Entity-Resolved Knowledge Graphs: Taking your RAG to the Next Level with Dr. Clair Sullivan

282 views Jul 8, 2025

Building applications powered by large language models (LLMs) is a relatively straightforward task. Despite this, creating performant applications that meet high standards of accuracy and reliability can be tricky. One of the primary challenges faced by LLM applications is mitigating hallucinations. To address this issue, retrieval-augmented generation (RAG) has become a widely adopted approach, enhancing LLM performance by augmenting its knowledge with additional sources of information such as documents and other auxiliary data sets, which can be represented in one of several different formats. One of the most common formats is as a vector database. However, recent work has shown that the accuracy of the RAG can be significantly improved through representing the data in a graph format such as a knowledge graph (KG).

Despite their potential, many KG implementations fail to deliver optimal performance due to difficulties in resolving multiple entities from the source information into a single entity – a technique called entity resolution (ER). LLMs relying on RAG assume that the data they are accessing is in some way unique and so having different nodes for things like "My Company Inc." versus "My Company, Inc." can decrease accuracy. This appears to be a straight-forward case that could be resolved with basic string matching and regex, but as the data gets more complicated, this is no longer possible. For example, consider more complex variations such as "Liz Smith," "Elizabeth Conner-Smith," and "Dr. L. Conner-Smith," which would be very difficult to resolve with simple regex.

It is possible to use more sophisticated ER techniques that incorporate multiple disparate data sources to obtain more accurate entities. The end result is the creation of an entity-resolved knowledge graph (ERKG) whereby multiple duplicate entities such as those shown above are collapsed into a single entity while maintaining all information on that entity. In this way ERKGs enhance both basic graph queries and LLM-driven applications by consolidating and clarifying relationships within the data. This talk will showcase the transformative impact of ER on KGs, using real-world data to highlight improvements in both graph data science tasks and LLM accuracy. Attendees will gain practical insights into implementing ERKGs, demonstrating the significant advantages of applying ER to KGs in RAG systems.

Entity-Resolved Knowledge Graphs: Taking your Retrieval-Augmented Generation to the Next Level

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github.com/cj2001/ odsc_east_2025

Outline

- Terminology: graphs and knowledge and entities, oh my!
- Why is entity resolution (ER) hard
- How to NOT do ER
- Why does ER matter for RAG?
- A worked example
- Conclusion

Some definitions

- Graph
- Knowledge graph (KG)
- Entity resolution (ER)
- Entity-resolved knowledge graph (ERKG)

What is an entity?

- Distinct thing
  - Person
  - Place
  - Organization
  - Object
- Think of them like rows in a table
- Defined by a combination of distinguishing characteristics
  - Some characteristics are more distinguishing than others!

Considering the following scenarios...

Five different people, each with a single transaction

A single person with five different transactions

Why does it matter?

- Counting records is the most basic task of a data scientist
- If you can't count, you can't predict
- If you can't count, you can't quantify
- Enables things like:
  - Good news / bad news
  - Red light / green light
  - To market to them or not
  - Benign / threat

Hot take: regex is not the answer

Names are complicated

Johnathan Edward Smith	Jonathan Edward Smith	Jonathon Edward Smith	Jonothan Edward Smith	Jonatan Edward Smith	John Edward Smith	Jon Edward Smith	Johnny Edward Smith
Jonny Edward Smith	Jack Edward Smith	Jono Edward Smith	Nate Edward Smith	Johnathan Ed Smith	Jonathan Ed Smith	Jonathon Ed Smith	Johnathan Eddie Smith
Jonathan Eddie Smith	Jon Eddie Smith	Johnathan Ted Smith	Johnny Ted Smith	Johnathan Teddy Smith	Johnathan Ned Smith	Johnathan E. Smith	Jonathan E. Smith
Jonathon E. Smith	Jon E. Smith	John E. Smith	Jack E. Smith	Jono E. Smith	Johnny E. Smith	J. Edward Smith	J. E. Smith
J.E. Smith	J. Smith	Jon Smith	John Smith	Johnny Smith	Jack Smith	Jono Smith	Eddie Smith
Ted Smith	Teddy Smith	Ned Smith	Nate Smith	Johnathan Edward Smithe	Jonathan Edward Smithe	Jonathon Edward Smithe	Jon E. Smithe
Johnny E. Smithe	Johnathan E. Smyth	Jonathan E. Smyth	Jon Smyth	Johnny Smyth	John Smyth	Jack Smyth	Jono Smyth
J. Edward Smyth	J. E. Smyth	J.E. Smyth	Johnathan Edward Smythe	Jonathan Edward Smythe	Jonathon E. Smythe	Jon Smythe	John Smythe
Johnny Smythe	J. E. Smythe	Ted Smythe	Eddie Smythe	Nate Smythe			

