《动态图概述》

主讲： 彭老师

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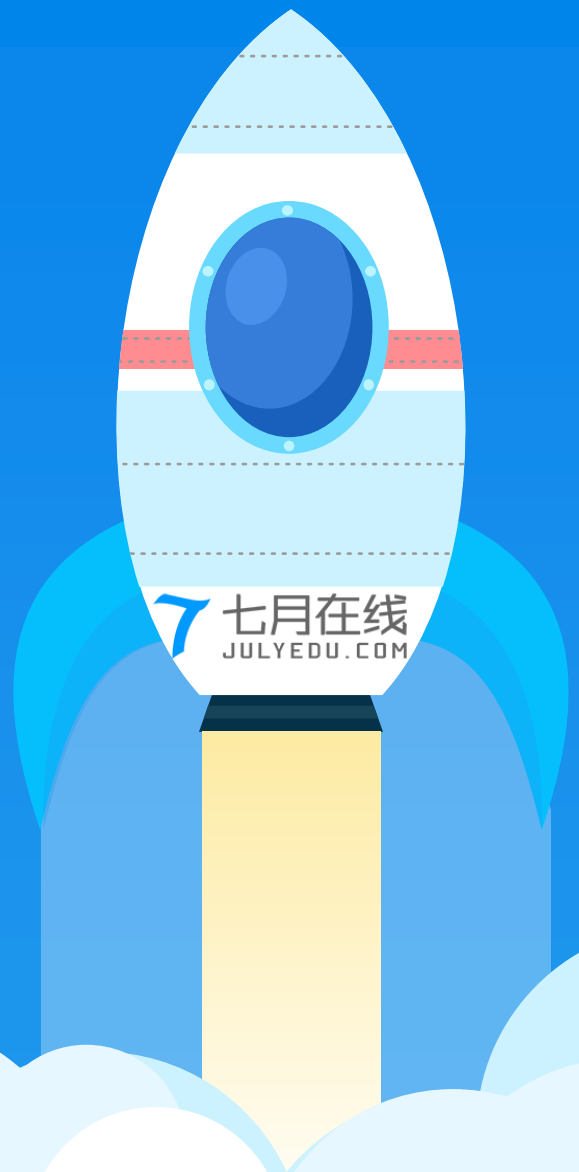

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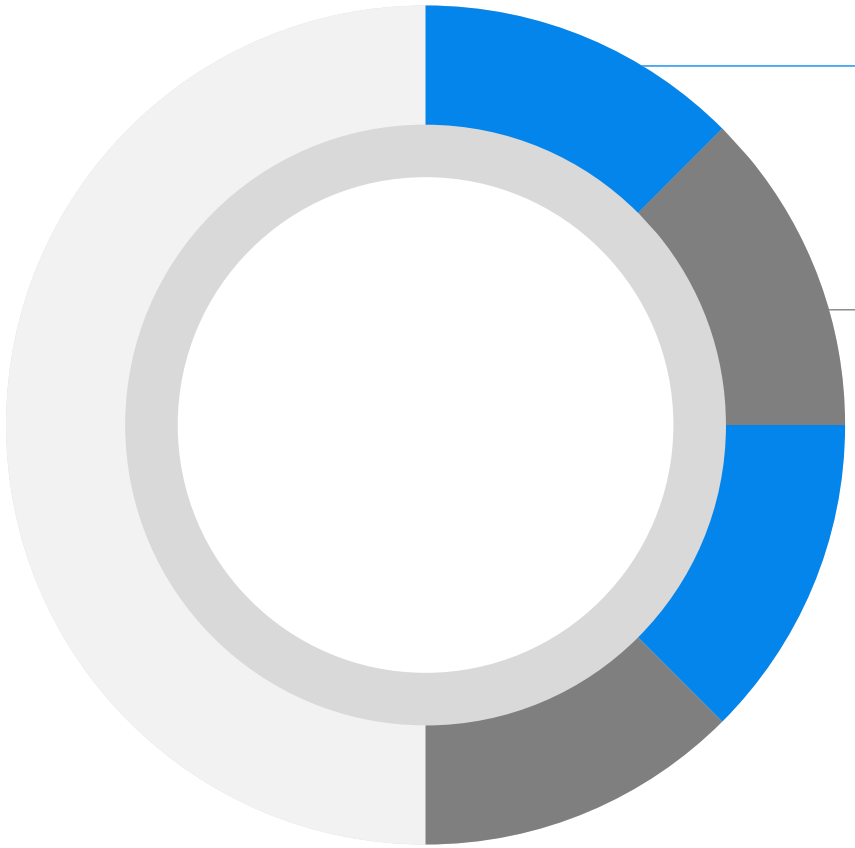


动态图数据集介绍

Dynamic Graph Datasets

动态图神经网络分类

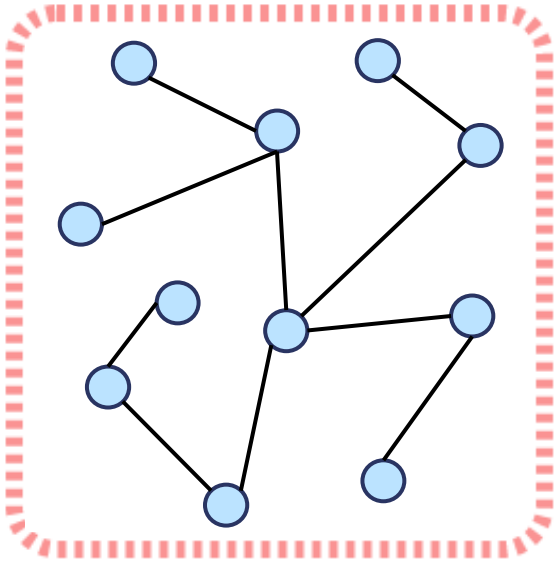
Dynamic Graph Neural Networks

/01 动态图数据集介绍

Dynamic Graph Datasets

Static Graph

Static Graphs are a kind of data structure that models a set of objects (nodes), their interactions (edges) and the corresponding information (representations).



