Faculty of Computer Science

Master Thesis

Querying Wikidata with GraphQL

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Declaration of originality

I hereby declare that I have written this Thesis on my own accord and any participation of others has been acknowledged. I have clearly marked all references to existing work. I have not submitted this work partly or as a whole anywhere else.

Dresden, XX.XX.XXXX

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(signature)

Acknowledgements

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Abstract

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Contents

1 Introduction

A knowledge graph is a collection of data in a graphical format. The data collected can be facts, rules or any other forms of knowledge that express some kind of relationships [1]. By knowledge, we refer to explicit knowledge, implying something that is known and can be written down [2]. For example, "Helium has the chemical formula He", is a statement that can be represented using a graph. There are many ways of modelling data as a graph. The most commonly used are directed edge-labelled graphs, heterogeneous graphs, property graphs and graph dataset [3]. We will see in section XYZ how we can use RDF to specify directed edge-labelled graphs.

Many companies such as Amazon, Facebook, Uber, Google, etc., use knowledge graphs for their applications. There can be open or enterprise knowledge graphs depending on the organization or community [3]. Open knowledge graphs include Wikidata, DBpedia, Freebase, YAGO, etc. These are available online and freely accessible to the public. Enterprise knowledge graphs are generally used internally within a company and have their commercial specific use-cases [3].

2 Preliminaries

2.1 RDF

The Resource Description Framework (RDF) is a framework used to represent information available in the Web [4]. In the context of graphs, RDF is used for describing and exchanging graphs. The graphs specified by RDF are directed edge-labelled graphs. This means that the edges connect to source and target nodes, and have labels. It can be the case that there are multiple edges between the same nodes but they must have different labels [1]. Figure 1 shows how knowledge about the chemical element Helium can be represented using directed edge-labelled graphs.

Now let us see how such a graph could be represented in a RDF graph. Before that, we must be familiar with some terms in the context of RDF, namely IRIs, literals and blank nodes. To identify resources on the Web uniquely we use Uniform Resource Identifiers (URIs). An URI is a sequence of a subset of ASCII characters that have a scheme, authority, path, and optional query and fragment [1]. An Internationalized Resource Identifier (IRI) is a generalized form of URI that helps to distinguish resources with Unicode. In RDF, an IRI is used as a name, or an equivalent of ID, for graph nodes [5]. Andy Seaborne has a good article that explains URIs and IRIs in detail [6].

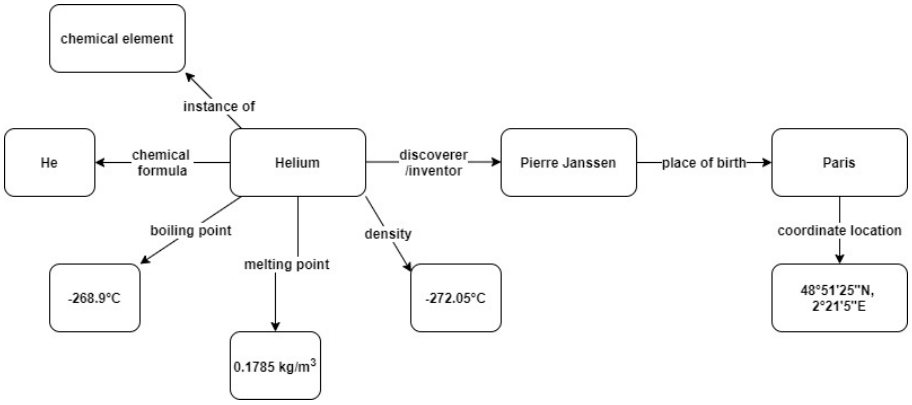

Figure 1: Directed edge-labelled graph describing Helium

RDF literals are used to represent resources that are values having datatypes such string, boolean, decimal, etc. RDF can support different datatypes, most of which are based on XML Schema - http://www.w3.org/2001/XMLSchema# (xsd) [1]. For example, the boiling point of Helium would be a RDF literal represented as -268.98sd:decimal. W3C has a good documentation on details about datatypes and XML Schema [4].

Lastly, let come to blank nodes. Unlike an IRI or a literal, a blank node does not identify some specific resource [4]. It is used as a placeholder for some node, i.e., it is used to say that something with the given relationship exits at the position without specifying what the node is.

