dataset

## Models

# RESULTS & CONCLUSIONS

# ANNEXES

# BIBLIOGRAPHY

1. Steven Walczak, N. C. (2003). *Encyclopedia of Physical Science and Technology (Third Edition).*