Addresses are complicated

123 Main, Apt 1A, Las Vegas, NV, 89111	123 Main, #1A, Las Vegas, Nevada, 89111	123 Main St, Apt 1A, Las Vegas, NV, 89111	123 Main St, #1A, Las Vegas, Nevada, 89111	123 Main St., Apt 1A, Las Vegas, NV, 89111	123 Main St., #1A, Las Vegas, Nevada, 89111	123 Main Street, Apt 1A, Las Vegas, NV, 89111	123 Main Street, #1A, Las Vegas, Nevada, 89111
123 Main, Apt 1A, Las Vegas, Nevada, 89111	123 Main, Apartment 1A, Las Vegas, NV, 89111	123 Main St, Apt 1A, Las Vegas, Nevada, 89111	123 Main St, Apartment 1A, Las Vegas, NV, 89111	123 Main St., Apt 1A, Las Vegas, Nevada, 89111	123 Main St., Apartment 1A, Las Vegas, NV, 89111	123 Main Street, Apt 1A, Las Vegas, Nevada, 89111	123 Main Street, Apartment 1A, Las Vegas, NV, 89111
123 Main, Apt. 1A, Las Vegas, NV, 89111	123 Main, Apartment 1A, Las Vegas, Nevada, 89111	123 Main St, Apt. 1A, Las Vegas, NV, 89111	123 Main St, Apartment 1A, Las Vegas, Nevada, 89111	123 Main St., Apt. 1A, Las Vegas, NV, 89111	123 Main St., Apartment 1A, Las Vegas, Nevada, 89111	123 Main Street, Apt. 1A, Las Vegas, NV, 89111	123 Main Street, Apartment 1A, Las Vegas, Nevada, 89111
123 Main, Apt. 1A, Las Vegas, Nevada, 89111	123 Main, Unit 1A, Las Vegas, NV, 89111	123 Main St, Apt. 1A, Las Vegas, Nevada, 89111	123 Main St, Unit 1A, Las Vegas, NV, 89111	123 Main St., Apt. 1A, Las Vegas, Nevada, 89111	123 Main St., Unit 1A, Las Vegas, NV, 89111	123 Main Street, Apt. 1A, Las Vegas, Nevada, 89111	123 Main Street, Unit 1A, Las Vegas, NV, 89111
123 Main, #1A, Las Vegas, NV, 89111	123 Main, Unit 1A, Las Vegas, Nevada, 89111	123 Main St, #1A, Las Vegas, NV, 89111	123 Main St, Unit 1A, Las Vegas, Nevada, 89111	123 Main St., #1A, Las Vegas, NV, 89111	123 Main St., Unit 1A, Las Vegas, Nevada, 89111	123 Main Street, #1A, Las Vegas, NV, 89111	123 Main Street, Unit 1A, Las Vegas, Nevada, 89111
123 Main, #1A, Las Vegas, Nevada, 89111	123 Main St, Apt 1A, Las Vegas, NV, 89111	123 Main St, #1A, Las Vegas, Nevada, 89111	123 Main St., Apt 1A, Las Vegas, NV, 89111	123 Main St., #1A, Las Vegas, Nevada, 89111	123 Main Street, Apt 1A, Las Vegas, NV, 89111	123 Main Street, #1A, Las Vegas, Nevada, 89111	123 Main Street, Apartment 1A, Las Vegas, Nevada, 89111
123 Main, Apartment 1A, Las Vegas, NV, 89111	123 Main St, Apt 1A, Las Vegas, Nevada, 89111	123 Main St, Apartment 1A, Las Vegas, NV, 89111	123 Main St., Apt 1A, Las Vegas, Nevada, 89111	123 Main St., Apartment 1A, Las Vegas, NV, 89111	123 Main Street, Apt 1A, Las Vegas, Nevada, 89111	123 Main Street, Apartment 1A, Las Vegas, NV, 89111	
123 Main, Apartment 1A, Las Vegas, Nevada, 89111	123 Main St, Apt. 1A, Las Vegas, NV, 89111	123 Main St, Apartment 1A, Las Vegas, Nevada, 89111	123 Main St., Apt. 1A, Las Vegas, NV, 89111	123 Main St., Apartment 1A, Las Vegas, Nevada, 89111	123 Main Street, Apt. 1A, Las Vegas, NV, 89111		

