上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

Relational Table Learning

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Social Network Analysis (NIS8023)

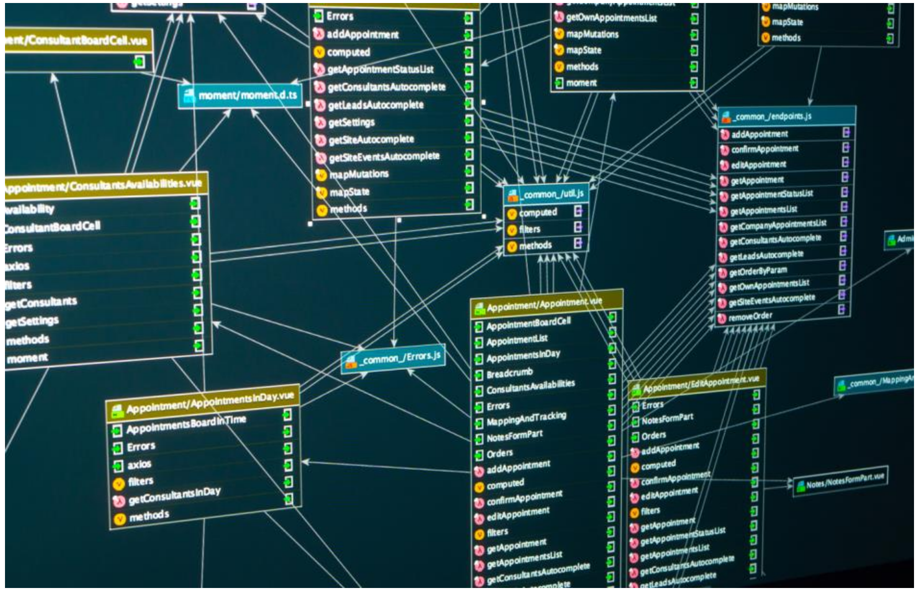
Shanghai Jiao Tong University

Outline

- **Relational Table Learning (RTL)**
- Generalized RTL
- Discussion

Relational/Graph Data are everywhere

- Recall that "relational links" exist in Relational DBs

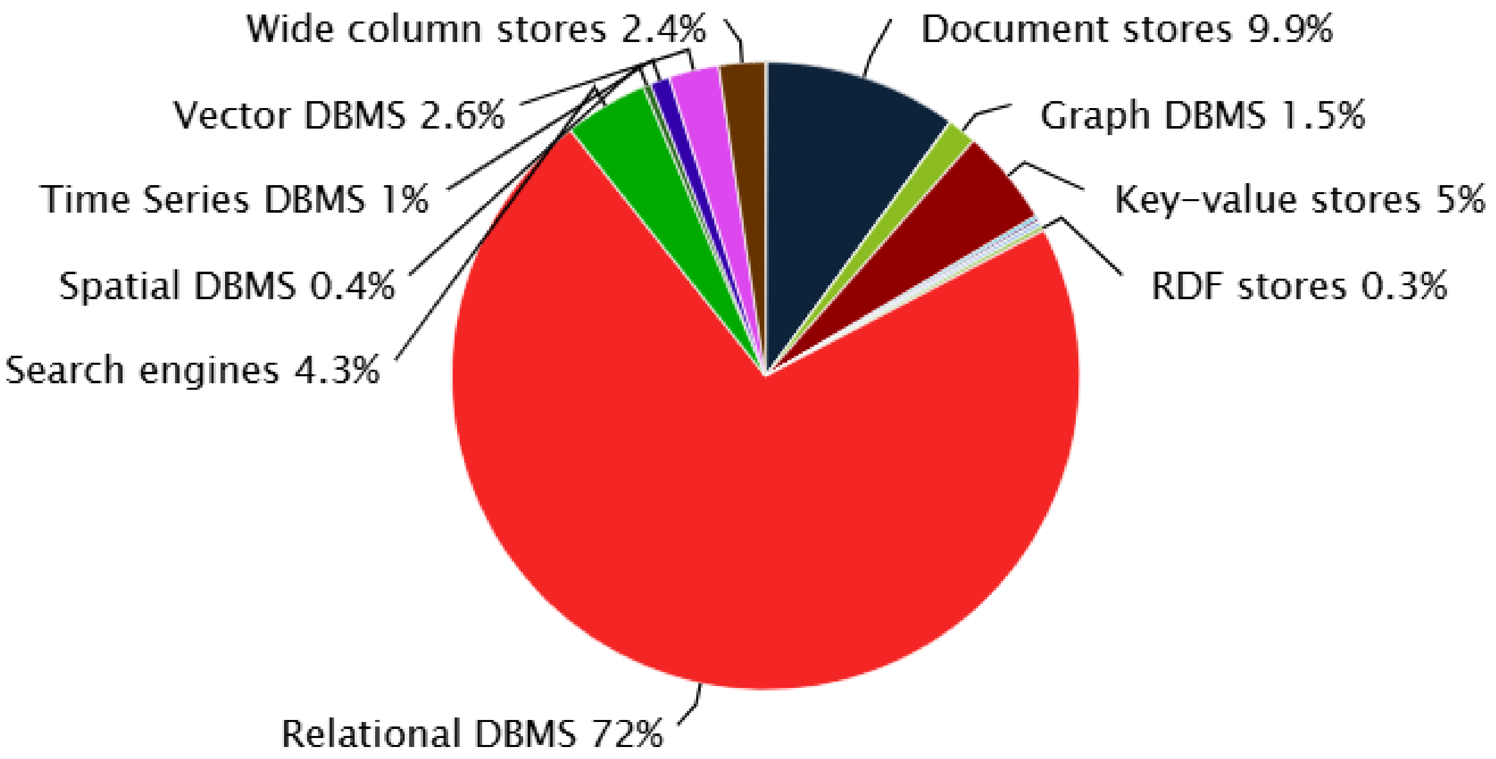


Relational databases

…

Relational databases domain the world data

Ranking scores per category in percent, February 2025



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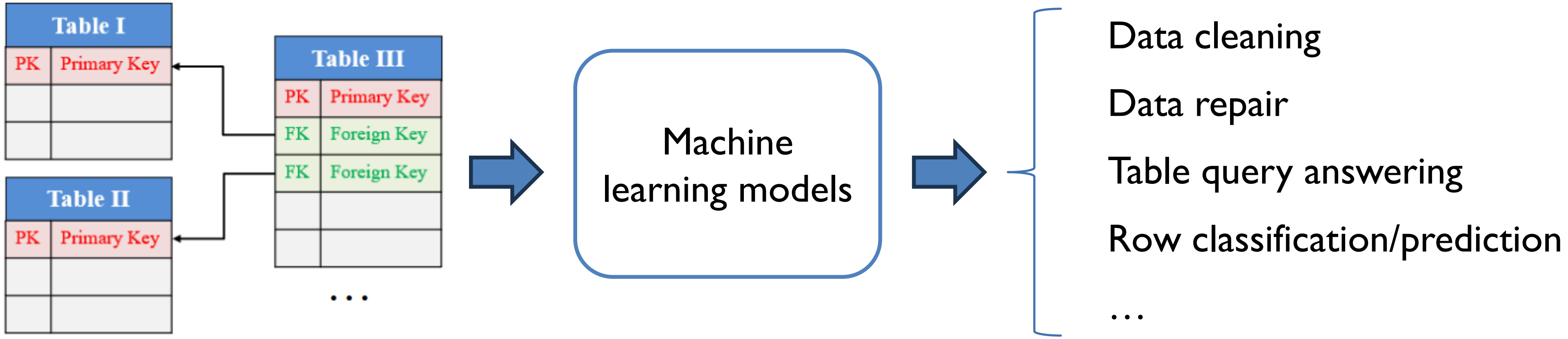
We need to pay great attention to Relational Table Learning (RTL).

