上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

Relational Table Learning

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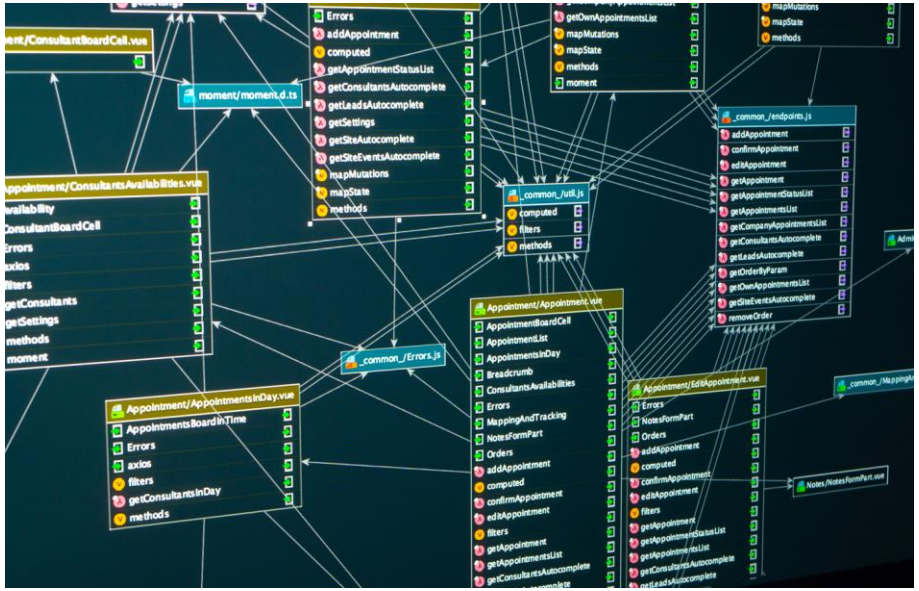
Outline

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

Relational/Graph Data are everywhere

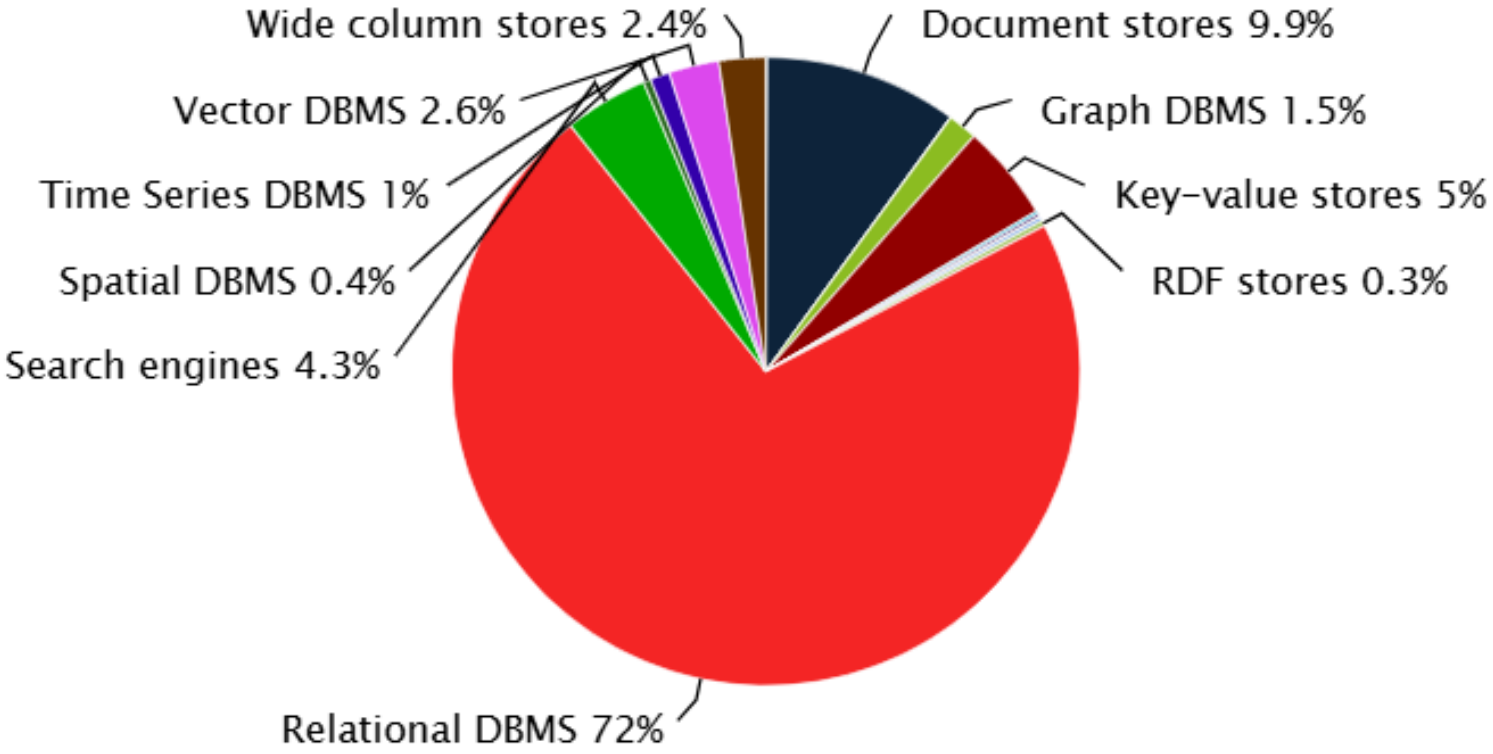
- Recall that "relational links" exist in Relational DBs