Different character sets

جوناثان إدوارد سميث

123 Aشارع مين، شقة 1

لاس فيغاس، نيفادا 89111

Cultural variations

Argentina: Piedras 623, Piso 2, depto 4, C1070AAM, Capital Federal

Belgium: Rue du Vivier 7C bte 5, 1000 Bruxelles, BELGIQUE

India: e-506 street number 78, uttam viharblock d, uttam nagar, bindapur, 110059, new delhi

New Zealand: 43 Vogel Street, Roslyn, Palmerston North 4414

Ukraine: vul. Shevchenka, bud. 17, m. Bila Tserkva, Kyivs'ka obl., 09117, UKRAINE

Your RAG is only as good as your ER!

Date of Birth: 9-22-61
Address: 123 Main St, Las Vegas, NV 89111
Phone: 555-654-1234
Email: j.smith@domain.com

Johnathan Smith

Date of Birth: 16.3.85
Address: 456 1st St, Las Vegas, NV 89111
Phone: 555-123-4567
Email: john.smith123@outlook.com

Jack Smith

Date of Birth: 16-Mar-1985
Address: 123 Main St #2B, Las Vegas, NV 89111
Phone: 555-654-1234
Email: j.smith@domain.com

John Smith

Date of Birth: Sept. 22, 1961
Address:
Phone:
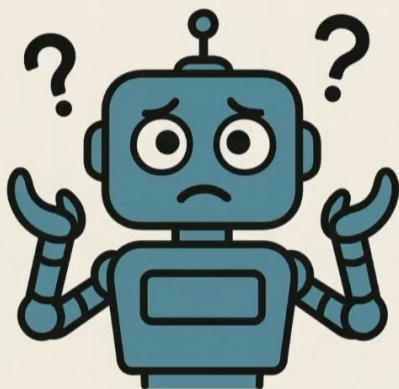Email: smith.john@gmail.com
ID#: 987654321