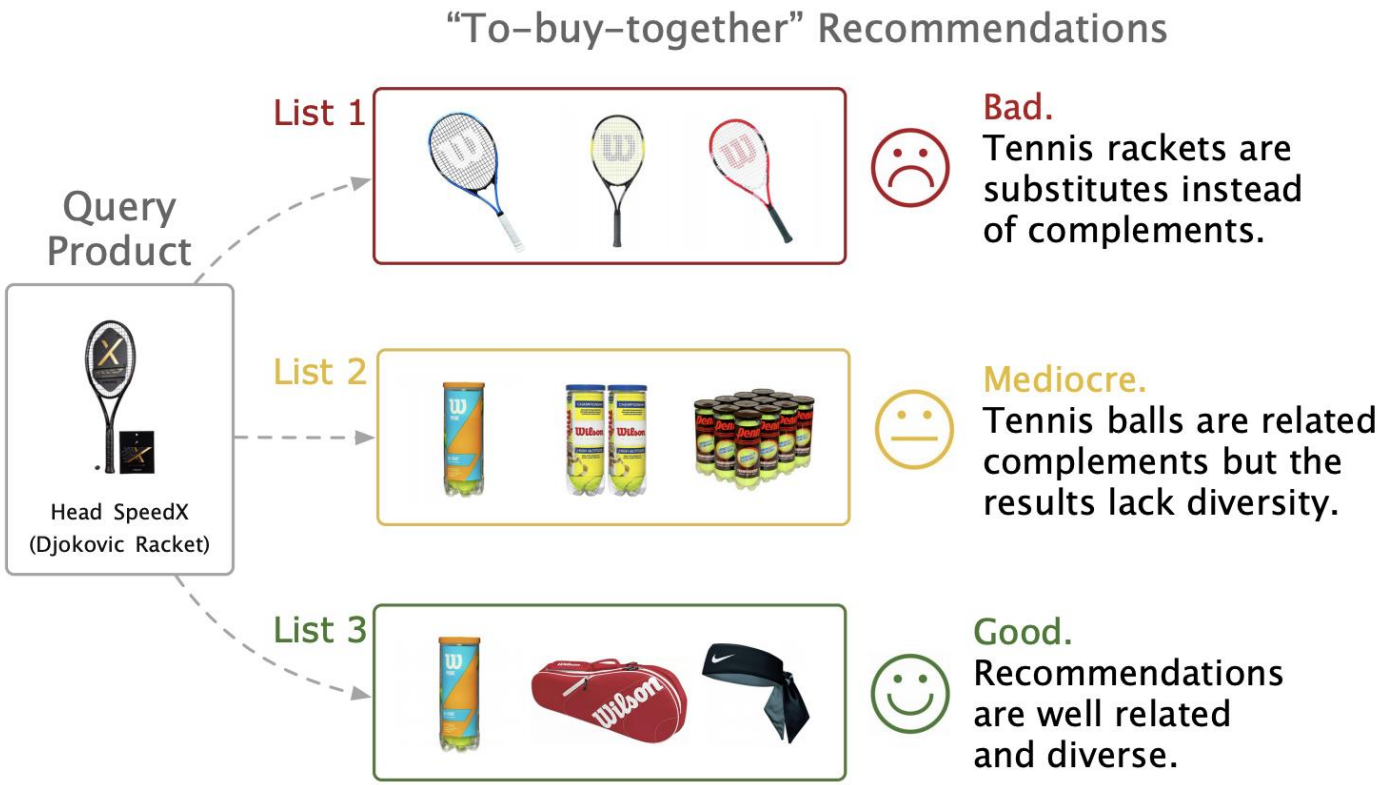
Node Representations

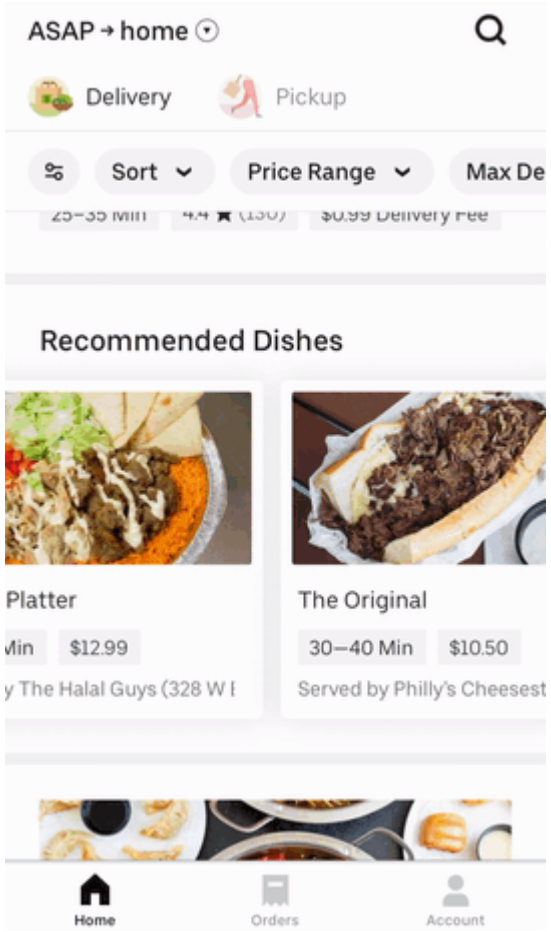
Link Representations

Graph Representations

Applications of Static GNNs

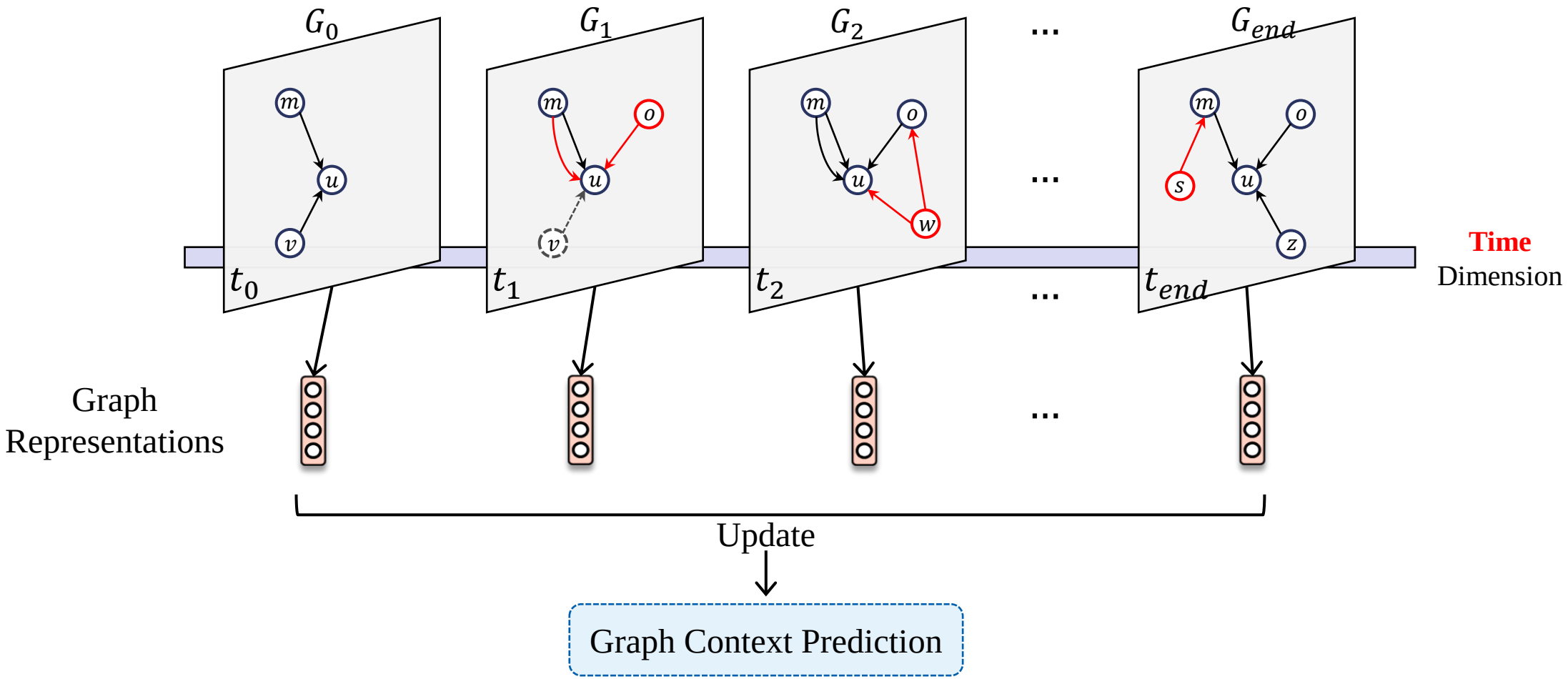
Recommender System





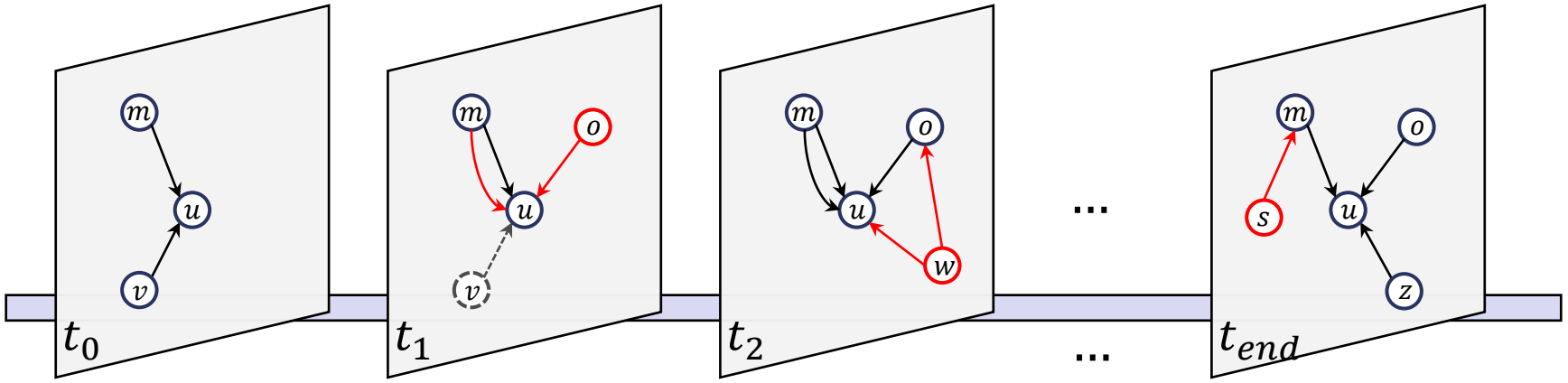
Dynamic Graph

Time-varied graph-based structure.



Dynamic Continuous Graph

Raw time-varied Data



Dynamic Continuous Graph

Pros: Information loss less

Cons: The most complicated network

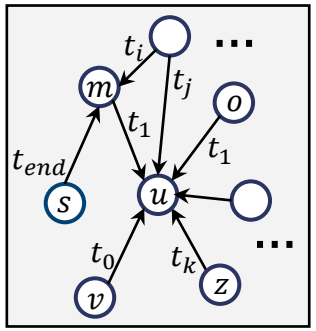
Node

t_0: $+u, +v, +m;$
t_1: $+o\ , -v;$
t_2: $+w;$
$\vdots$
t_{end}: $+s;$

Edge

t_0: $+e_{vu}, +e_{mu};$
t_1: $+e_{ou}, +e_{mu}, -e_{vu};$
t_2: $+e_{wu}, +e_{wo};$
$\vdots$
t_{end}: $+e_{sm};$

Graph Evolution



Projection on 2D Temporal graph

Dynamic Continuous Graph

Reddit post dataset consists of one month of posts made by users on subreddits;