Relational databases

Relational databases domain the world data

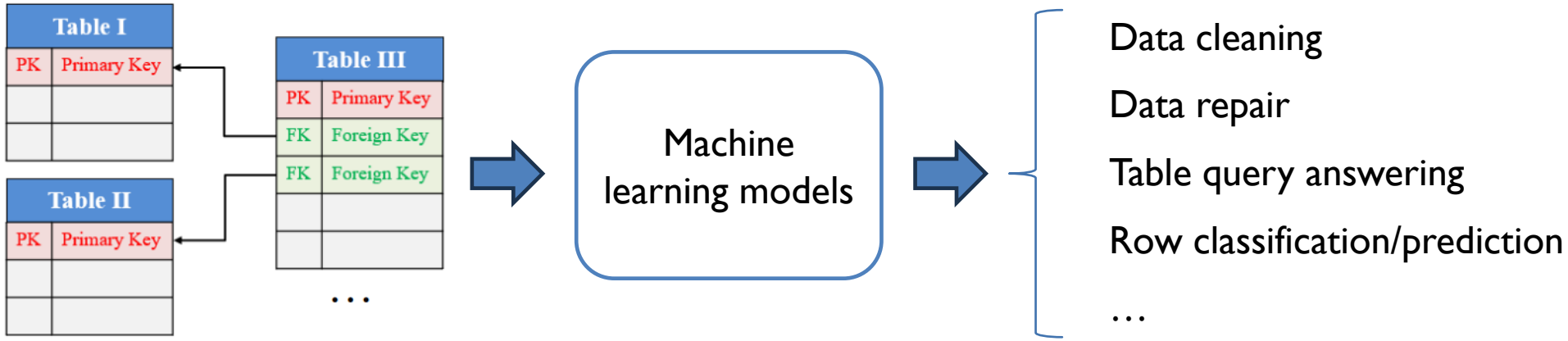
Ranking scores per category in percent, February 2025



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.



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*.