Dr. J. Smith
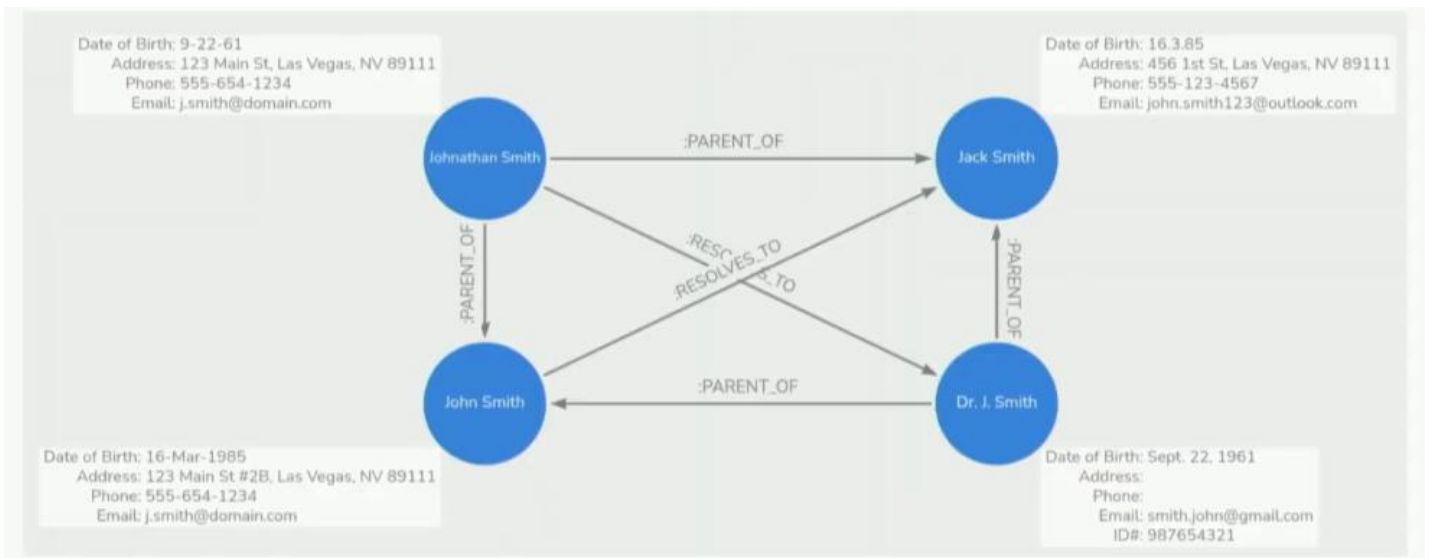
"Tell me about Johnathan Smith"

Date of Birth: 16-Mar-1985
Address: 123 Main St #2B, Las Vegas, NV 89111

Address:
Phone:

Date of Birth: 9-22-61
Address: 123 Main St, Las Vegas, NV 89111
Phone: 555-654-1234
Email: j.smith@domain.com

Johnathan Smith

:PARENT_OF

Jack Smith

Date of Birth: 16.3.85
Address: 456 1st St, Las Vegas, NV 89111
Phone: 555-123-4567
Email: john.smith123@outlook.com

:PARENT_OF

:RESC...TO
:RESOLVES_TO
...TO

:PARENT_OF

John Smith

:PARENT_OF

Dr. J. Smith

Date of Birth: 16-Mar-1985
Address: 123 Main St #2B, Las Vegas, NV 89111
Phone: 555-654-1234
Email: j.smith@domain.com

Date of Birth: Sept. 22, 1961
Address:
Phone:
Email: smith.john@gmail.com
ID#: 987654321

Example

- Three publicly-available data sets
  - SafeGraph (SG)
  - US Department of Labor Wage and Hour Compliance Action Data (DOL)
  - US Small Business Administration PPP Loans over $150K (PPP)
- Senzing (https://github.com/senzing) ER Python package
  - Commercial-grade ER on multiple languages without the need for training/tuning
- LangChain
- Approach: RAG one of two ways
  - SQL tables
  - Run data through Senzing, ingest as an ERKG in Neo4j