Wikipedia edits dataset is one month of edits made by edits on Wikipedia pages;

LastFM song listens dataset has one month of who listens-to-which song information;

Task 1: Details of MOOC datasets?

Data	Users	Items	Interactions
Reddit	10,000	984	672,447
Wikipedia	8,227	1,000	157,474
LastFM	980	1,000	1,293,103
MOOC	7,047	97	411,749

Dynamic Continuous Graph

Node：

User ID; Item ID

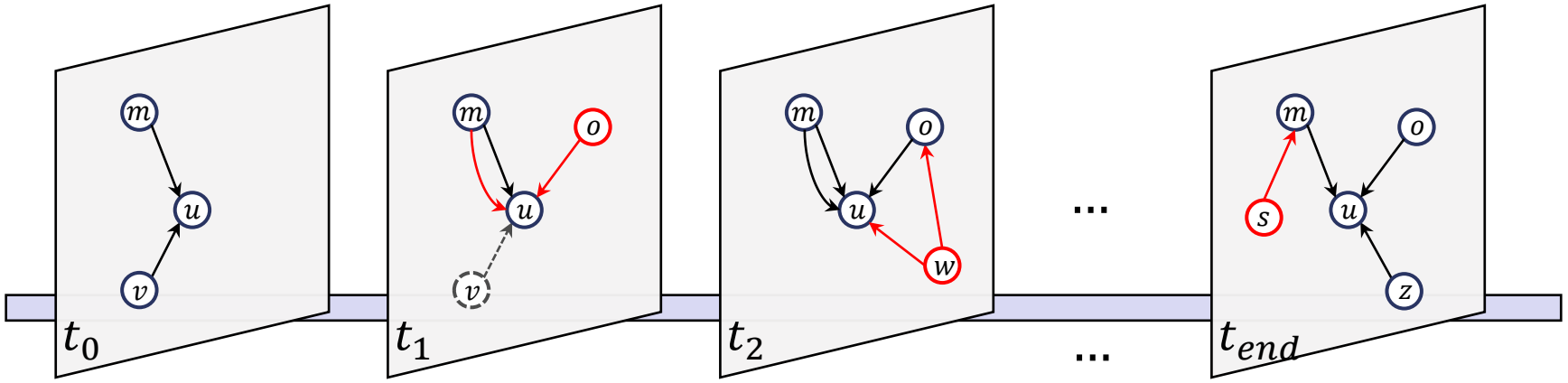
Time：

Timestamp

	A	B	C	D	E	F	G	H
1	user_id	item_id	timestamp	state_labe	comma_separated_list_of_features			
2	0	0	0	0	-0.31999	-0.4357	0.106784	-0.06731
3	0	1	6	0	-0.31999	-0.4357	0.106784	-0.06731
4	1	12	7839	0	-0.31999	-0.4357	0.106784	-0.06731
5	1	11	7846	0	-0.31999	-0.4357	0.106784	-0.06731
6	2	1	37868	0	-0.31999	-0.4357	0.607805	1.337563
7	3	1	37953	0	-0.31999	-0.4357	0.106784	-0.06731
8	4	1	37969	0	-0.31999	-0.4357	1.108826	7.157747
9	4	3	38018	0	-0.31999	-0.4357	0.607805	0.133387