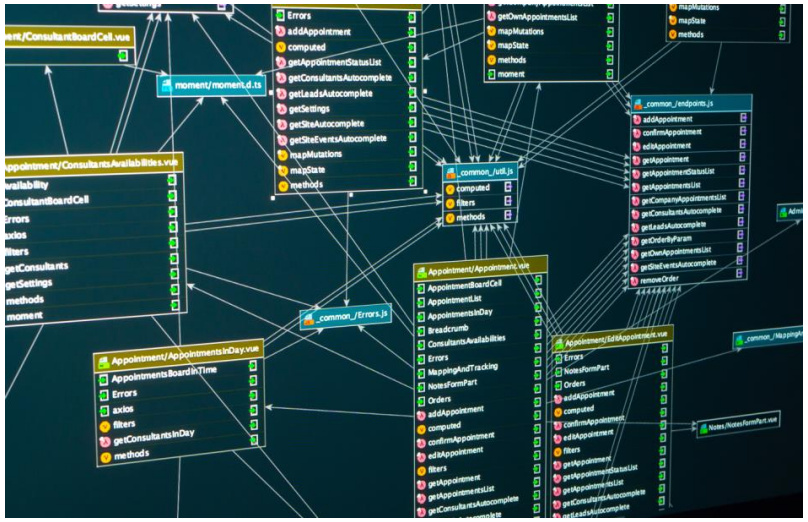
Key question

- 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

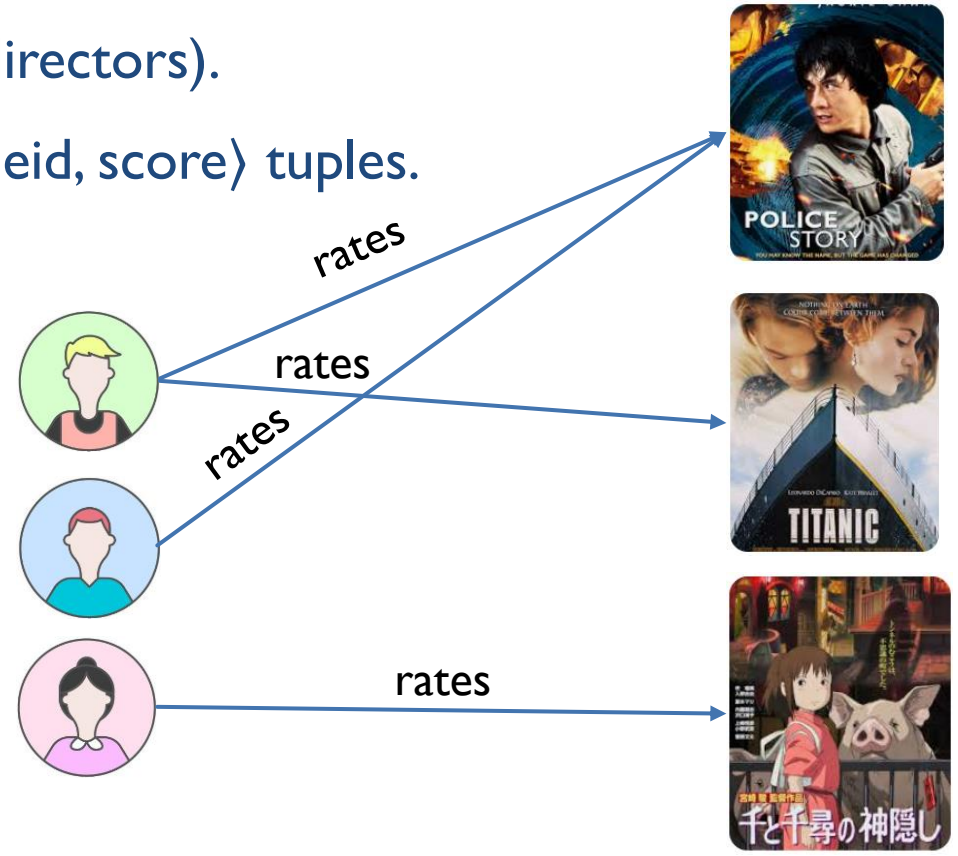
- A relational database is a graph
  - Nodes: rows in various tables
  - Links: relationships presented by primary and foreign keys



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.

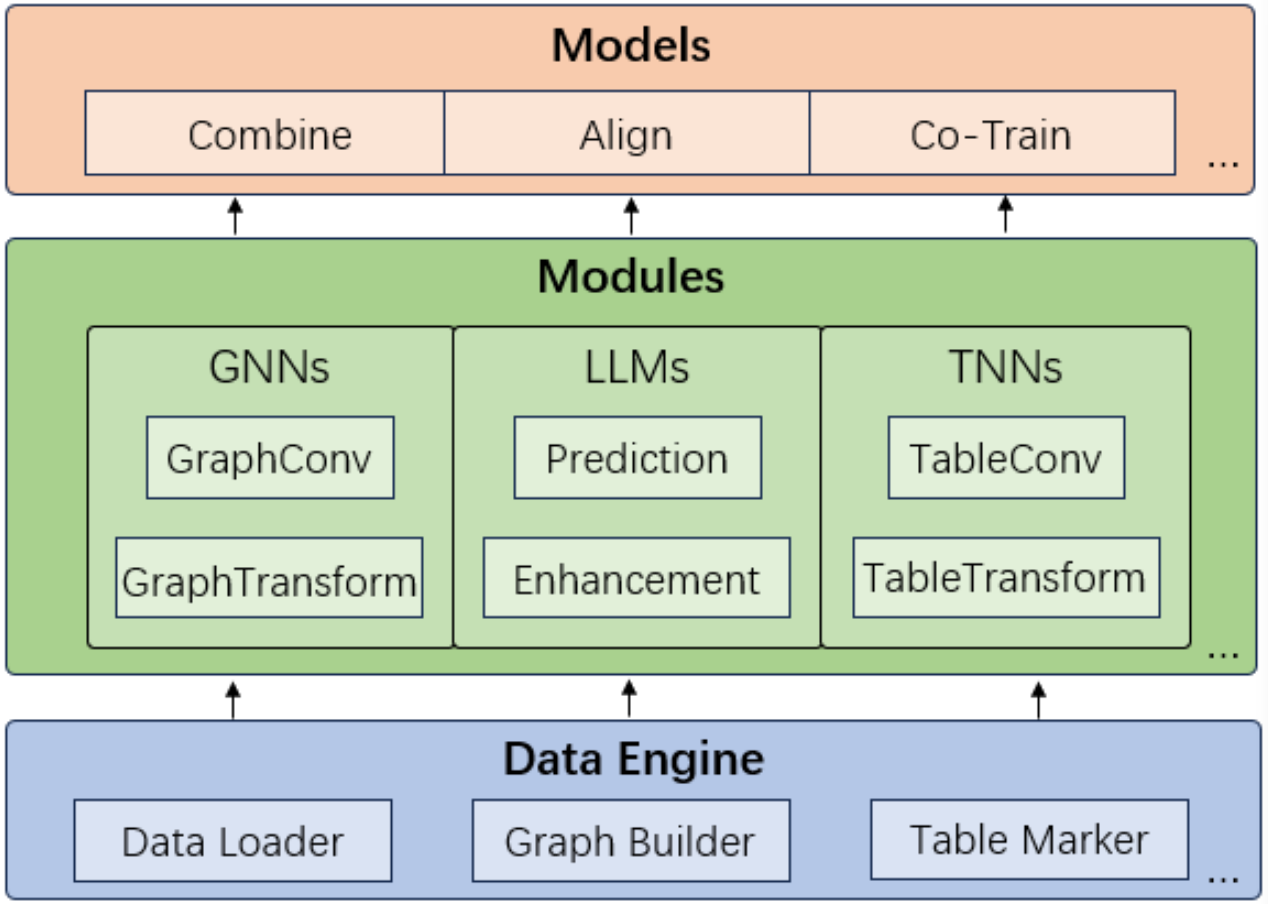
A PyTorch Library for Relational Table Learning with LLMs