An RDF graph is a set of triples consisting of the following parts: 1) a subject (node) that is an IRI or a blank node; 2) a predicate (edge) that is an IRI; 3) an object (node) that is an IRI, a blank node, or a literal [1]. Figure 2 shows what an RDF graph could look like taking our example represented in Figure 1. We have added a label predicate to identify Helium. Our main interest is in querying the knowledge graph Wikidata, and so all the data correspond to the resources in its knowledge base. Literals are drawn as rectangular nodes. Here wd is a prefix for http://www.wikidata.org/entity/ and wdt for http://www.wikidata.org/prop/direct/. In Wikidata items (nodes) and properties (predicates) are identified uniquely by an entity ID. Table 1 helps to understand the RDF graph in Figure 2 better.

From Table 1 we can see that wd:Q560 is an abbreviation for the IRI http://www.wikidata.org/entity/Q560, where Q560 is the entity ID for Helium. The IRI helps is to identify the resource Helium on Wikidata. The rest of the nodes and edges in Figure 2 can be understood analogously. We can also see that for labelling we use rdfs:label which is used to give a human-readable version of a resource's name [7] . Also, geo:wktLiteral (http://www.opengis.net/ont/geosparql#wjktLiteral) is a datatype for representing geographic coordinates.

So far, we have shown an abstract syntax of RDF. For exchanging graphs, we need to have

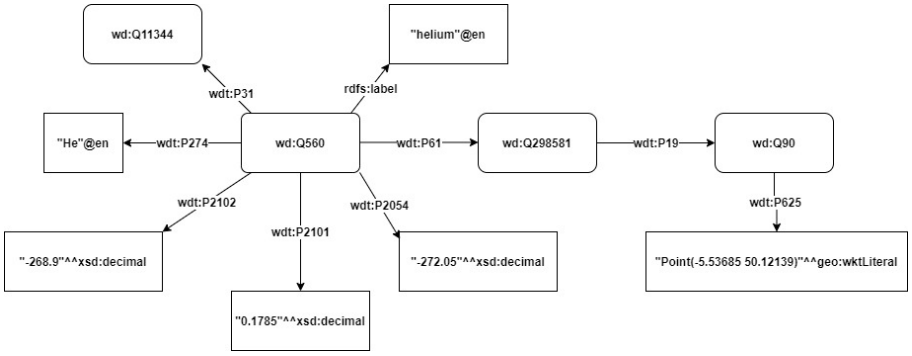

Figure 2: RDF graph describing Helium

a concrete syntactic representation to encode RDF graphs [1]. The most relevant formats are N-Triples, Turtle, JSON-LD, RDF/XML and RDFa. W3C has provided a comprehensive explanation for each format mentioned here, along with other formats [8]. The RDF graph in Figure 2 can be represented in N-Triples format as follows:

Table 1: Abbreviation/IDs and their meanings.

wd	http://www.wikidata.org/entity/
wdt	http://www.wikidata.org/prop/direct/
rdfs	http://www.w3.org/2000/01/rdf-schema#
Q560	Helium
Q298581	discoverer/inventor
Q90	Paris
P31	instance of
P274	chemical formula
P2102	boiling point
P2101	melting point
P2054	density
P61	discoverer/inventor
P19	place of birth
P625	coordinate location

```
<http://www.wikidata.org/entity/Q560> <http://www.wikidata.org/prop/direct/P31>
                                          <http://www.wikidata.org/entity/Q11344> .

<http://www.wikidata.org/entity/Q560> <http://www.w3.org/2000/01/rdf-schema#label>
                                                                    "helium"@en .

<http://www.wikidata.org/entity/Q560> <http://www.wikidata.org/prop/direct/P274>
                                                                        "He"@en .

<http://www.wikidata.org/entity/Q560>  <http://www.wikidata.org/prop/direct/P2102>
                                    "-268.9"^^<http://www.w3.org/2001/XMLSchema#decimal> .

<http://www.wikidata.org/entity/Q560> <http://www.wikidata.org/prop/direct/P2101>
                                    "0.1785"^^<http://www.w3.org/2001/XMLSchema#decimal> .

<http://www.wikidata.org/entity/Q560> <http://www.wikidata.org/prop/direct/P2054>
                                   "-272.05"^^<http://www.w3.org/2001/XMLSchema#decimal> .

<http://www.wikidata.org/entity/Q560> <http://www.wikidata.org/prop/direct/P61>
                                          <http://www.wikidata.org/entity/Q298581> .

<http://www.wikidata.org/entity/Q298581> <http://www.wikidata.org/prop/direct/P19>
                                              <http://www.wikidata.org/entity/Q90> .

<http://www.wikidata.org/entity/Q90> <http://www.wikidata.org/prop/direct/P625>
          "Point(-5.53685 50.12139"^^<http://www.opengis.net/ont/geosparql#wjktLiteral> .
```

2.2 SPARQL

SPARQL Protocol and RDF Query Language (SPARQL) is a query language for RDF. It is based on matching graph patterns [9]. There can be different types of queries such as SELECT, ASK, CONSTRUCT and DESCRIBE. We will be talking about SELECT queries in this report. W3C provides a comprehensive document on SPARQL [10]. SELECT queries consist of the following blocks:

- Prologue: for declaring PREFIX and BASE;
- Select clause: SELECT keyword followed by either a list of variables and variable assignments, or by *;
- Where clause: WHERE keyword followed by a pattern
- Solution set modifiers: such as OFFSET [1].