Dynamic Discrete Graph

Raw time-varied Data

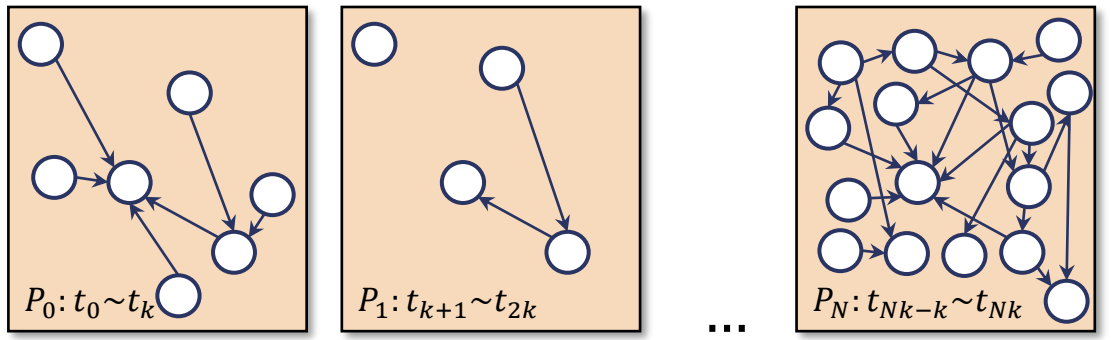


Time Dimension

Dynamic Discrete Graph

Pros: Less complex Network

Cons: Information loss more

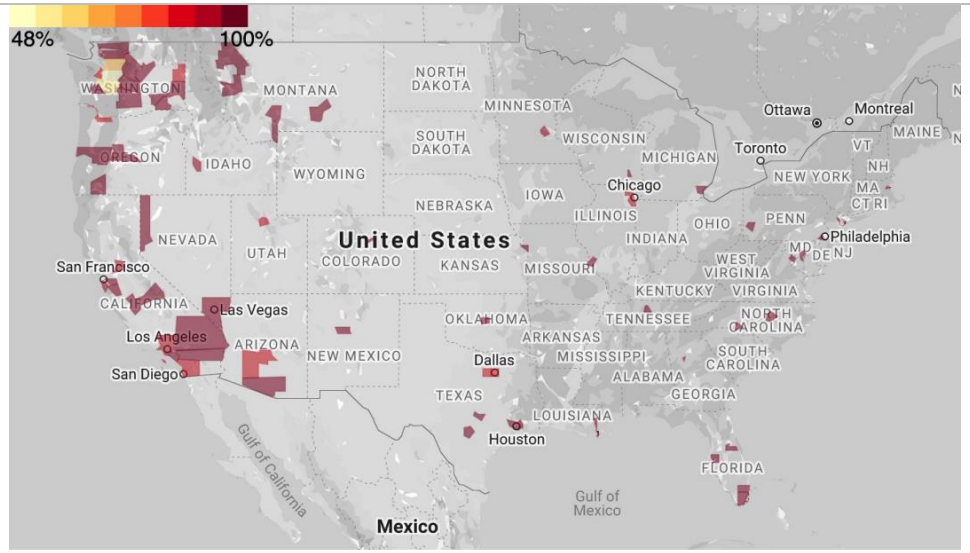


Dynamic Discrete Graph

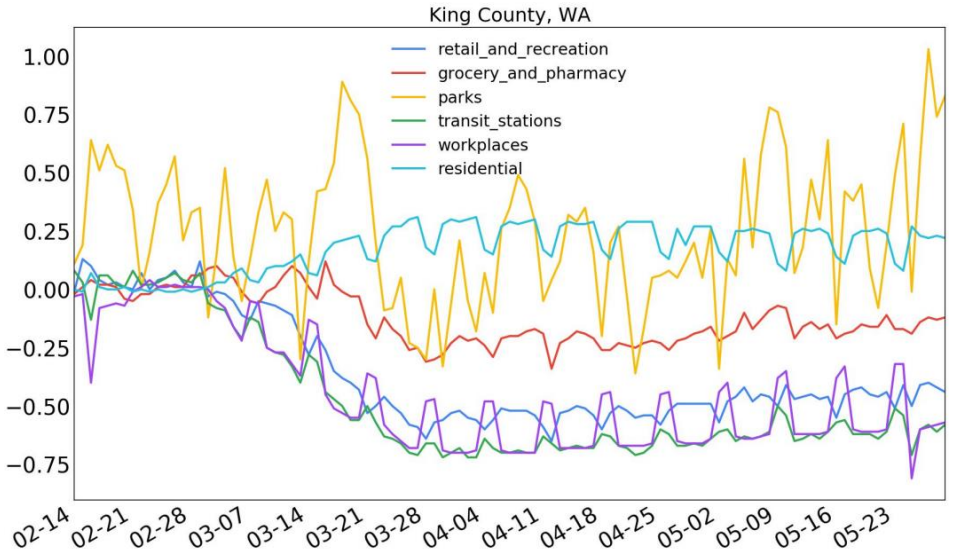
Time Step ==> Duration
Timestamp ==> Instant

	Communication		Rating	
Attribute	Enron	UCI	Yelp	ML-10M
# of Nodes	143	1,809	6,569	20,537
# of Links	2,347	16,822	95,361	43,760
# of Time steps	12	13	12	13

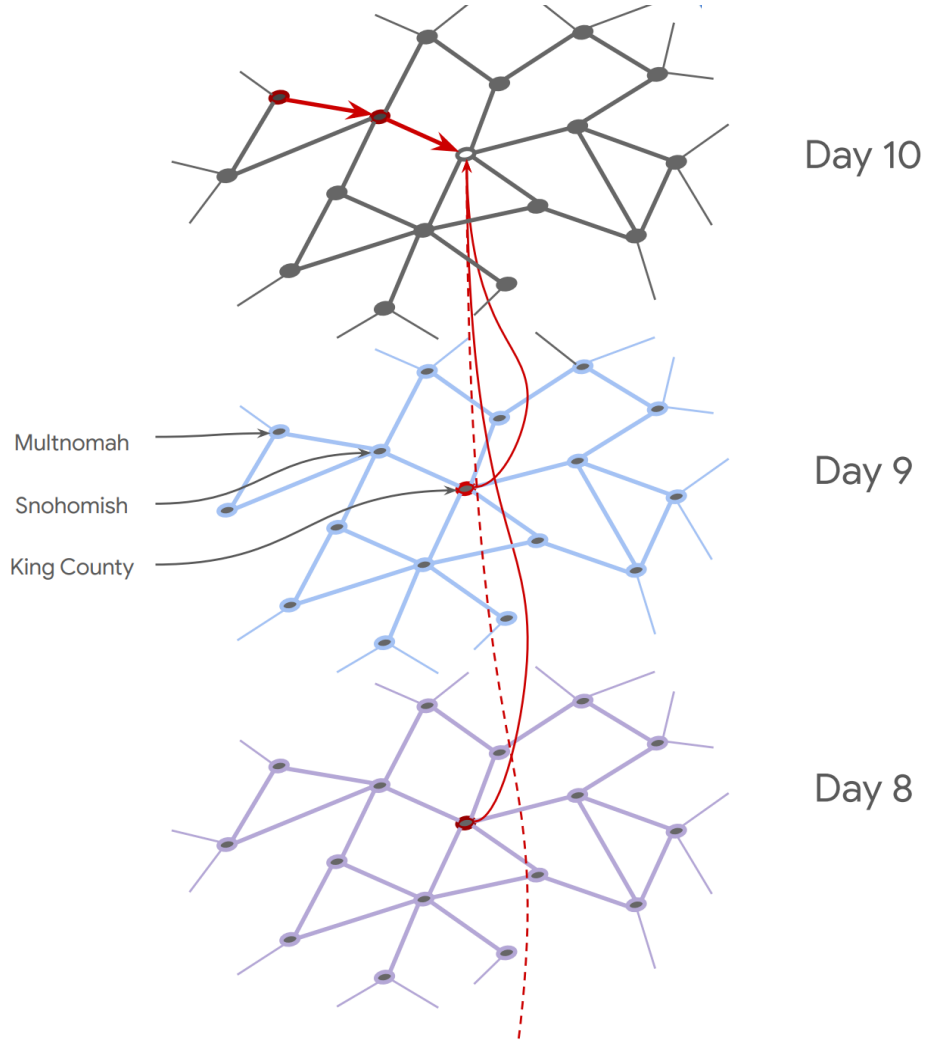
Applications of Dynamic GNNs



Top: Inter-county mobility data from King County.
Bottom: Intra-county mobility data from King County.



