



UNIVERSITY OF  
TORONTO

**Engineering**

# Graph-based prognosis application

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Zihan Zhang, MSc student

Centre for Maintenance Optimization & Reliability Engineering (CMORE)

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## Part 1

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# Background

## ■ RUL prediction

- Remaining useful life (RUL) prediction is a critical technique supporting safety-critical and cost-effective condition-based maintenance (CBM).
- Basic information for maintenance decision-making.

## ■ Methods

### Statistical Approach

- Physical model
- Statistical model
- Physical-statistical model

### AI Approach

- Machine learning
- Deep learning

### Hybrid Approach

- AI + physical model
- AI + statistical model
- AI Combination

# Limitations of traditional methods in RUL prediction

## ■ Traditional methods have been widely used in prognosis application, but they all have some limitations:

- **Statistical methods:** **1. hard to generalize;** **2. cannot explore data information**
  - It is necessary to understand the characteristics of acquired data to construct a manual HI.
  - A manual HI is generally constructed for a specific degradation process, which may not be generalized well to others.
- **AI methods:** **1. lack physical interpretation;** **2. limited in component-level**
  - Data-driven approach is mostly like a “black box”, but fails to explain why it fails and hard to help engineers to locate possible failures.
  - At most time, even if components fail, the system will still work for a while, frequent maintenance will increase downtime costs as well as maintenance costs.

# Motivation

## ■ RUL prediction

- A reasonable **physical interpretation** of RUL prediction result
- **Hidden pattern** in data
- **System-level** RUL → relationship between component and system

## ■ Further



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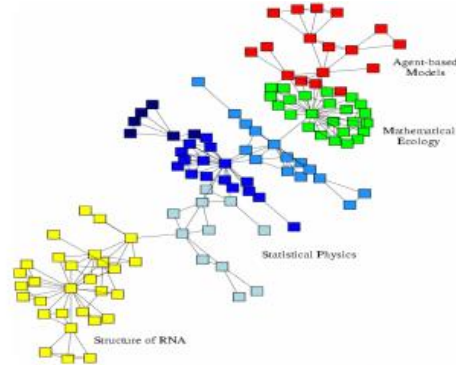
# GNN

- **Graphs** are a kind of data structure which models a set of objects (nodes) and their relationships (edges).
  - Non-Euclidean data
- **Graph Neural Network** is a type of Neural Network which directly operates on the Graph structure.
  - Graph analysis
    1. node classification
    2. link prediction
    3. clustering.
- Due to its **convincing performance** and **high interpretability**, GNN has been a widely applied graph analysis method recently.
  - Social science (social networks)
  - Natural science (physical system)

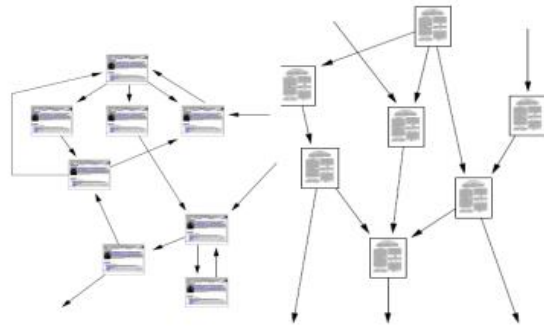
# Application based on GNN



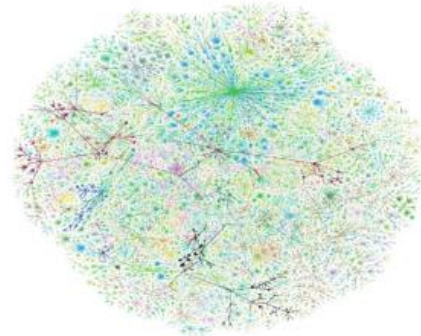
Social networks



Economic networks



Information networks:  
Web & citations



Internet



NELL: Never-Ending Language Learning



OpenIE  
(Reverb, OLLIE)