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.

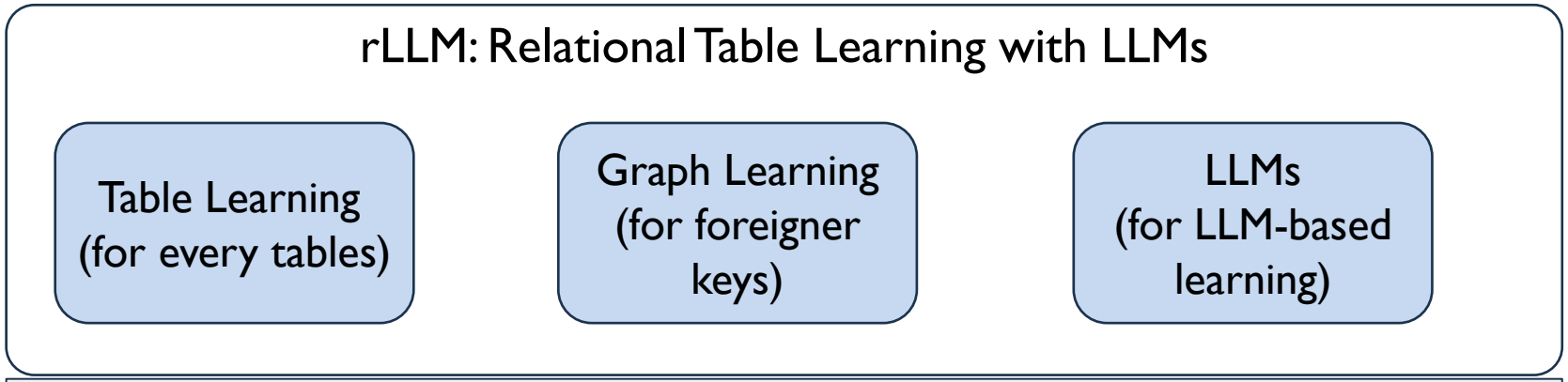
Overview of rLLM



The rLLM Overall Architecture

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

The Key of rLLM (relationLLM)