What's Relational Table Learning (RTL)

- RTL is a field of AI that focuses on enabling computers to understand the content across multiple tables linked by primary and foreign keys.



Machine learning models

Data cleaning

Data repair

Table query answering

Row classification/prediction

…

Input: relational tables

Various applications

1. Li, W., Huang, X., Zheng, J., Wang, Z., Wang, C., Pan, L., & Li, J. (2024). rLLM: Relational table learning with LLMs. *arXiv preprint arXiv:2407.20157*.

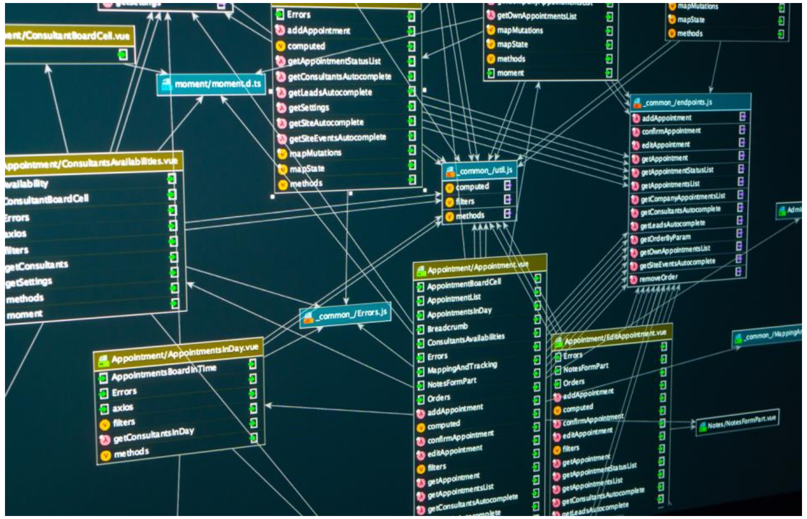
Key question

- How to jointly model multiple tables and their relationships?
  - Table data are the data stored in each table.
  - Non-table data the relationships by primary and foreign keys.

Can machine learning methods do this totally automatically?

Observation on RTL

- A relational database is a graph
  - Nodes: rows in various tables
  - Links: relationships presented by primary and foreign keys

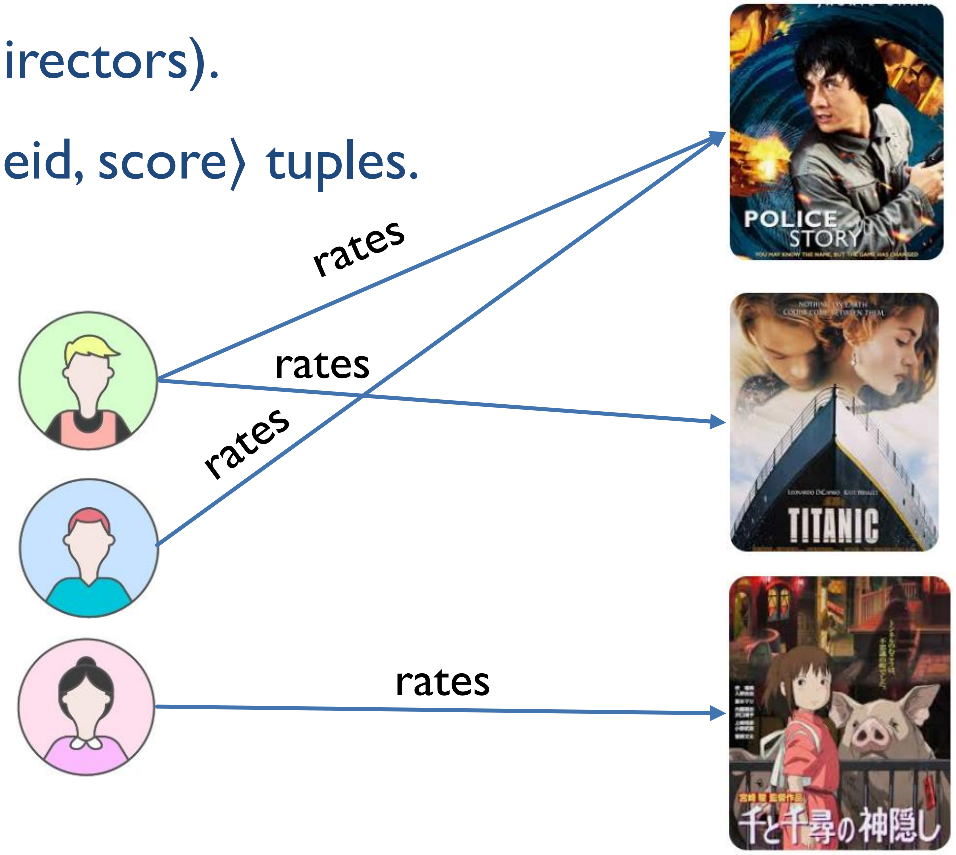


moment/moment.d.ts
common/util.js
common/endpoints.js
Appointment/ConsultantsAvailabilities.vue
Appointment/Appointment.vue
common/Errors.js
Appointment/AppointmentsInDay.vue
Appointment/EditAppointment.vue
Notes/NotesFormPart.vue

Relational databases

A very simple example: movie rate prediction

- On IMDb, users rate movies, with data stored in three key tables:
  - User Table: Stores user details (e.g., age, gender).
  - Movie Table: Contains movie details (e.g., actors, directors).
  - Rating Table: Records user ratings as ⟨userid, movieid, score⟩ tuples.



How to conduct RTL

- The existing solution is very straightforward:
  - Adopting Table Neural Networks to model table data
  - Adopting Graph Neural Networks to model their relationships

We think more **seamless** RTL type methods will be proposed soon.