SafeGraph

{'BRANDS': '[{ "safegraph_brand_id": '
'"SG_BRAND_f372f9969f6e1ae119a13ff4fc78fd2d", '
'"safegraph_brand_name": "Pieology Pizzeria" }]',
'BUSINESS_ADDR_COUNTRY': 'US',
'BUSINESS_ADDR_FULL': '10965 Lavender Hill Dr Ste 130 Las Vegas NV
89135-2951',
'BUSINESS_GEO_LATITUDE': '36.144906',
'BUSINESS_GEO_LONGITUDE': '-115.332644',
'CATEGORY_TAGS': '["Counter Service", "Dinner", "Fast Food", "Lunch",
"Pizza"]',
'CLOSED_ON': 'Not Provided',
'DATA_SOURCE': 'SAFEGRAPH',
'IS_INTERSECTION': 'Not Provided',
'LOCATION_NAME_ORG': 'Pieology Pizzeria',
'MAILING_VERIFIED_STATUS': 'VERIFIED_DELIVERY_POINT',
'NAICS_CODE': '722513',
'OPENED_ON': 'Not Provided',
'PHONE_NUMBER': '+17023314454',
'PLACEKEY': '226-222@5yv-hmm-whq',
'RECORD_ID': '226-222@5yv-hmm-whq',
'RECORD_TYPE': 'ORGANIZATION',
'REL_ANCHOR_DOMAIN': 'PLACEKEY',
'REL_ANCHOR_KEY': '226-222@5yv-hmm-whq',
'REL_POINTER_DOMAIN': 'PLACEKEY',
'REL_POINTER_KEY': 'zzw-223@5yv-hkm-rc5',
'REL_POINTER_ROLE': 'PARENT',
'SUB_CATEGORY': 'Limited-Service Restaurants',
'TOP_CATEGORY': 'Restaurants and Other Eating Places',
'TRACKING_CLOSED_SINCE': '2019-07-01',
'name': 'Pieology Pizzeria',
'uid': 'SAFEGRAPH.226-222@5yv-hmm-whq'}

DoL

{'BUSINESS_ADDR_CITY': 'Las Vegas',
'BUSINESS_ADDR_LINE1': '9611 Trail Wood Drive',
'BUSINESS_ADDR_POSTAL_CODE': 89134,
'BUSINESS_ADDR_STATE': 'NV',
'BUSINESS_NAME_ORG': "Fabulous Freddy's (Trailwood)",
'DATA_SOURCE': 'DoL_WHISARD',
'LEGAL_NAME_ORG': 'Fabulous LLC',
'RECORD_ID': 53,
'RECORD_TYPE': 'ORGANIZATION',
'address': '9611 Trail Wood Drive Las Vegas NV 89134',
'case_id': 1658108,
'case_violtn_cnt': 0,
'naic_cd': 811192,
'naics_code_description': 'Car Washes',
'name': "Fabulous Freddy's (Trailwood)",
'uid': 'DOL_WHISARD.53'}

PPP

{'BUSINESS_ADDR_CITY': 'PHOENIX',
'BUSINESS_ADDR_LINE1': '5110 N 40TH ST STE 107',
'BUSINESS_ADDR_POSTAL_CODE': 85018,
'BUSINESS_ADDR_STATE': 'AZ',
'BUSINESS_NAME_ORG': 'INFINITY HOSPICE CARE OF LAS
VEGAS, LLC',
'Business_Type': 'Limited Liability Company(LLC)',
'CD': 'AZ-09',
'DATA_SOURCE': 'PPP_LOANS',
'DateApproved': '05/01/2020',
'JobsReported': 137,
'Lender': 'JPMorgan Chase Bank, National Association',
'Loan_Range': 'c $1-2 million',
'NAICS_Code': 623110,
'NonProfit': '',
'OwnedBy': 'Male Owned',
'OwnedByRaceEthnicity': 'Unanswered',
'OwnedByVeteran': 'Unanswered',
'RECORD_ID': 7017,
'RECORD_TYPE': 'ORGANIZATION',
'address': '5110 N 40TH ST STE 107 PHOENIX AZ 85018',
'name': 'INFINITY HOSPICE CARE OF LAS VEGAS, LLC',
'uid': 'PPP_LOANS.7017'}

The SQL approach without ER

```
sql_agent_executor.invoke('find all references
to Union Cabs in all of the tables')

>>
> Finished chain.
{'input': 'find all references to Union Cabs
in all of the tables',
 'output': 'The only reference to "Union Cabs"
found in the database is in the `sg` table
under the `LOCATION_NAME_ORG` column.\n\nHere
is the result:\n- `sg` table: `Union
Cabs`\n\nNo references were found in the `dol`
or `ppp` tables.'}
```

```
sql_agent_executor.invoke('does Union Cabs have
any violations?')

>>
> Finished chain.
{'input': 'does Union Cabs have any
violations?',
 'output': 'It appears that Union Cabs does not
have any violations recorded in the database.'}
```