rLLM (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

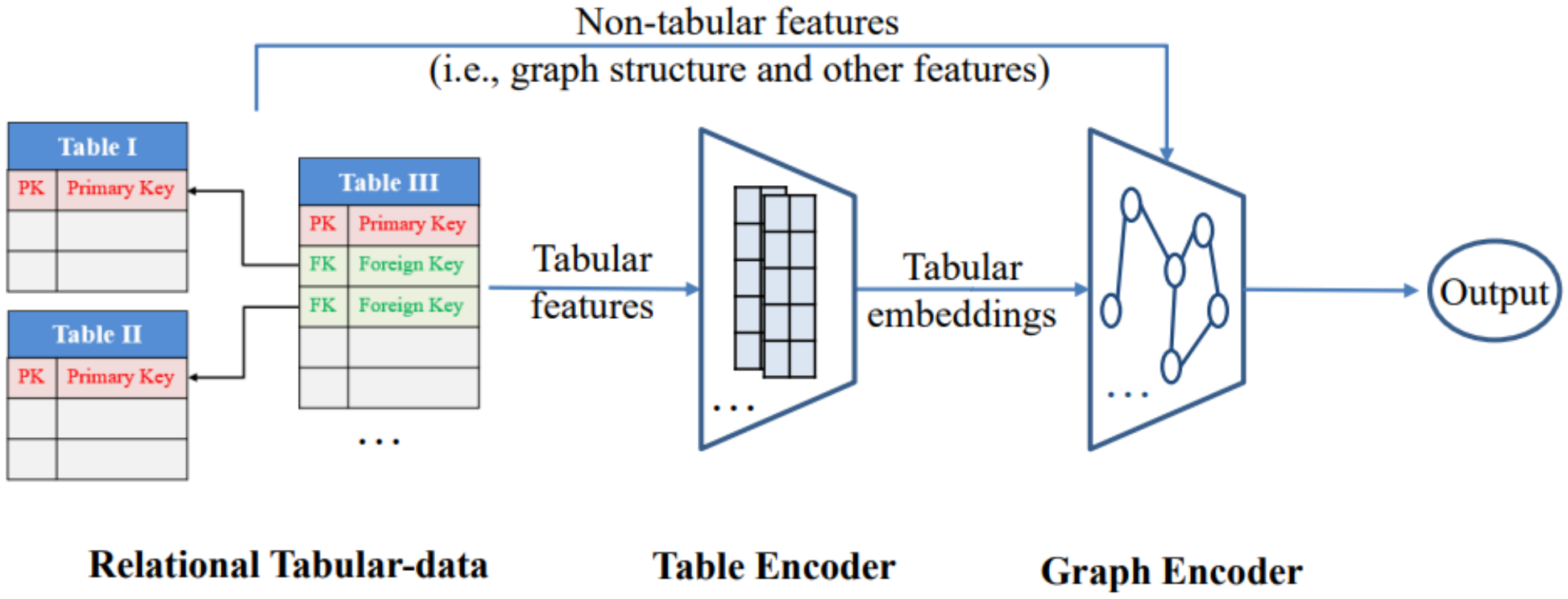


Figure 4: The architecture of BRIDGE

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

```python
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!

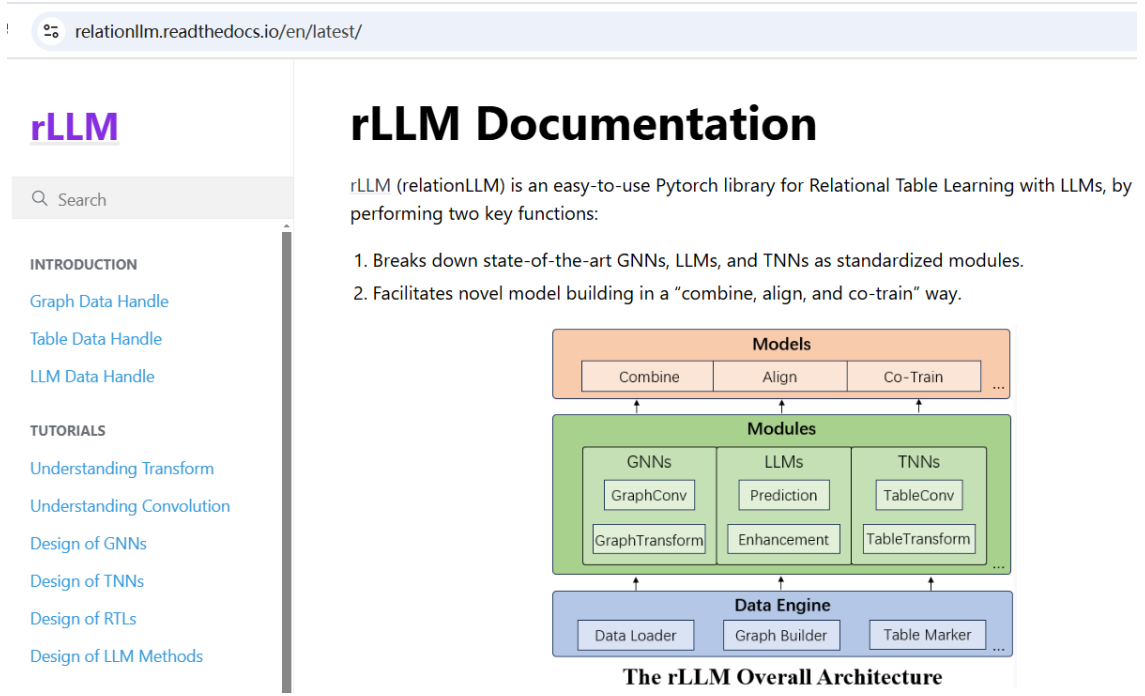
Table 2: Classification accuracy.

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
```