COVID-2019 Mobility



/02 动态图神经网络分类

Dynamic Graph Neural Networks

Dynamic Graph Neural Networks

Dynamic networks add a new dimension to network modelling and prediction – **time**.

A DGNN, is considered to be a neural network architecture which can encode a dynamic network and where the aggregation of neighbouring node features is part of the neural network architecture.

A dynamic network have both **temporal** and **structural** patterns.

Two Keys:

- **Structural** Information;
- **Temporal** Information.

Dynamic Graph Neural Networks

Dynamic Network: A Dynamic Network is a graph $G = (V, E)$

where:

$V = \{(v, t_s, t_e)\}$, with v a vertex of the graph and t_s, t_e are respectively the start and end timestamps for the existence of the vertex (with $t_s \leq t_e$).

$E = \{(u, v, t_s, t_e)\}$, with $u, v \in V$ and t_s, t_e are respectively the start and end timestamps for the existence of the edge (with $t_s \leq t_e$).

Dynamic Graph Neural Networks

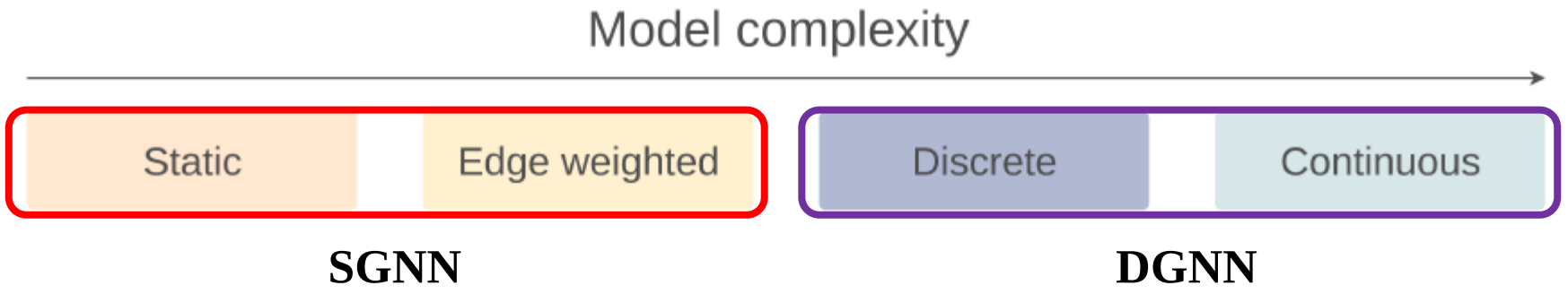
Priori knowledge:

- Temporal granularity
- Link duration spectrum
- Node dynamic

Temporal Granularity

Dynamic Network: A Dynamic Network is a graph $G = (V, E)$

Dynamic network representations can be grouped into four distinct levels ordered by temporal granularity: (i) static, (ii) edge weighted, (iii) **discrete**, and (iv) **continuous** networks.

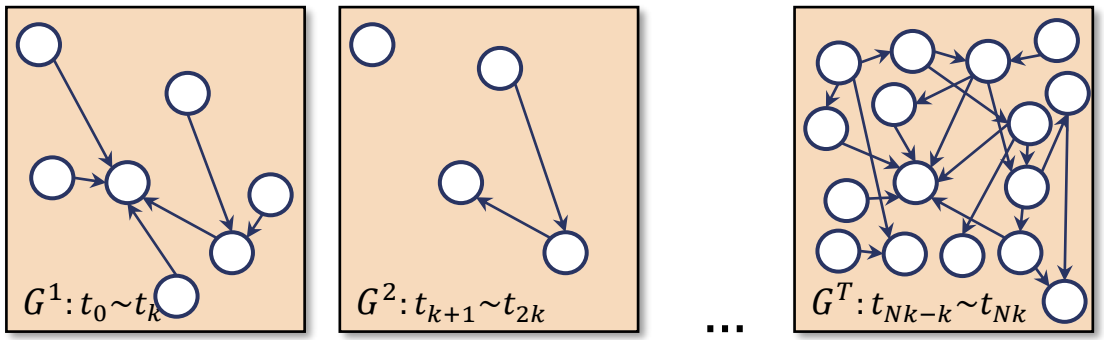


Dynamic Discrete Representations

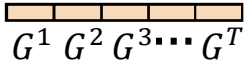
Discrete Representations: use an ordered set of graphs (snapshots) to represent a dynamic graph.

$$DG = (G^1, G^2 ... G^T)$$

T: Snapshot



Uniform Dara Encoding



Dynamic Continuous Representation

Dynamic **Continuous** network representations are the only representations that have exact temporal information.

This makes them the most complex but also the representation with the most potential.

Three continuous representations:

(i) event-based;
(ii) contact sequence;
(iii) graph streams.

Dynamic Continuous Representation

Event-based continuous representation: $\boldsymbol{EB} = \{(u_i, v_i, t_i, \Delta_i),\ \ i = 1, 2, 3 \ldots\}$

Contact Sequence continuous representation: $\boldsymbol{CS} = \{(u_i, v_i, t_i),\ \ i = 1, 2, 3 \ldots\}$

Graph Streams continuous representation: $\boldsymbol{GS} = \{e_1, e_2, \ldots\}$

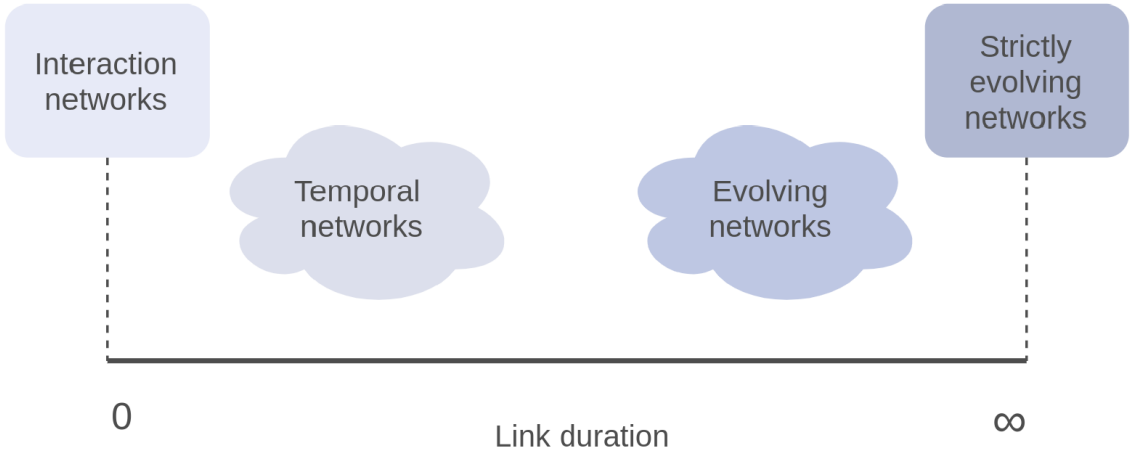
where u_i and v_i is a node pair on which the i event occurs, t_i is the timestamp for when the event starts and Δ_i is the duration of the event.