The ERKG approach


```
(g2) search Desert Springs Landscaping

Searching ...


Search Results
```

Index	Entity ID	Entity Name	Data Sources	Match Key	Match Score	Relationships
1	12093	DESERT SPRINGS LANDSCAPING LLC	SAFEGRAPH: 224-226@5yv-jbb-jvz PPP_LOANS: 8321	NAME Principle 206: CNAME	99	6 (derived)

```
(g2) get 12093

Entity summary for entity 12093: DESERT SPRINGS LANDSCAPING LLC
```

Record ID	Entity Data	Additional Data
PPP_LOANS 8321	BUSINESS: DESERT SPRINGS LANDSCAPING LLC RECORD TYPE: ORGANIZATION BUSINESS: 8130 S VALLEY VIEW BLVD LAS VEGAS NV 89139	BUSINESS TYPE: Limited Liability Company(LLC) CD: NV-03 DATEAPPROVED: 04/08/2020 JOBSREPORTED: 40 LENDER: Meadows Bank LOAN RANGE: d $350,000-1 million NAICS CODE: 561730 OWNEDBY: Unanswered OWNEDBYRACEETHNICITY: Unanswered OWNEDBYVETERAN: Unanswered
SAFEGRAPH 224-226@5yv-jbb-jvz	LOCATION: Desert Springs Landscaping RECORD TYPE: ORGANIZATION PLACEKEY: 224-226@5yv-jbb-jvz BUSINESS: 36.042112 -115.189595 BUSINESS: 8130 S Valley View Blvd Las Vegas NV 89139-7892 US PHONE: +17024368080	BRANDS: [] CATEGORY TAGS: ["Landscaping", "Pool Cleaner", "Pool Service"] MAILING VERIFIED STATUS: VERIFIED_DELIVERY_POINT NAICS CODE: 5617 TOP CATEGORY: Services to Buildings and Dwellings TRACKING_CLOSED_SINCE: 2019-07-01

```
└─ Possible relationships (6)
   ├─ ADDRESS (4)
   │   ├─ 49974 SAFEGRAPH (1) | PPP_LOANS (1) DESERT SPRINGS POOLS AND SPAS INC
   │   ├─ 71900 SAFEGRAPH (1) Build Your Own Pool
   │   ├─ 200936 PPP_LOANS (1) HARSHMAN EXCAVATING CORP
   │   └─ 202069 PPP_LOANS (1) DESERT SPRINGS RENOVATIONS LLC
   ├─ ADDRESS+GEO_LOC (1)
   │   └─ 49150 SAFEGRAPH (1) Oasis Springs Builders
   └─ ADDRESS+GEO_LOC+PHONE (1)
       └─ 67084 SAFEGRAPH (1) Desert Springs Group
```



```
(g2) get 49974

Entity summary for entity 49974: DESERT SPRINGS POOLS AND SPAS INC
```
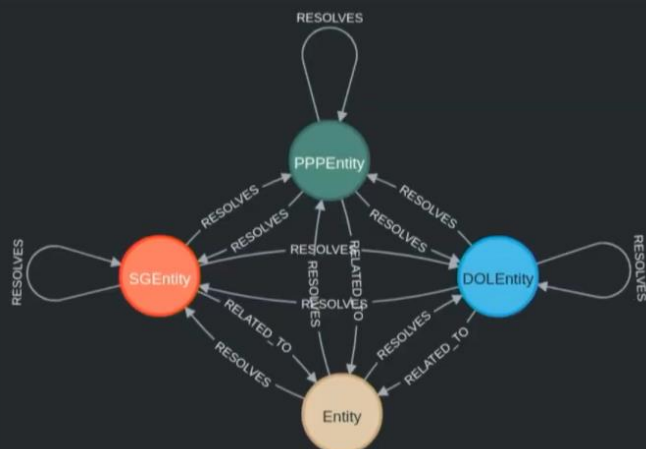
Record ID	Entity Data	Additional Data
PPP_LOANS 8323	BUSINESS: DESERT SPRINGS POOLS AND SPAS, INC RECORD TYPE: ORGANIZATION BUSINESS: 8130 S. Valley View Blvd. LAS VEGAS NV 89139	BUSINESS TYPE: Subchapter S Corporation CD: NV-03 DATEAPPROVED: 04/15/2020 JOBSREPORTED: 36 LENDER: Zions Bank, A Division of LOAN RANGE: d $350,000-1 million NAICS CODE: 238990 OWNEDBY: Unanswered OWNEDBYRACEETHNICITY: Unanswered OWNEDBYVETERAN: Unanswered