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



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- **Generalized RTL**
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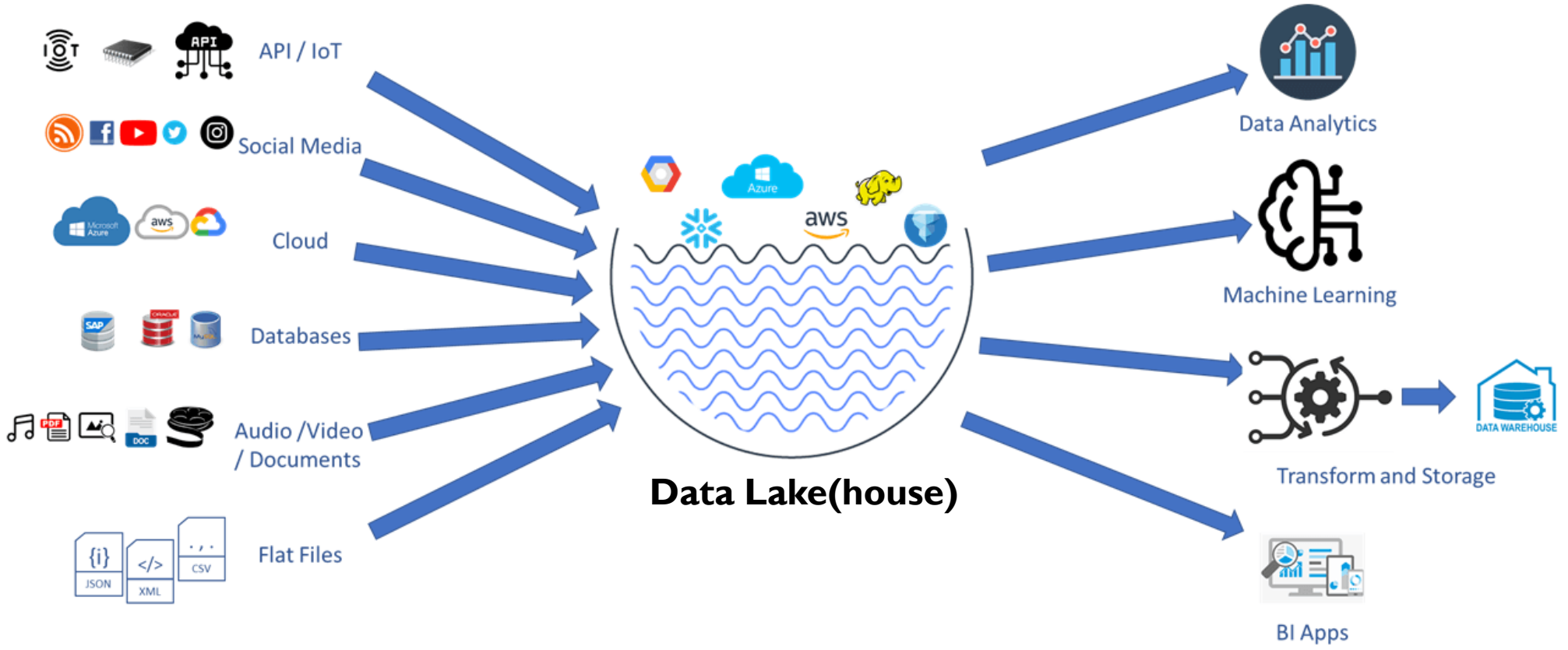
Data Lake(house): a central hub for machine learning

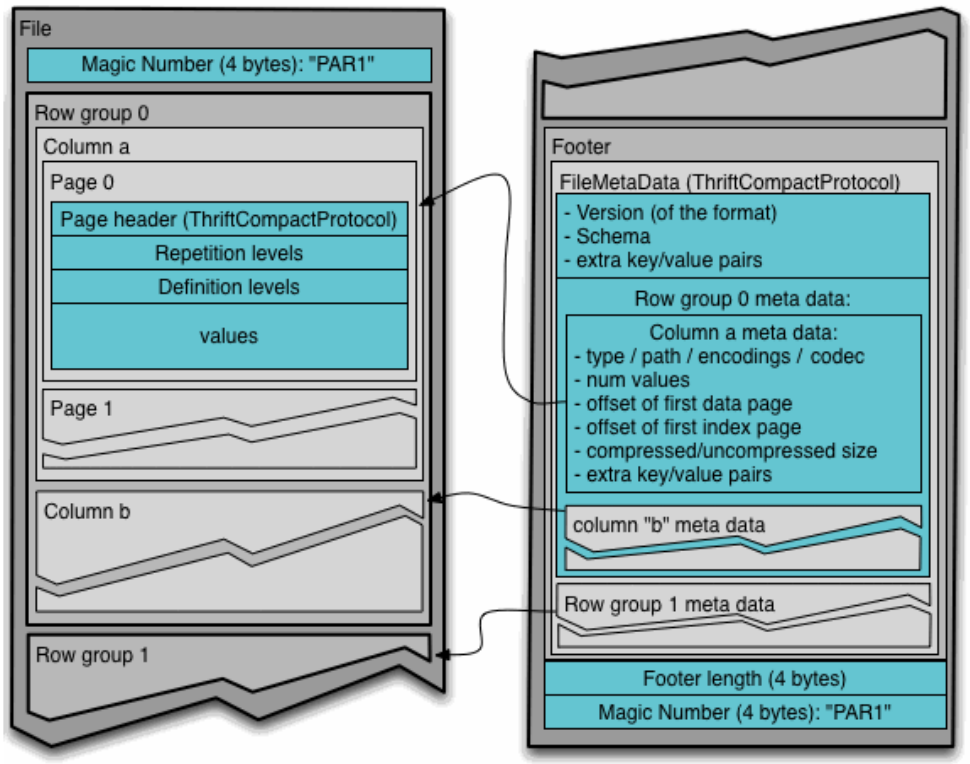


Question: how to conduct machine learning (maybe RTL) in Data Lake(house)?