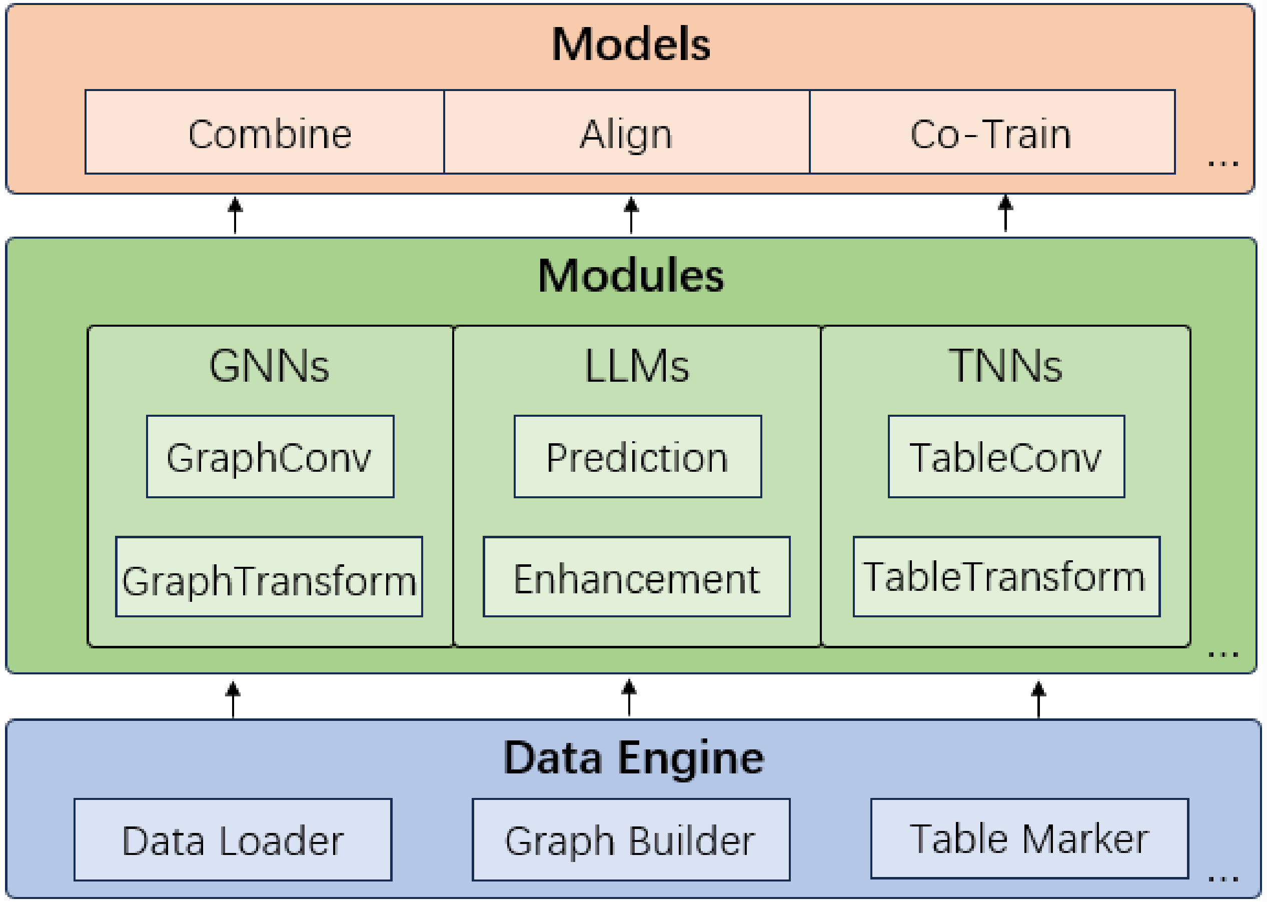
A PyTorch Library for Relational Table Learning with LLMs

rLLM: Relational Table Learning with LLMs

Weichen Li[1], Xiaotong Huang[1], Jianwu Zheng[1], Zheng Wang[1], Chaokun Wang[2], Li Pan[1], Jianhua Li[1]
[1] Shanghai Jiao Tong University, China
[2] Tsinghua University, China
{wzheng,panli,lijh888}@sjtu.edu.cn,chaokun@tsinghua.edu.cn

Paper: https://arxiv.org/abs/2407.20157.

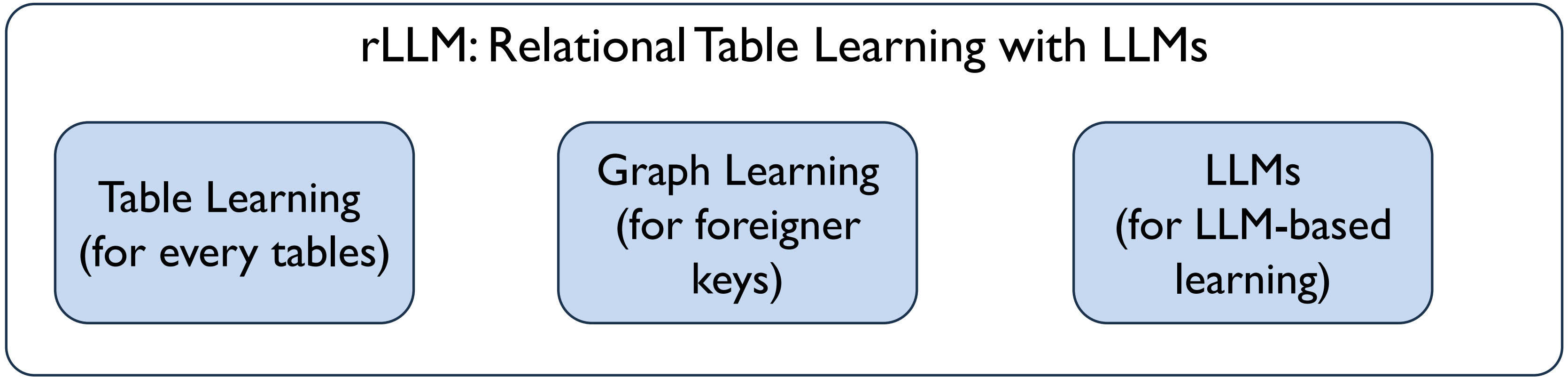
Overview of rLLM



The rLLM Overall Architecture

Project: https://github.com/rllm-project/rllm

The Key of rLLM (relationLLM)



rLLM: Relational Table Learning with LLMs

Table Learning (for every tables)

Graph Learning (for foreigner keys)

LLMs (for LLM-based learning)

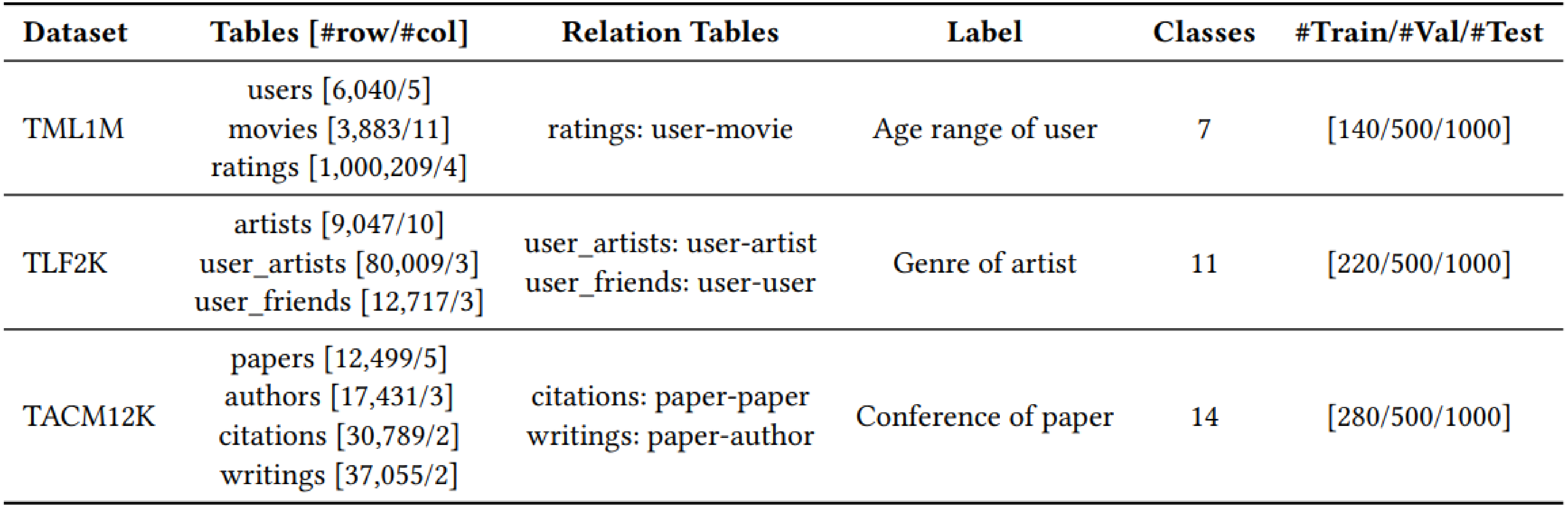
rLLM (relationLLM) is an easy-to-use Pytorch library for Relational Table Learning with LLMs, by performing two key functions:

- Breaks down state-of-the-art GNNs, LLMs, and TNNs as standardized modules.
- Facilitates novel RTL model building in a "combine, align, and co-train“ way.