To get a list of all chemical elements that has a chemical formula, boiling point, melting point, density, an inventor or discoverer, birth place of that inventor or discoverer and the coordinate location of the birth place we can a write a SPARQL query as follows:

```
PREFIX wd: <http://www.wikidata.org/entity/>
PREFIX wdt: <http://www.wikidata.org/prop/direct/>
SELECT ?element ?element_formula ?boiling_point ?melting_point ?density ?discoverer ?
    place_birth ?place_coordinate
WHERE {
  ?element wdt:P31 wd:Q11344.
  ?element wdt:P274 ?element_formula.
  ?element wdt:P2102 ?boiling_point.
  ?element wdt:P2101 ?melting_point.
  ?element wdt:P2054 ?density.
  ?element wdt:P61 ?discoverer.
  ?discoverer wdt:P19 ?place_birth.
  ?place_birth wdt:P625 ?place_coordinate.
}
```

We can run this query in Wikidata's query service (insert footnote about not having to use Prefix for wd and wdt since wikidata recognizes the abbreviations). Among the results, there will be also our element Helium (Q560) that we have used as an example in Figure 1 and Figure 2.

2.3 Wikidata

Wikidata is a free and publicly available open knowledge base. Editable by anyone, it acts as a central storage for the structured data for a variety of Wiki projects like Wikipedia, Wiktionary, Wikisource, etc [11]. It is more commonly known as the knowledge graph of Wikidata. Wikidata contains different data types like text, images, dates, etc., that can be queried using SPARQL [12]. There is a wide range of applications for Wikidata. We previously mentioned that Wikidata functions as a database for Wikimedia community like Wikipedia. According to the lecture given by Krötzsch [1], it also has external uses in many large organizations like Eurowings, Google, Apple and Amazon for tasks such as data integration, authority control, identity providing and data-driven journalism. The lecture also mentions that in the field of research, Wikidata is used for collecting test data for knowledge graph related algorithms and training data for machine learning projects. The easiest and most popular way to query Wikidata is through the Wikidata Query Service (WDQS). This is Wikidata's SPARQL endpoint. We can use this service two ways. Firstly, we can write queries in SPARQL directly on the web user interface of the service (footnote https://query.wikidata.org/) and obtain the results in different formats like table, tree, graph, etc. Secondly, the service can also be used pragmatically by submitting GET or POST requests (footnote https://query.wikidata.org/sparql) [13]. Another popular way to query Wikidata is by using the Wikidata API (footnote https://www.wikidata.org/wiki/Special:ApiSandbox). However, this API should mainly be used when we want to edit the contents of Wikidata or get data about entities like revision history. Wikidata dumps is useful when we know our result set will be significantly large or if we want to set up our own local query service. These dumps are full exports of all the available en-

tities in Wikidata (footnote https://dumps.wikimedia.org/). To get started you should download the latest complete dump (footnote https://dumps.wikimedia.org/wikidatawiki/latest/). Wikidata also mentions some other ways to accessing Wikidata's data like Search and Linked Data Fragments endpoint, the complete list and usage of which can be found on Wikidata's Data Access webpage [13].

3 GraphQL

Stuff about GraphQL

3.1 GraphQL vs SPARQL

Stuff about GraphQL vs SPARQL

4 Literature Review

Stuff about GraphQL-LD and HypergraphQL and other tools do not have so many examples, and the ones that do are mainly for dbpedia.

5 GraphQL-LD

5.1 JSON-LD

Elaborate on concrete JSON-LD represetation

5.2 Using Graphql-LD with Wikidata

6 HypergraphQL

6.1 Schema

Elaborate on schema of HypergraphQL

6.2 Using HypergraphQL with Wikidata

7 GraphQL vs generated SPARQL queries

8 Differences between the generated SPARQL queries by both tools

9 Performance Evaluation

1. Evaluate performance of both approaches by writing SPARQL queries and equivalent GraphQL queries
2. Discuss in how far the generated Sparql queries differ from the handwritten ones.
3. analyze how well the approach scales with larger (deeper) GraphQL queries.

10 Effort for the setup

Evaluate/discuss the effort for the setup of both tools

11 Default context

12 Repository

13 Challenges faced and Conclusion

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