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



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
  - …

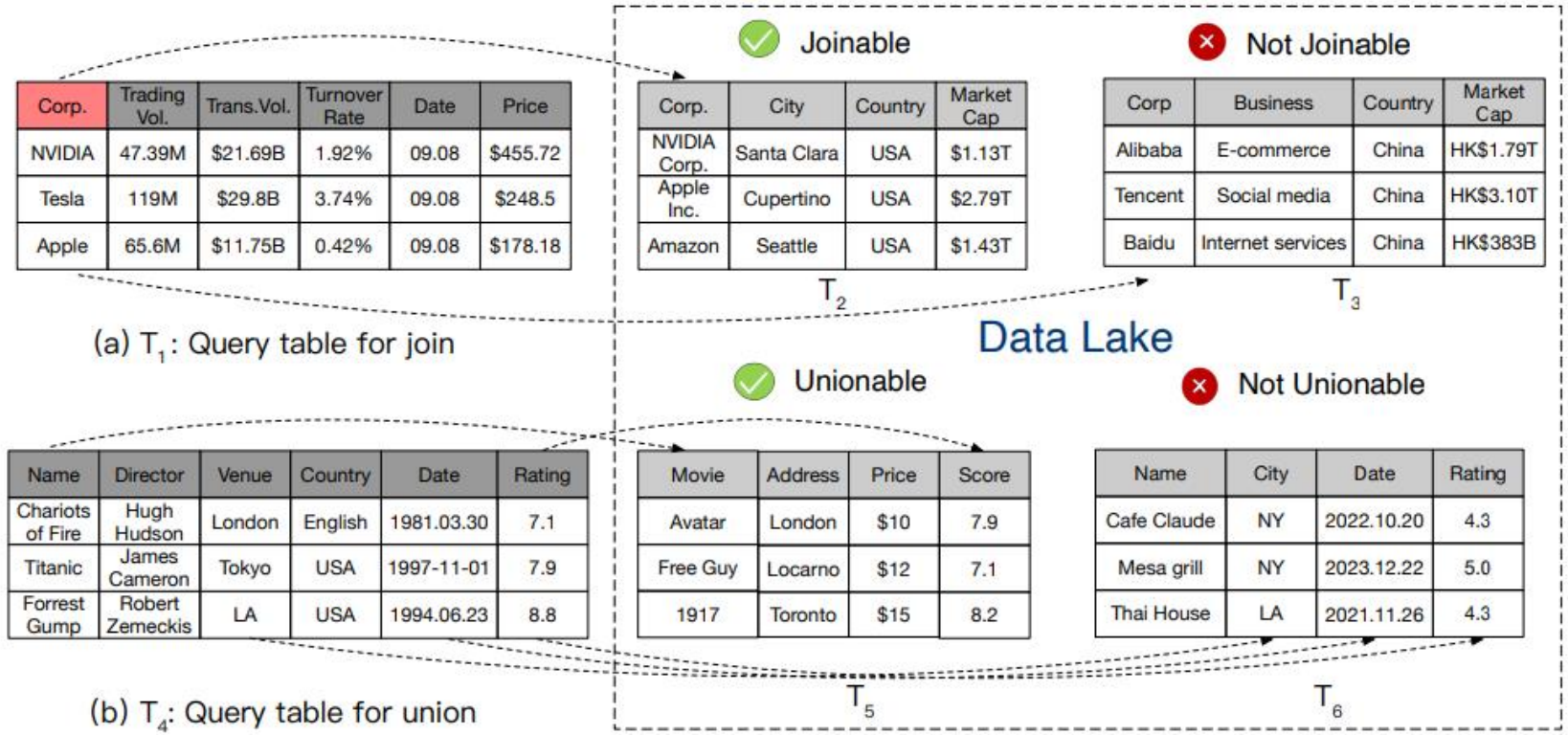
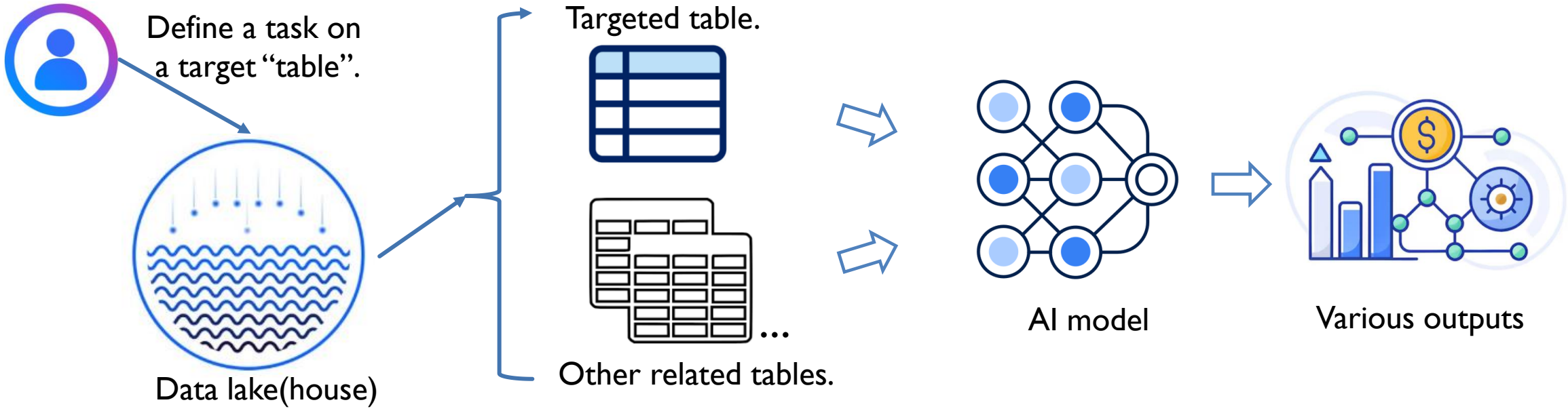