Project page: https://github.com/rllm-project/rllm

Three new relational table datasets with standard classification tasks

- TML1M is derived from the classical MovieLens1M dataset.
- TLF2K is derived from the classical LastFM2K dataset.
- TACM12K is derived from the ACM heterogeneous graph dataset.



Dataset	Tables [#row/#col]	Relation Tables	Label	Classes	#Train/#Val/#Test
TML1M	users [6,040/5] movies [3,883/11] ratings [1,000,209/4]	ratings: user-movie	Age range of user	7	[140/500/1000]
TLF2K	artists [9,047/10] user_artists [80,009/3] user_friends [12,717/3]	user_artists: user-artist user_friends: user-user	Genre of artist	11	[220/500/1000]
TACM12K	papers [12,499/5] authors [17,431/3] citations [30,789/2] writings [37,055/2]	citations: paper-paper writings: paper-author	Conference of paper	14	[280/500/1000]

An illustration RTL method - BRIDGE

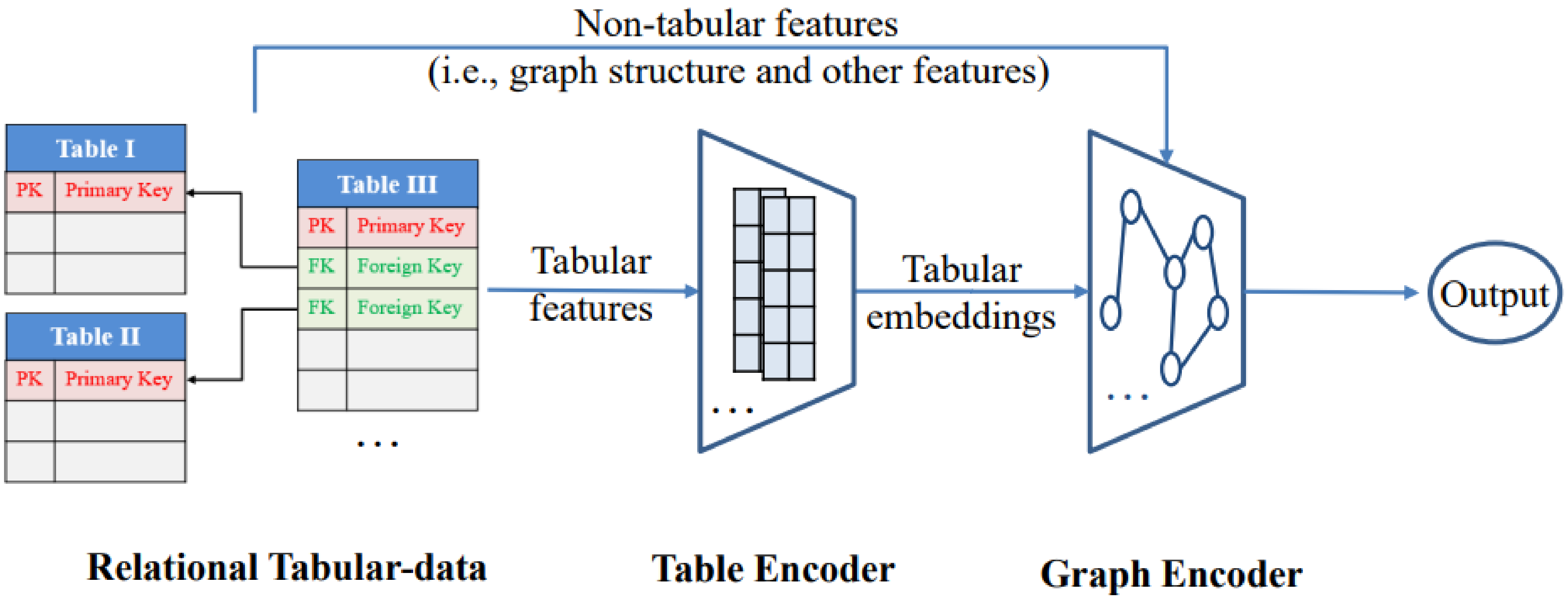
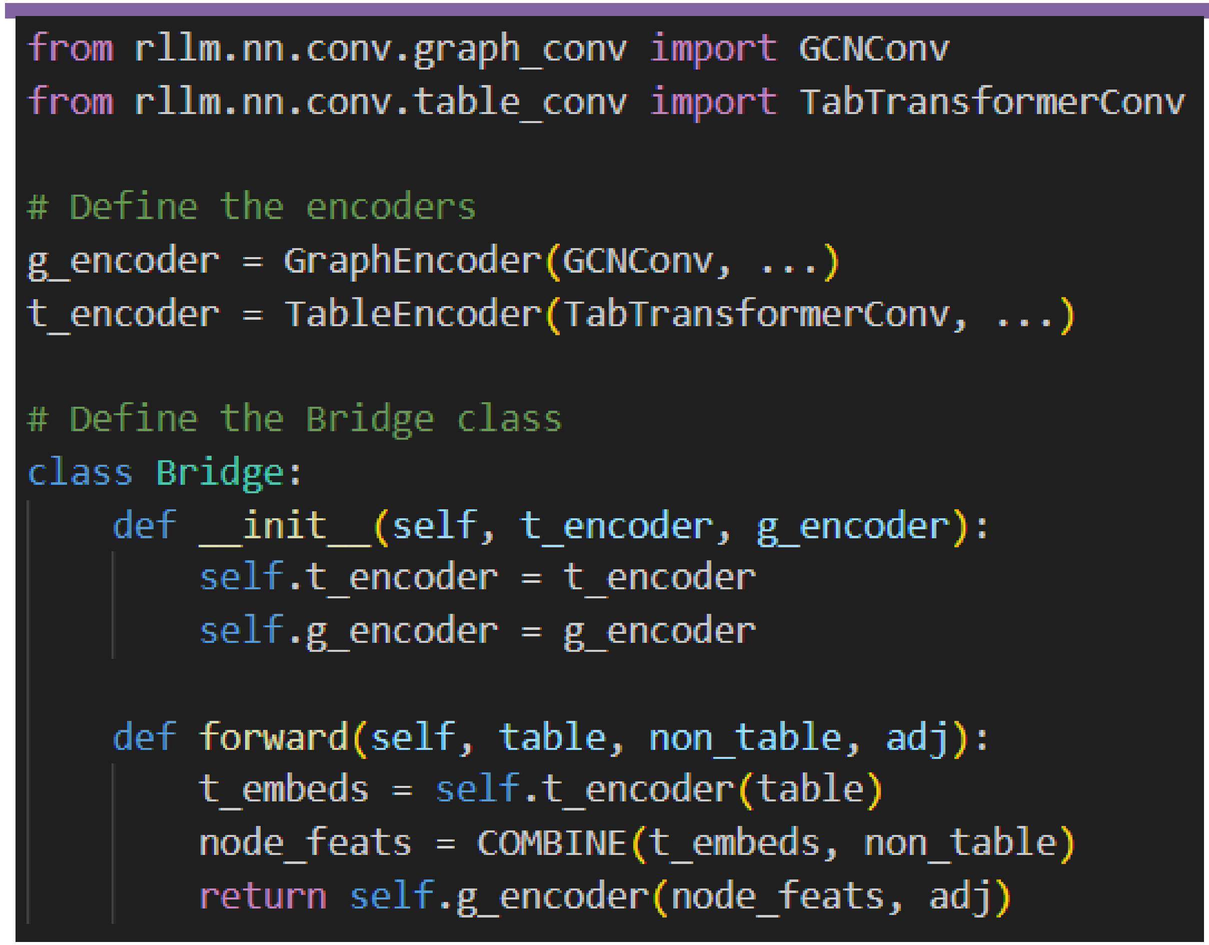


Figure 4: The architecture of BRIDGE

BRIDGE utilizes TNNs to process table data and leverages the "foreign keys" in relational tables to construct relationships between table samples, which are then analyzed using GNNs.