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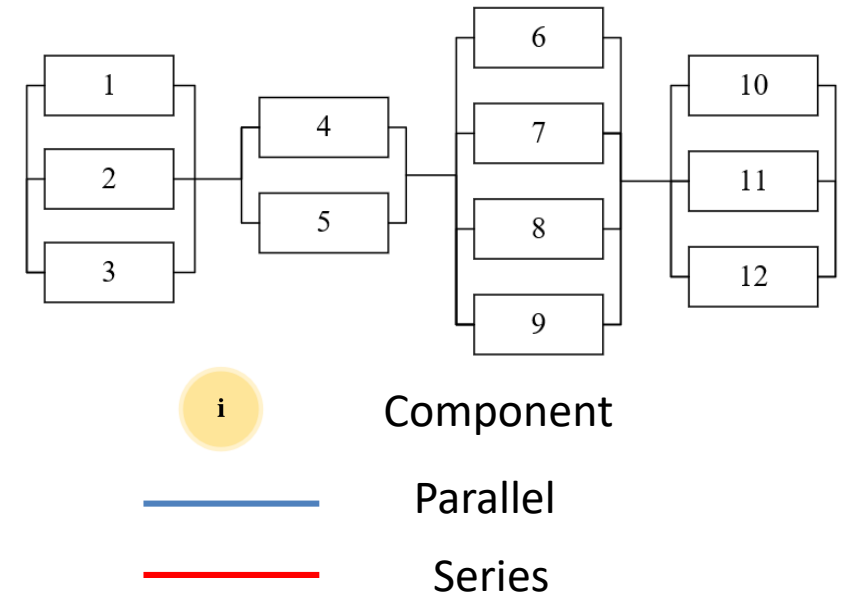
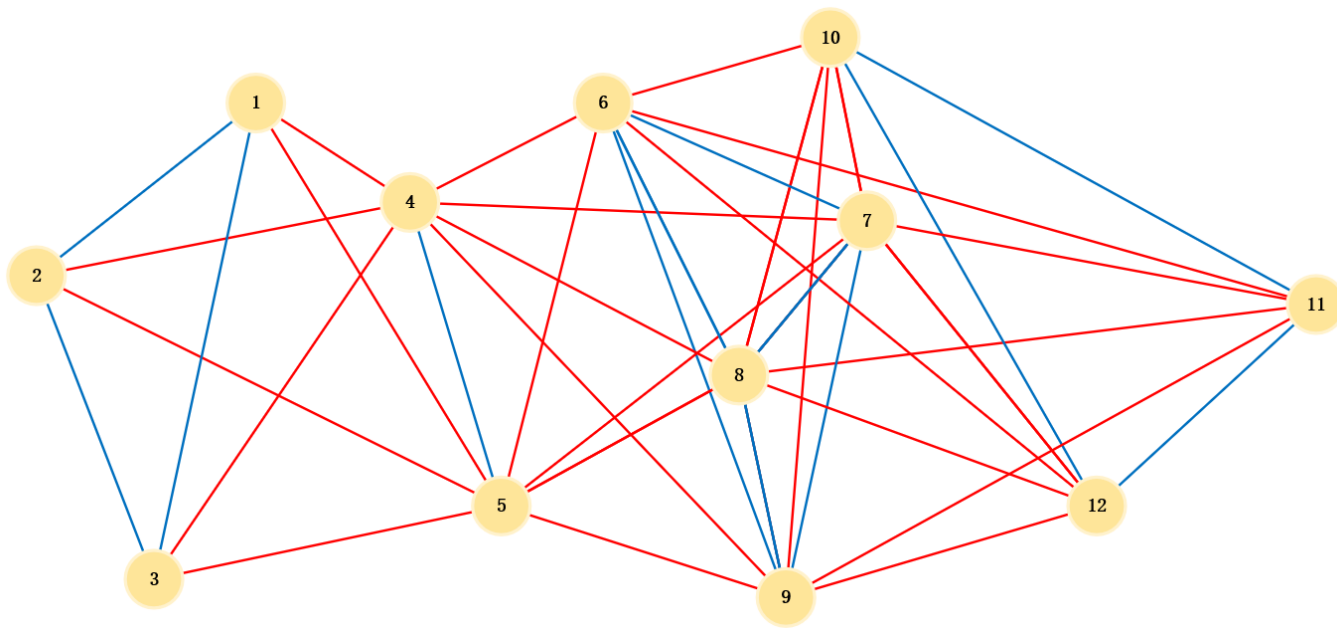
**Part 3**

**Current Process**

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# Graph Definition

- A large system can be regarded as a graph network  $G = (N, L)$ 
  - A collection of N parts interconnected by L links
  - The topology of the system network is the arrangement and connectivity of parts and links, which is represented by a square adjacent matrix.