Table discovery in data lake(house)

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)
  - …

LakeMLB (Data Lake Machine Learning Benchmark)
Github: https://github.com/zhengwang100/LakeMLB

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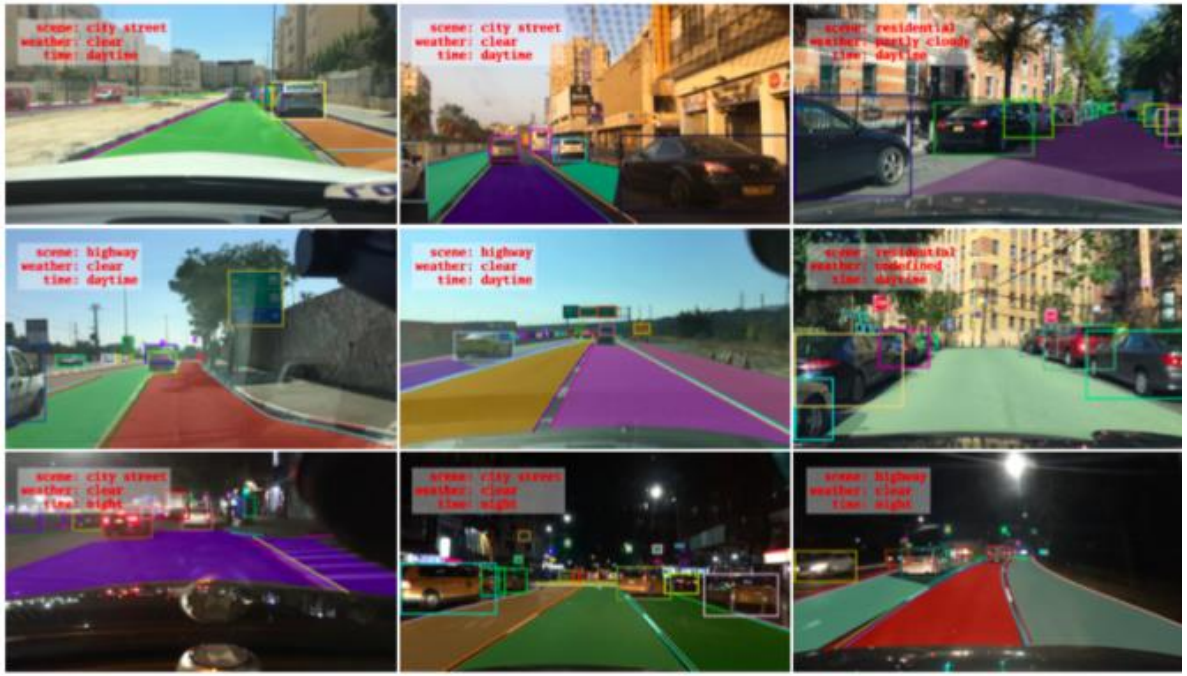
Applications of RTL methods: Self-driving car

- 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 like 3 Follow Unitree Robot

Modalities: Video

Dataset card | Viewer | Files and versions | Community

Dataset Preview API Embed Full Screen Viewer

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.