Pseudo-code of BRIDGE



```
from rllm.nn.conv.graph_conv import GCNConv
from rllm.nn.conv.table_conv import TabTransformerConv

# Define the encoders
g_encoder = GraphEncoder(GCNConv, ...)
t_encoder = TableEncoder(TabTransformerConv, ...)

# Define the Bridge class
class Bridge:
    def __init__(self, t_encoder, g_encoder):
        self.t_encoder = t_encoder
        self.g_encoder = g_encoder

    def forward(self, table, non_table, adj):
        t_embeds = self.t_encoder(table)
        node_feats = COMBINE(t_embeds, non_table)
        return self.g_encoder(node_feats, adj)
```

In practical implementations, the code lines are around 40.

Without rLLM, more than 400+ lines are needed!

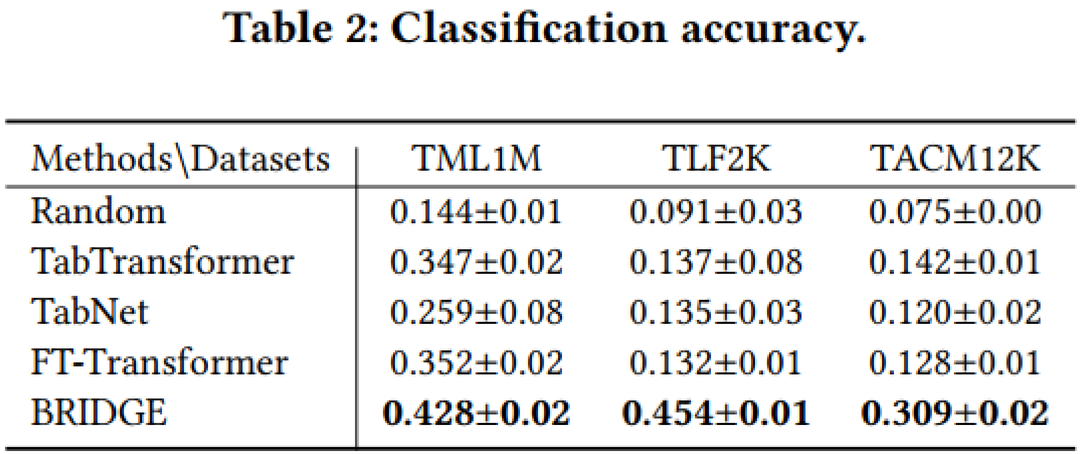


Table 2: Classification accuracy.

Methods\Datasets	TML1M	TLF2K	TACM12K
Random	0.144±0.01	0.091±0.03	0.075±0.00
TabTransformer	0.347±0.02	0.137±0.08	0.142±0.01
TabNet	0.259±0.08	0.135±0.03	0.120±0.02
FT-Transformer	0.352±0.02	0.132±0.01	0.128±0.01
BRIDGE	**0.428±0.02**	**0.454±0.01**	**0.309±0.02**

How to try

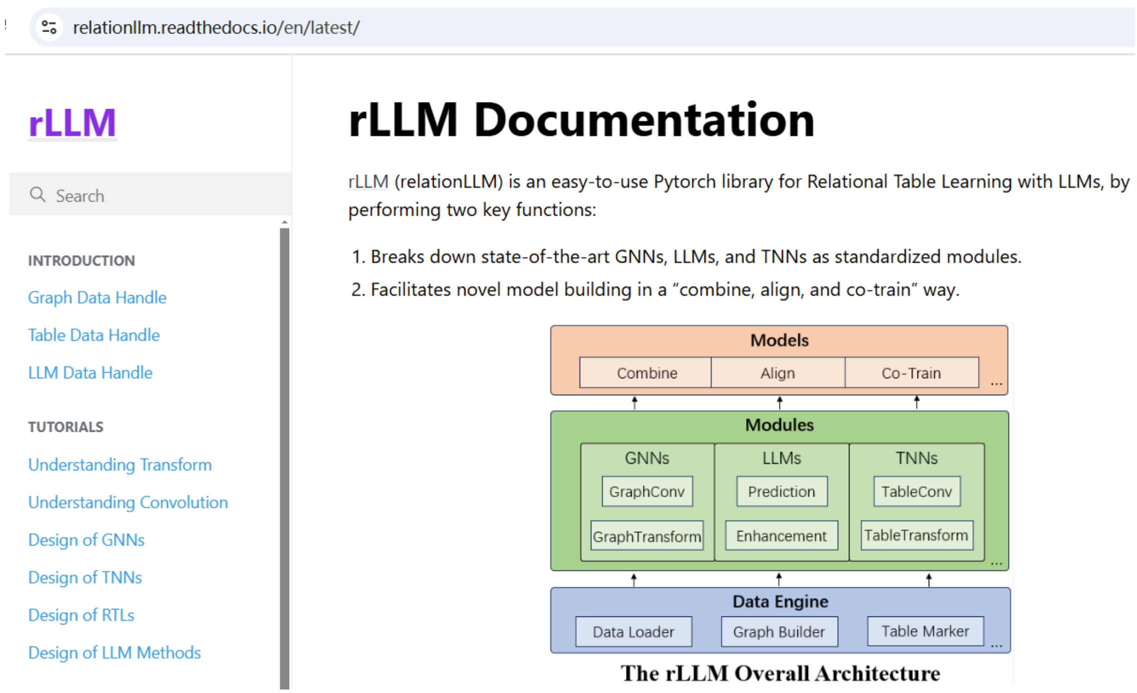
```
# cd ./examples

# set parameters if necessary


python bridge/bridge_tml1m.py

python bridge/bridge_tlf2k.py

python bridge/bridge_tacm12k.py
```



relationllm.readthedocs.io/en/latest/

rLLM Documentation

rLLM (relationLLM) is an easy-to-use Pytorch library for Relational Table Learning with LLMs, by performing two key functions:

1. Breaks down state-of-the-art GNNs, LLMs, and TNNs as standardized modules.
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- **Generalized RTL**
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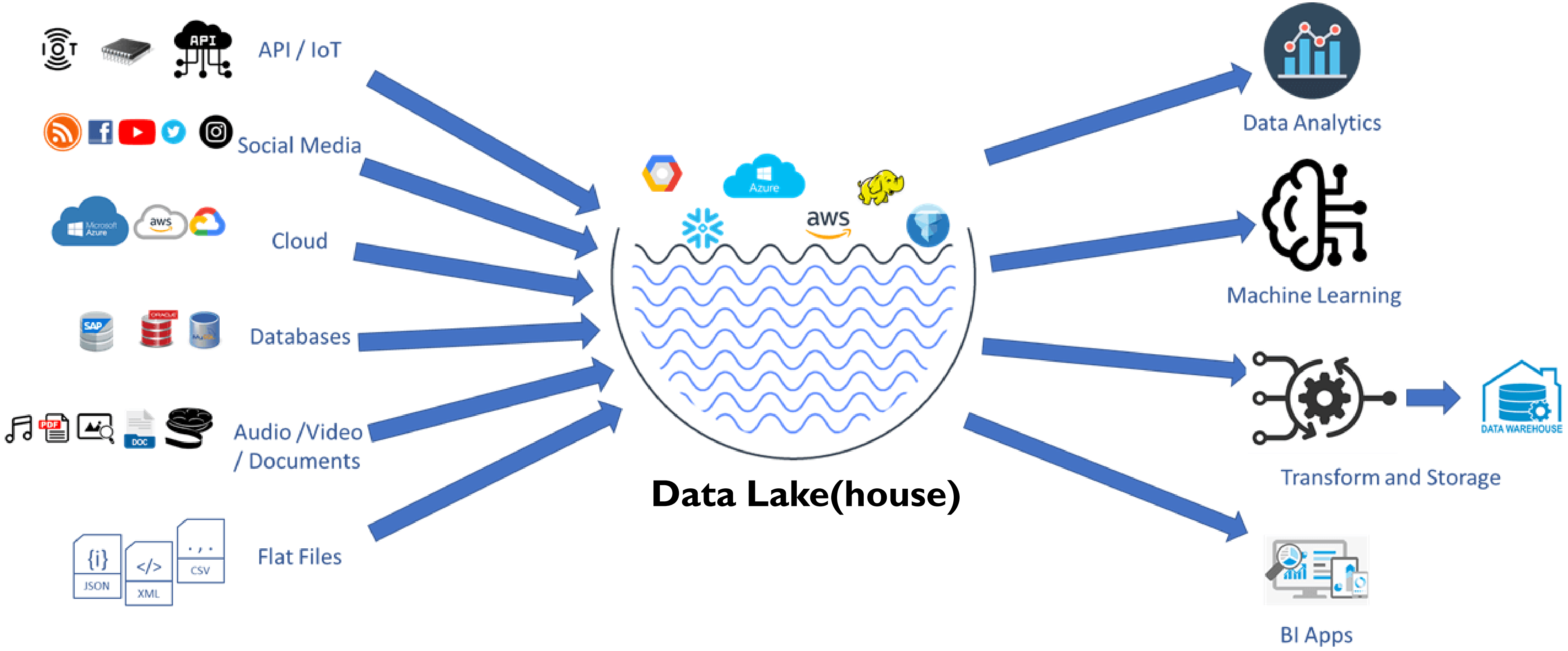
Data Lake(house): a central hub for machine learning

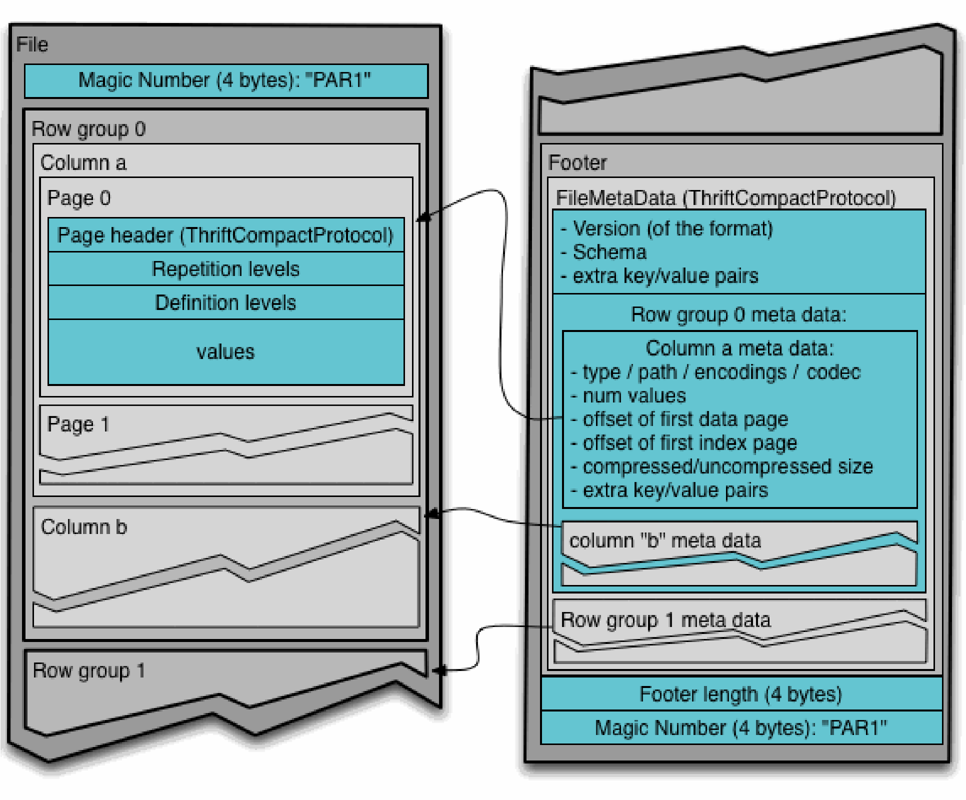


Question: how to conduct machine learning (maybe RTL) in Data Lake(house)?

Image from https://helicaltech.com/services/data-lake-services/

Preliminary: the data stores in data lake(house)

- Open-source file formats, like Parquet and ORC



File

Magic Number (4 bytes): "PAR1"

Row group 0

Column a

Page 0

Page header (ThriftCompactProtocol)

Repetition levels

Definition levels

values

Page 1

Column b

Row group 1

Footer

FileMetaData (ThriftCompactProtocol)

- Version (of the format)
- Schema
- extra key/value pairs

Row group 0 meta data:

Column a meta data:

- type / path / encodings / codec
- num values
- offset of first data page
- offset of first index page
- compressed/uncompressed size
- extra key/value pairs

column "b" meta data

Row group 1 meta data

Footer length (4 bytes)

Magic Number (4 bytes): "PAR1"