Where $e_i = (u_i, v_i, t_i, \delta_i)$, $\delta_i \in \{-1,1\}$: -1 represents an edge removal and 1 represents that an edge is added.

Link Duration Spectrum

Temporal and evolving networks on the link duration spectrum:

The spectrum go from 0 (links have no duration) to infinity (links last forever).



Link Duration Spectrum

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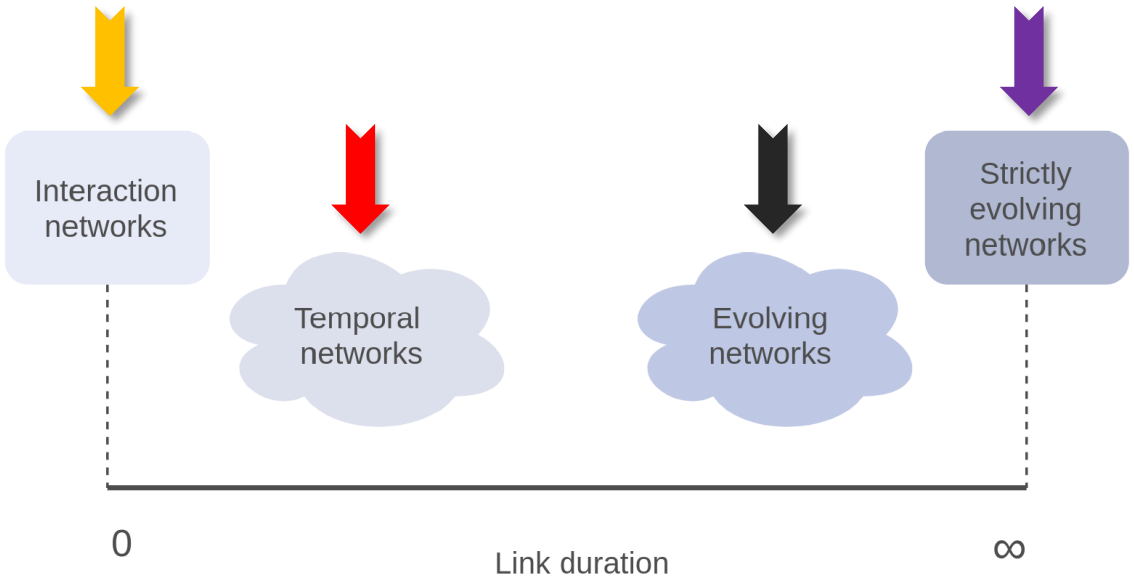


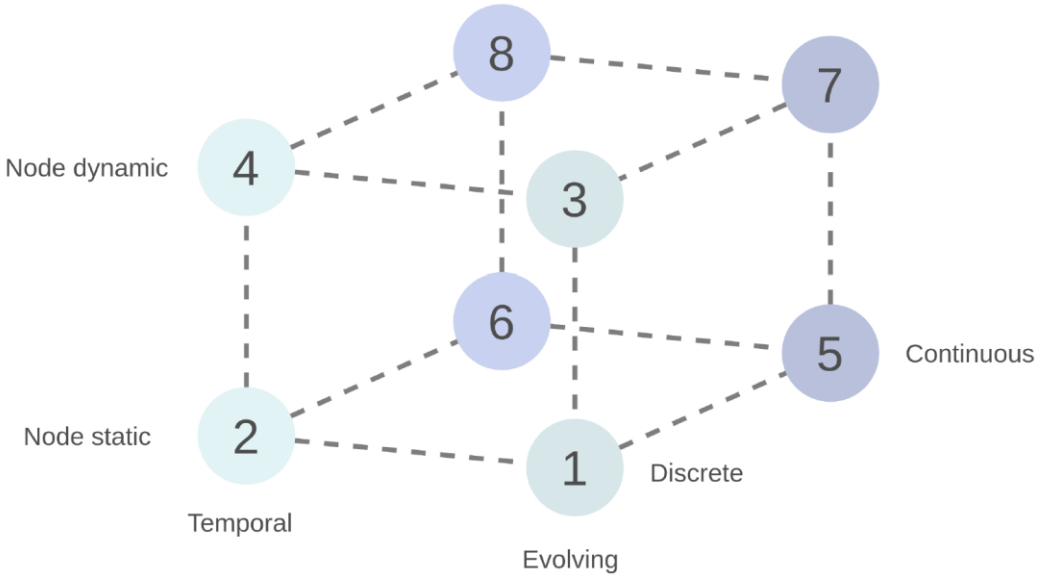
Node Dynamics

Static where the number of nodes stay static over time;

Dynamic where the nodes may appear and disappear. A notable special case of node dynamic networks are the networks where nodes may only appear;

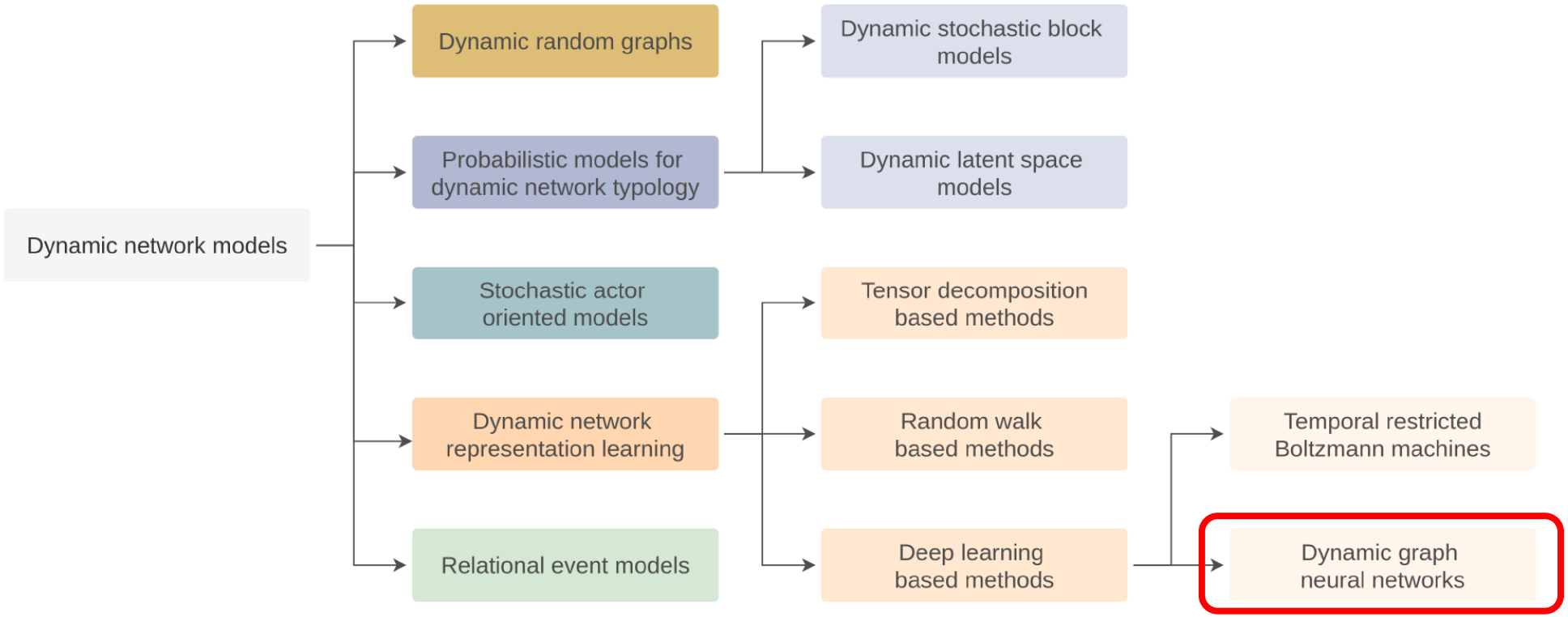
Growing networks are those where nodes may only appear. (special case of dynamic ones)

