# Spatial Networks and Analysis Using Machine Learning Approaches

Sagar Tamang, Bhupinder Juneja  
taman011@umn.edu, junej003@umn.edu

**Abstract**: This tutorial provides a brief introduction to key fundamentals of Spatial Networks and Analysis of events occurring along networks. The societal applications include social networks characterization and analysis, predicting pipeline failure risk, analysis of road accidents, analyzing hotspots of disparity in a health care supply chain. Spread of disease etc. as all these scenarios represent complex systems that can be abstracted as spatial networks though in some cases (e.g. spread of disease) could be more appropriately abstracted as spatio-temporal networks that evolve over time, In this tutorial however we will limit our focus on characterization and analysis of spatial networks only.

**Keywords**: spatial networks, spatial data mining, machine learning, regression, collocation detection, neighbor networks, dense networks, SANET.

## Basic Concepts

* **Space**: Mathematically, a space represents a set with some additional structure.
* **Spatial**: Webster dictionary defines spatial as “relating to or having character of space”.
* **Spatial Network**: “A Spatial network is a graph whose nodes are geometric objects and edges are spatial elements associated with a notion of distance e.g. Euclidian distance. Essentially nodes and edges in a spatial network can be viewed as being constrained by geometry [2].
* **Network Event**: Comprises of events that are constrained by networks [1]. Network events can be classified based on whether they occur directly on a network (e.g. road accidents, pipeline failure etc.) or occur alongside networks e.g. (disparity persists along side a health care supply chain network). Based on this classification the network events can be referred to as on-network events or alongside network events.
* **Nearest Neighbor distance**: This is defined as distance between each node and its nearest neighbor. This distance is often used in network segmentation and partitioning.

## Introduction

A Spatial network is a graph whose nodes are geometric objects and edges are spatial elements associated with a notion of distance e.g. Euclidian distance. Essentially nodes and edges in a spatial network can be viewed as being constrained by geometry [2]. In some literature a spatial network is also referred to as a social network. This viewpoint was furthered by sociologists like Henri Lefebvre who characterized any kind of space and spatial network be it physical (as in road network) or virtual (as in communication network) as a social space. In his words “All Space is Social” [3]. This notion gave birth to idea of spatial network as a relational network (a viewpoint that became prevalent in computer science esp. in Spatial datasets and databases.) as opposed to abstract network (a mathematical entity). This viewpoint also became a prominent probe of analysis of events happening on or alongside many spatial networks including communication networks, internet and supply chains.

## Mathematical and Computational Foundations of Spatial Networks

## Statistical Foundations of Spatial Networks

## Machine Learning meets Spatial Networks

## Case Studies

## SANET

## Learning Objectives

* Understand Key Ideas behind spatial networks.
* Mathematical Models of Spatial Networks.
* An overview of Statistical Approaches to characterize spatial networks.
* Spatial Network Events Analysis using Data Mining and Machine Learning
* SANET: An open source Tool for Spatial Network Analysis.

## Instructional Assessment Questions

* What are key characteristics of spatial network?
* What is difference between dense vs. sparse network?
* Provide examples of spatial networks arising in domains like Economics, Finance Astronomy.
* What are common approaches discussed to predict occurrence of events on and alongside spatial networks?

## Additional Resources

* [Social and Technological Network Analysis: Spatial Networks, Mobility and Applications.](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=2ahUKEwjb78z07NrnAhUE7qwKHYj2A1YQFjABegQIBBAB&url=https%3A%2F%2Fwww.cl.cam.ac.uk%2Fteaching%2F1415%2FL109%2Fl109-lecture10.pdf&usg=AOvVaw2euHFQ_u6l6EkqcAMWoOaT)
* [Combining Satellite Imagery and Machine Learning to Predict Poverty](https://science.sciencemag.org/content/353/6301/790)

## Reference

1. Okabe, Sugihara, Sugihara, Kōkichi, and Ebrary, Inc. Spatial Analysis along Networks: Statistical and Computational Methods. Statistics in Practice. Hoboken, N.J.: Wiley, 2012.
2. Barthélemy, Marc. "Spatial Networks." Physics Reports 499, no. 1-3 (2011): 1-101.
3. Lefebvre, Henri. The Production of Space. Oxford, OX, UK ; Cambridge, Mass., USA: Blackwell, 1991.