SAFEGRAPH 224-224@5yv-jbb-jvz	LOCATION: Desert Springs Pools & Spas RECORD TYPE: ORGANIZATION PLACEKEY: 224-224@5yv-jbb-jvz BUSINESS: 8130 S Valley View Blvd Las Vegas NV 89139-7892 US BUSINESS: 36.041785 -115.190721 PHONE: +17024525900	BRANDS: [] CATEGORY TAGS: ["Patio Coverings", "Pool Service"] MAILING VERIFIED STATUS: VERIFIED_DELIVERY_POINT NAICS CODE: 2389 TOP CATEGORY: Other Specialty Trade Contractors TRACKING_CLOSED_SINCE: 2019-07-01

```
├─ Possible relationships (7)
│   ├─ ADDRESS (6)
│   │   ├─ 12093 SAFEGRAPH (1) | PPP_LOANS (1) DESERT SPRINGS LANDSCAPING LLC
│   │   ├─ 49150 SAFEGRAPH (1) Oasis Springs Builders
│   │   ├─ 67084 SAFEGRAPH (1) Desert Springs Group
│   │   ├─ 71900 SAFEGRAPH (1) Build Your Own Pool
│   │   ├─ 200936 PPP_LOANS (1) HARSHMAN EXCAVATING CORP
│   │   └─ 202069 PPP_LOANS (1) DESERT SPRINGS RENOVATIONS LLC
│   └─ GEO_LOC (1)
│       └─ 37912 SAFEGRAPH (1) Discount Tire
└─ Disclosed relationships (1)
    └─ PARENT (1)
        └─ 65977 SAFEGRAPH (1) Blue Diamond Crossing
```

```
response = chain.invoke({"query": "Tell me about Union Cab
Co"})
...


>>
> Finished chain.
{'query': 'Tell me about Union Cab Co',
 'result': 'Union Cab Co, also known as ABC Union Cab Co, was
located at 5010 S Valley View Blvd,  Las Vegas, NV 89118-1705.
It operated in the Taxi Service industry, specifically under
the NAICS code 485310. The company was categorized under "Taxi
and Limousine Service"
and had tags such as "Airport Shuttles" and "Taxis." Union Cab
Co had a verified mailing  status and was tracked as closed
since July 1, 2019, with its official closure on March 1,
2022. The company had one recorded case violation and was
related to other entities like Vegas Western Cab, Inc and A
NLV Cab Co.'}
```

```
response = chain.invoke({"query": "How many
violations have entities Union Cab Co is
related to been involved in?"})
...


> Finished chain.
{'query': 'How many violations have entities
Union Cab Co is related to been involved in?',
 'result': 'Entities related to Union Cab Co
have been involved in a total of 6
violations.'}
```

Conclusions

- ~~RAG is important~~
- ~~GraphRAG is important~~
- Doing ER properly is much more difficult than can be solved with regex, edit distance algorithms, clustering, etc.
- GraphRAG with ERKG is important-est!!!

Thank you!

clair@clairsullivan.com

https://github.com/cj2001/odsc_east_2025