Dynamics Network Cube

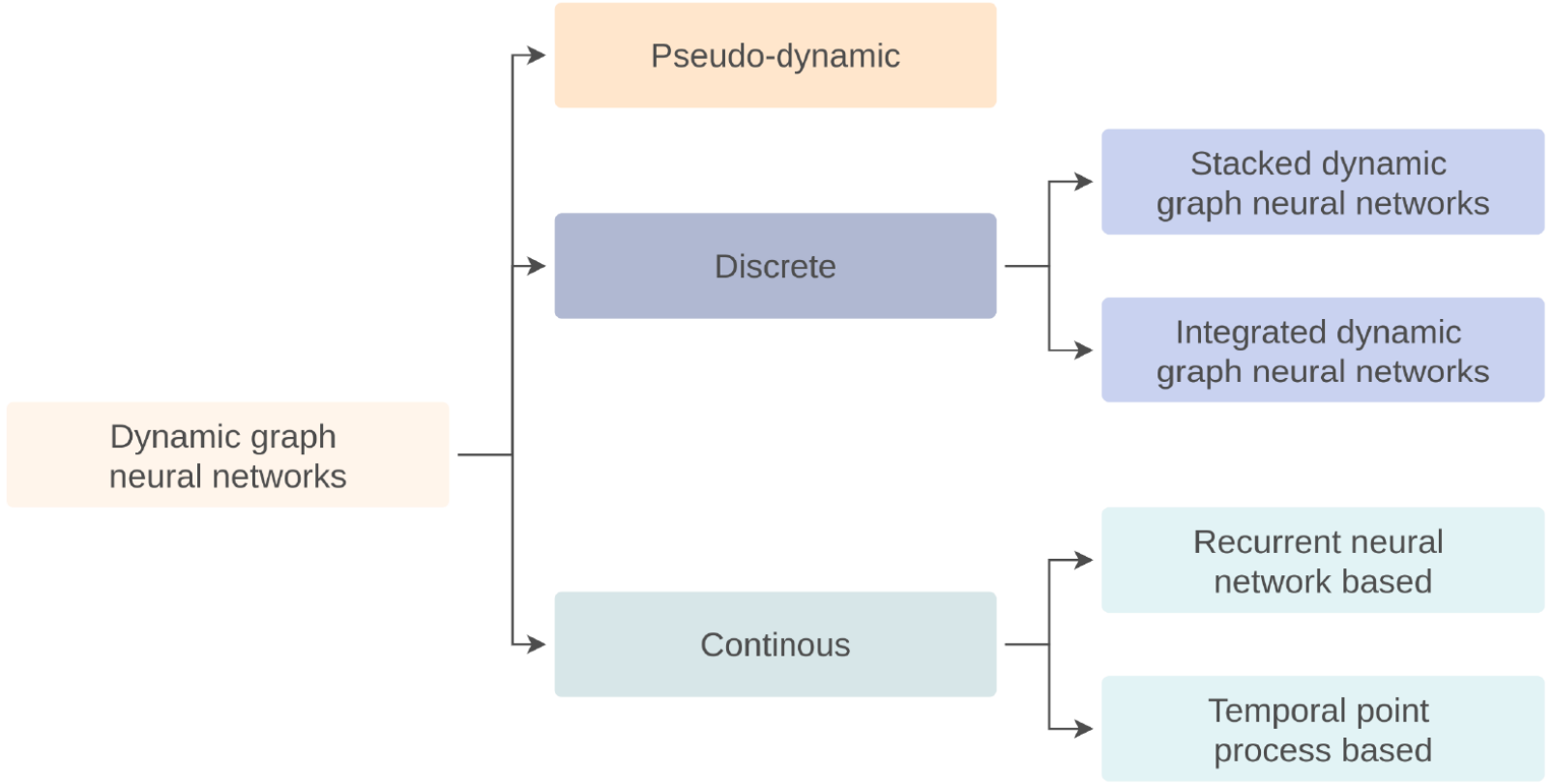


Node	Temporal granularity	Node dynamics	Link duration	Precise dynamic network term
1	Discrete	Node static	Evolving	Discrete node static evolving network
2			Temporal	Discrete node static temporal network
3		Node dynamic	Evolving	Discrete node dynamic evolving network
4			Temporal	Discrete node dynamic temporal network
5	Continuous	Node static	Evolving	Continuous node static evolving network
6			Temporal	Continuous node static temporal network
7		Node dynamic	Evolving	Continuous node dynamic evolving network
8			Temporal	Continuous node dynamic temporal network