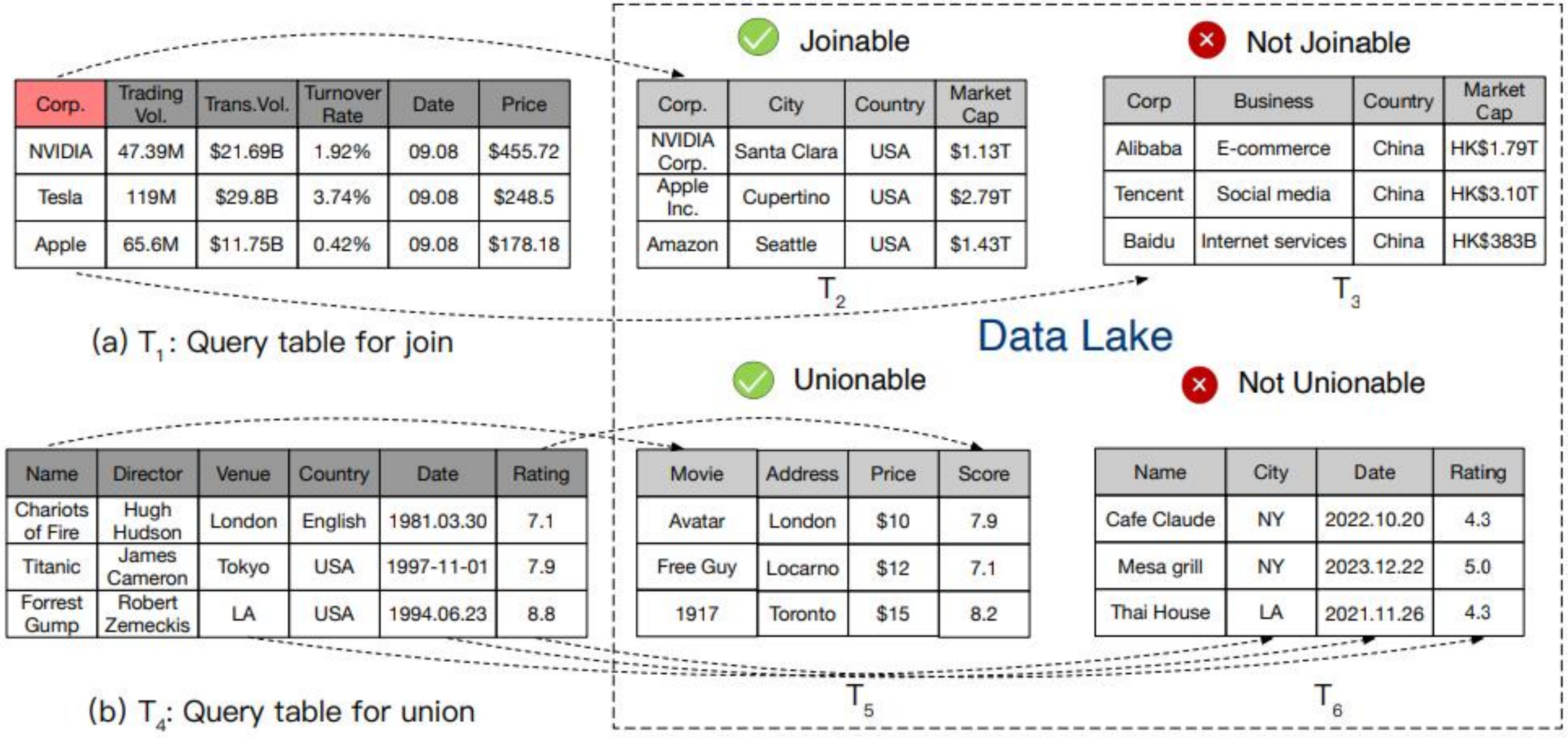
Question: can we convert columnar data to table data?

Answer: Yes, but only obtain very sparse tables.

Apache Parquet is a binary, efficient columnar data format.

How to prepare data in data lake(house)

- Data discover (i.e., find their relationships) is one of the most important tasks, including
  - Joinable Tables
  - Unionable Tables
  - Subsetable Tables
  - …



Corp.	Trading Vol.	Trans.Vol.	Turnover Rate	Date	Price
NVIDIA	47.39M	$21.69B	1.92%	09.08	$455.72
Tesla	119M	$29.8B	3.74%	09.08	$248.5
Apple	65.6M	$11.75B	0.42%	09.08	$178.18

(a) T_1: Query table for join

Corp.	City	Country	Market Cap
NVIDIA Corp.	Santa Clara	USA	$1.13T
Apple Inc.	Cupertino	USA	$2.79T
Amazon	Seattle	USA	$1.43T

T_2

Corp	Business	Country	Market Cap
Alibaba	E-commerce	China	HK$1.79T
Tencent	Social media	China	HK$3.10T
Baidu	Internet services	China	HK$383B

T_3

Name	Director	Venue	Country	Date	Rating
Chariots of Fire	Hugh Hudson	London	English	1981.03.30	7.1
Titanic	James Cameron	Tokyo	USA	1997-11-01	7.9
Forrest Gump	Robert Zemeckis	LA	USA	1994.06.23	8.8

(b) T_4: Query table for union

Movie	Address	Price	Score
Avatar	London	$10	7.9
Free Guy	Locarno	$12	7.1
1917	Toronto	$15	8.2

T_5

Name	City	Date	Rating
Cafe Claude	NY	2022.10.20	4.3
Mesa grill	NY	2023.12.22	5.0
Thai House	LA	2021.11.26	4.3

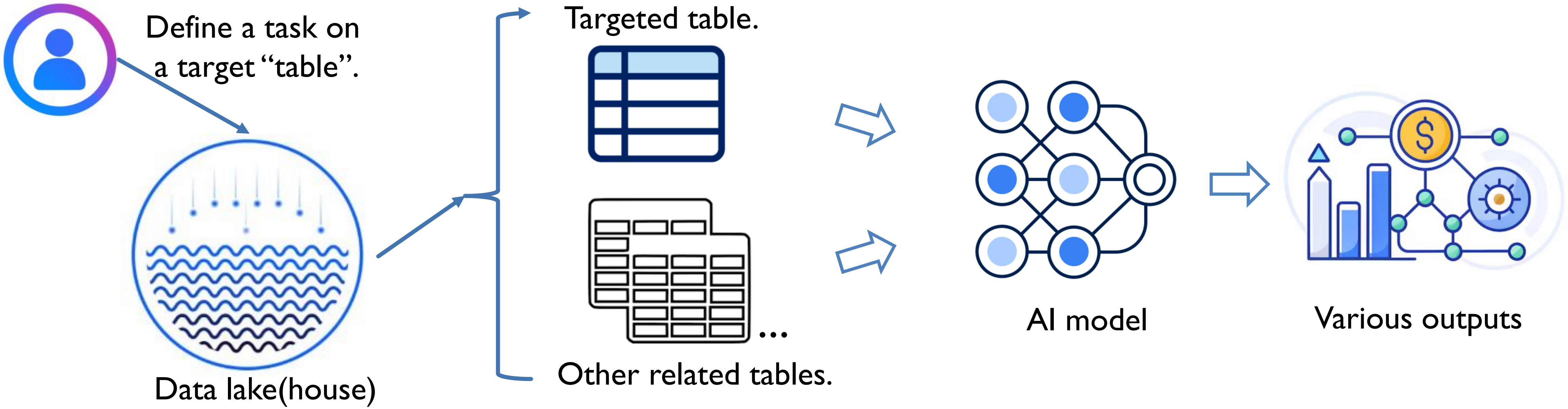
T_6

Table discovery in data lake(house)

Deng, Yuhao, et al. "LakeBench: A Benchmark for Discovering Joinable and Unionable Tables in Data Lakes." *Proceedings of the VLDB Endowment* 17.8 (2024): 1925-1938.
Srinivas, Kavitha, et al. "Lakebench: Benchmarks for data discovery over data lakes." arXiv preprint arXiv:2307.04217 (2023).

Machine Learning in a Data Lakehouse: Possible Steps

- Machine learning in data lake(house), possible steps:
  - Define a Task: Identify the target table and define the goal.
  - Discover Related Tables: Find other task related tables.
  - Model Learning: Use the combined data for AI training and get insights.