# Link Definition

- **Degeneration dependence**

- **Functional dependence**

- considers the similarity in function, such as replaceable components with spares

- **Stochastic dependence**

- tires to find the degeneration relationship among components from statistical perspective

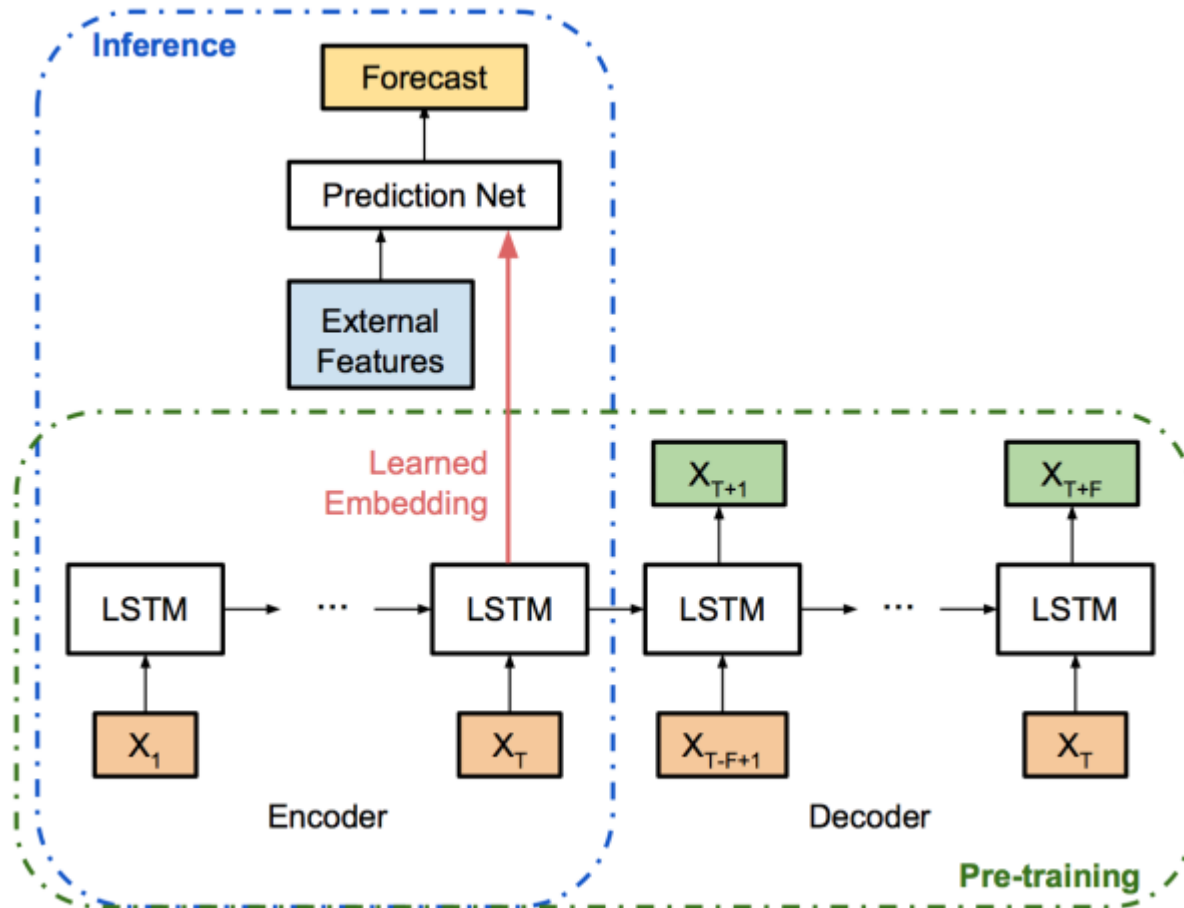
- **Structural dependence**

- describes components' relationship in mechanical transmission structure

Based on the informed graph, we can predict remaining lifetime of the entire system with better interpretation in system level.

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# Prediction – component & system level



- Define the importance of each component
- Find the most troublesome component.
- Infer its adjacent components' degeneration trend

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**Background and Motivation**

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## Next...

- About prediction
  - Further define the graph structure
  - Based on graph structure, evaluate the importance of each component and its degeneration influence on the system
- Others
  - Fault location
  - Maintenance decision-making based on system graph
  - ...

A low-angle, upward-looking photograph of a grand, classical building with a curved facade and several prominent columns. The building is partially obscured by lush green leaves in the foreground, which are slightly out of focus. The sky is bright and blue with some light clouds. The overall mood is bright and positive.

**Thanks for listening !**