Dynamic Network Models

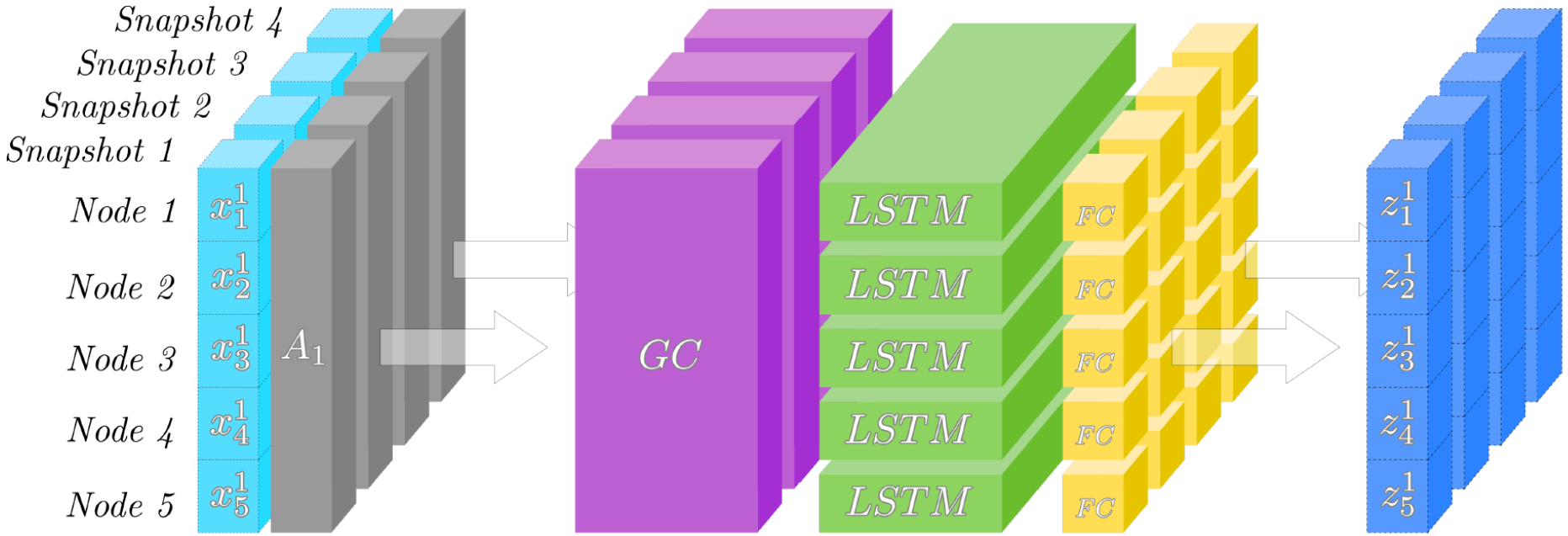


Dynamic Graph Neural Networks



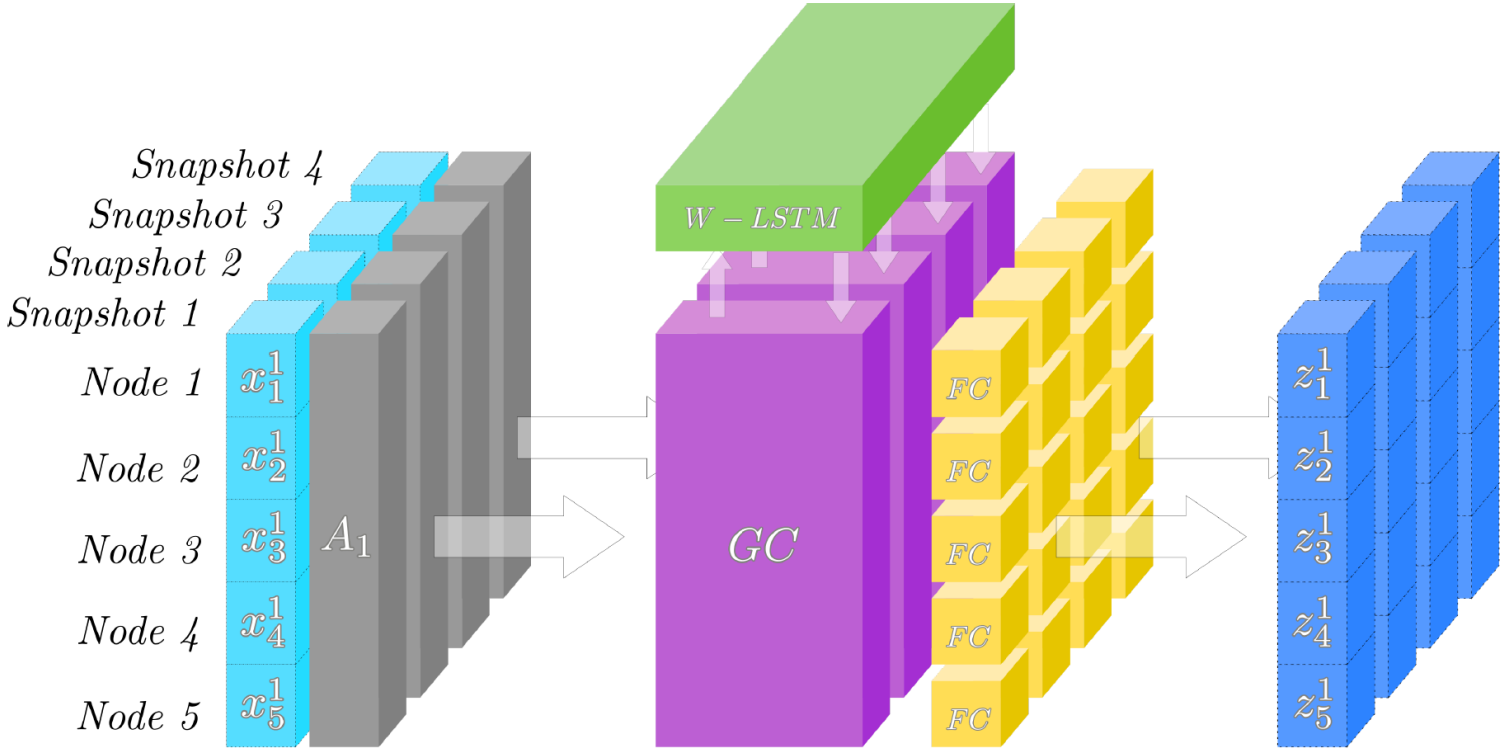
Stacked Dynamic Graph Neural Networks

SDGNN: model a discrete dynamic graph is to have a separate GNN handle each snapshot of the graph and feed the output of each GNN to a time series component.



Integrated Dynamic Graph Neural Networks

IDGNN: are encoders which combine GNNs and RNNs in one layer and thus combine modeling of the spatial and the temporal domain in that one layer.



Dynamic Continuous Graph Neural Networks

Task 2:

a. *Types of Dynamic Continuous Graph Neural Networks;*
b. *Classical Approaches of each type.*

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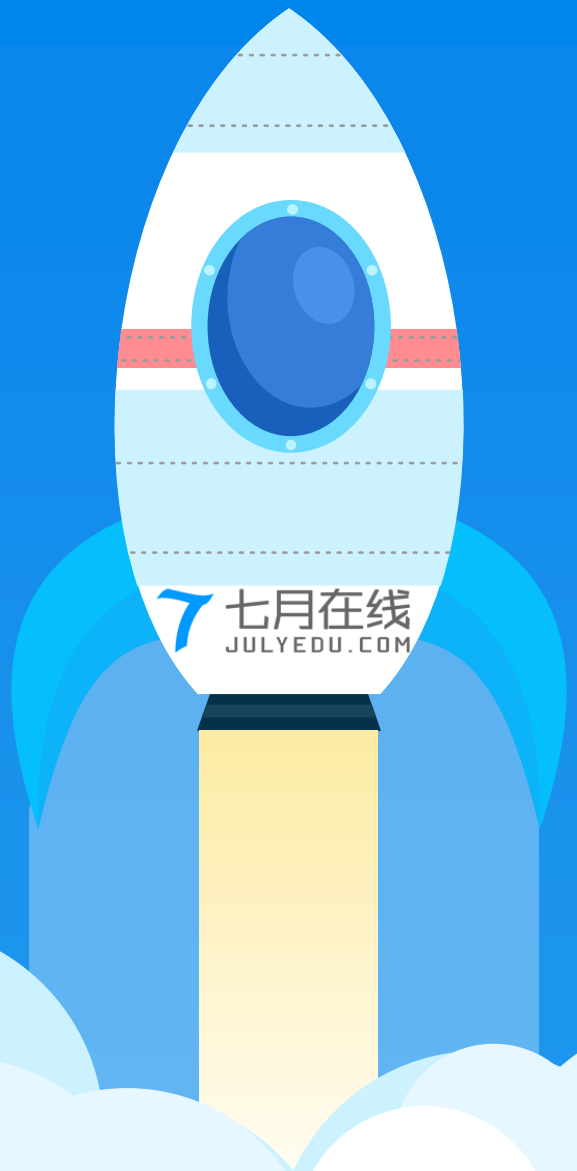

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