Generalized Relational Table Learning (GRTL)

- Compared to RTL, GRTL further extends the model's ability to capture more general relationships between tables, including:
  - Joins on different keys (e.g., <pri, for>, <pri, pri>, <anycol, anycol>)
  - Union (combining result sets from two or more SELECT statements)
  - Subset (some tables are subsets of others)
  - …

Outline

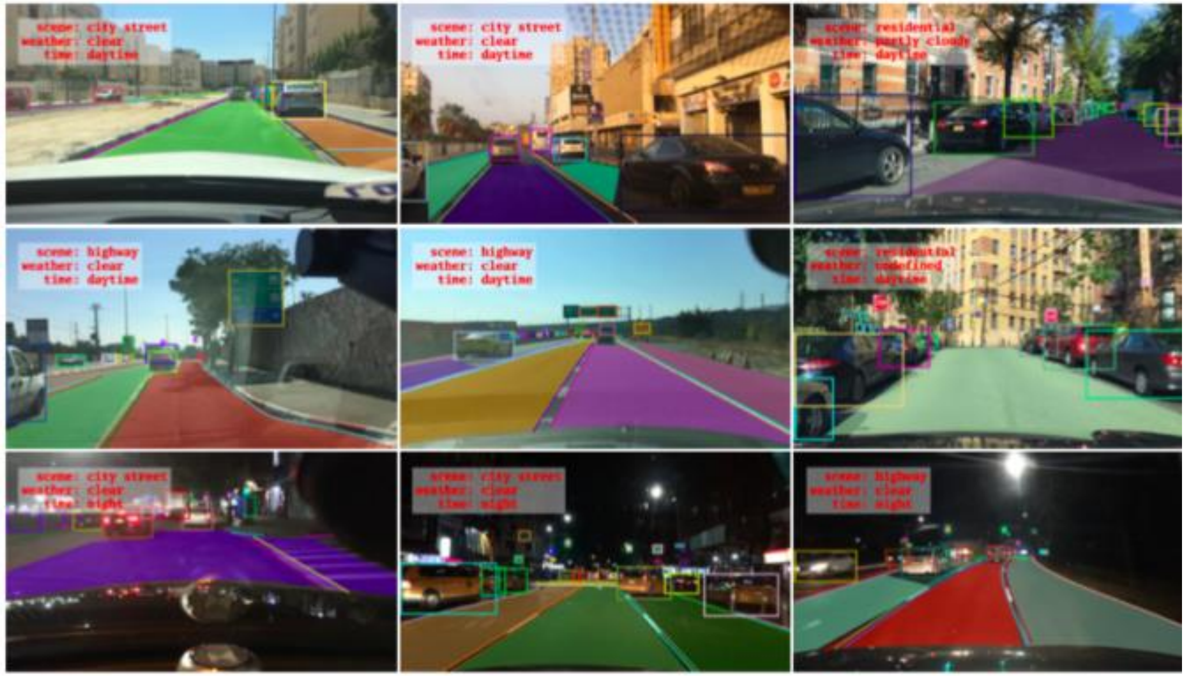
- Relational Table Learning (RTL)
- Generalized RTL
- **Discussion**

Applications of RTL methods: Self-driving car

- Sensors: cameras, LiDAR, radar, audio, and ultrasound, GPS, and inertial measurement.
- Data source: single/multiple sources
- Data platform: RDB, Data Lake(house), …
- Method: Deep Learning -> Large Model

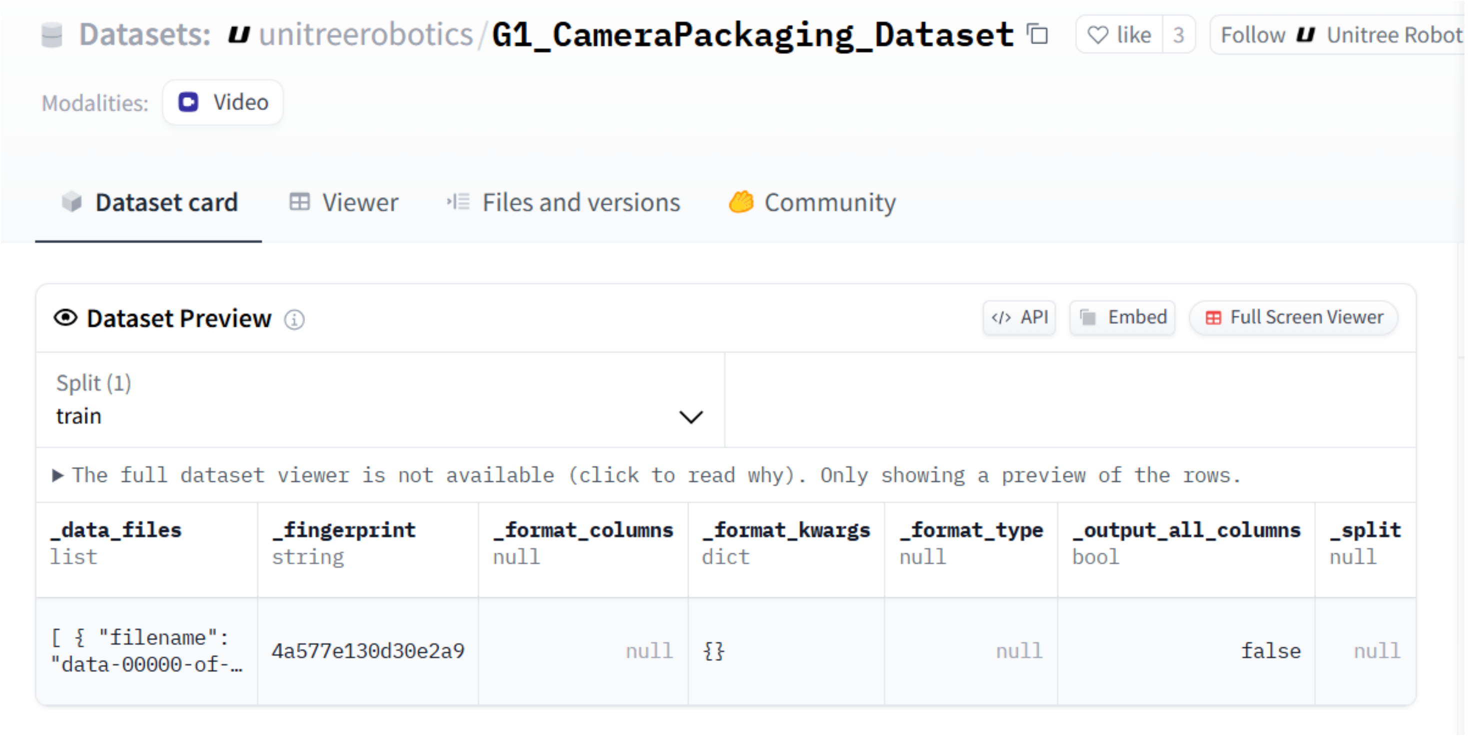
Question:

1. Should the processed sensor data be stored in tables?
2. Can RTL aid in developing self-driving models?



Berkeley Deep Drive dataset

Applications of RTL methods: robots



Datasets: unitreerobotics/G1_CameraPackaging_Dataset

Split (1)
train

▸ The full dataset viewer is not available (click to read why). Only showing a preview of the rows.

_data_files list	_fingerprint string	_format_columns null	_format_kwargs dict	_format_type null	_output_all_columns bool	_split null
[{ "filename": "data-00000-of-…	4a577e130d30e2a9	null	{}	null	false	null

A dataset of Unitree Robotics

Game Developer Conference (GDC) 2024

Question:

1. Should the processed sensor data be stored in tables?
2. Can RTL aid in developing robot models?

Thanks for your time.
QA.