Parser-Combinators for Contex-Free Path Querying

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ABSTRACT

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CCS CONCEPTS

• **Information systems → Graph-based database models**; **Query languages for non-relational engines**; • **Software and its engineering** → *Functional languages*; • **Theory of computation** → *Grammars and context-free languages*;

KEYWORDS

Graph data bases, Language-constrained path problem, Context-Free path querying, Parser Combinators, Domain Specific Language, Generalized LL, GLL, Neo4J, Scala

ACM Reference Format:
Smolina, Ekaterina Verbitskaia, Ilya Kirillov, and Semyon Grigorev. 2018. Parser-Combinators for Contex-Free Path Querying. In *Proceedings of Joint International Workshop on Graph Data Management Experiences & Systems (GRADES) and Network Data Analytics (NDA) 2018 (GRADES-NDA'18)*. ACM, New York, NY, USA, Article 4, 4 pages. https://doi.org/10.475/123_4

GRADES-NDA'18, June 2018, Houston, Texas USA

ACM ISBN 123-4567-24-567/08/06…$15.00
https://doi.org/10.475/123_4

1 INTRODUCTION

Data-centric applications, data access, languages integration for graph-structured data (or graph DB) access.

Navigation queries. Path querying and context-free path querying. Same generation query is not a regular. Static code analysis.

Integration with general purpose programming languages is a problem. String-embedded DSLs. Special DSL vs Combinators (LINQ [4, 11], etc) [9]

We propose !!! and we make the following contributions in this paper.

(1) Combinators for CF path querying with structural representation of result. Transparent integration of query language into general-purpose programming language.
(2) Implementation in Scala. Generalization of linear parsing. Integration with Neo4J graph data base. Available on gitHub:https://github.com/YaccConstructor/Meerkat
(3) Evaluation on realistic data, which shows that it is applicable. Comparison with other tools for CF path querying.

2 RELATED WORK

Some different formulation of the similar problems: Language-constrained path querying and language reachability. Language-constrained path querying, Yannakakis [18]. Hellings [6, 7], RDF [19], etc [2, 3, 12, 15, 17]

Special graph query languages. SPARQL, cypher

Languge integration problem: special DSLs for SQL, ORM, Linq. Transperent integration inpo gp programming language: static correctness, typing.

Parser-combinators is one of classical approach for parsing!!!.

Scala combinators for graph [9] — one of attempt to adopt combinators technique for graph processing. Only an idea of combinators using, but language class and restrictions are not discussed. Problems with cycles in graph. Ad-hoc solution. We propose a general solution. Problems with left-recursive grammars(???Should be checked)

Classical combinators are based on LL(k) and has restrictions: left-recursive grammars. GLL [16] can handle arbitrary context-free grammars, SPPF [13]

Parser combinators library bsed on GLL — Meerkat [1] [8]. Can handle arbitrary context-free grammars Written in Scala

[1] https://github.com/meerkat-parser/Meerkat

Structural representation of result: not only reachability, but paths; debuggibg; understanding.

3 PARSER-COMBITATORS FOR PATH QUERYING

In this section we present our implementation of and describe some details.

Our implenemtation is based on Meerkat library. We need only some steps for generalization.

As far as linear input is a one of case of graph, it is possible to provide input abstraction which make possible to generalize combinators.

SPPF may be an arbitrary graph in opposite of linear input parsing.

Let we introduce an example. Graph. Grammar. In terms of combinators.

Interface for Neo4J bata base

Extensible solution

An architecture of the solution.

4 EVALUATION

In this section we present evalution of Meerkat graph parsing. We show its perfomance on a classical ontology graphs for in memory graph and for Neo4j database, show application on may-alias static code analysis problem, and compare with Trails [9] library for graph traversals.

All tests are perfomed on a machine running Fedora 27 with quad-core Intel Core i7 2.5 GHz CPU with 8 GB of memory.

Some experiments on real data and comarison with existing solutions

4.1 Ontology querying

One of well-known graph querying problems is a queries for ontologies [1]. We use Meerkat to evaluate it on some popular ontologies presented as RDF files from paper [19]. We convert RDF files to a labeled directed graph like the following: for every RDF triple $(subject,\ predicate,\ object)$ we create two edges $(subject,\ predicate,\ object)$ and $(object,\ predicate^{-1},\ subject)$. On those graphs we apply two queries from the paper [5] which grammars are on Fig. 1, and Fig. 2

$$S \rightarrow subClassOf^{-1}\ S\ subClassOf$$
$$S \rightarrow type^{-1}\ S\ type$$
$$S \rightarrow subClassOf^{-1}\ subClassOf$$
$$S \rightarrow type^{-1}\ type$$

Figure 1: Query 1 grammar

Meerkat represetaion of those queries in terms of parser combinators is similar to its EBNF form and presnted on Fig. 3 and Fig. 4

The queries applied in two following ways.

- Convert RDF files to a graph input for meerkat and then directly parse on query 1 and query 2

$$S \rightarrow\ B\ subClassOf$$
$$B \rightarrow subClassOf^{-1}\ B\ subClassOf$$
$$B \rightarrow subClassOf^{-1}\ subClassOf$$

Figure 2: Query 2 grammar

```
val S: Nonterminal = syn(
   "subclassof-1" ~~ S ~~ "subclassof" |
   "type-1" ~~ S ~~ "type" |
   "subclassof-1" ~~ "subclassof" |
   "type-1" ~~ "type")
```

Figure 3: Meerkat representation of Query 1

```
val S: Nonterminal = syn(
   "subclassof-1" ~~ S ~~ "subclassof" |
   "subclassof")
```

Figure 4: Meerkat representation of Query 2

- Convert RDF files to a Neo4j database and then parse this database on given queries

Table 1 shows experimental results of those two aproaches over the testing RDF files where $number\ of\ results$ is a number of pairs of nodes $(v_1,\ v_2)$ such that exists S-path from v_1 to v_2.

The perfomance is about 2 times slower than in [5] and shows the same results. If compare the perfomance of in memory graph querying and database querying, the second one is slower in about $2-4$ times.

4.2 Integration with Neo4j

4.3 Static code analysis

Alias analysis is one of the fundamental static analysis problems[10]. Alias analysis checks may-alias relations between code expressions and can be formulated as a Context-Free language (CFL) reachability problem[14]. In that case program represeted as Program Expression Graph (PEG)[20]. Verticies in PEG are program expressions and edges are relations between them. In a case of analysisng C source code there is two kind of edges **D**-edge and **A**-edge.

- Pointer dereference edge (**D**-edge). For each pointer deference $*e$ there is a directed D-edge from e to $*e$.
- Pointer assignment edge (**A**-edge). For each assignment $*e_1 = e_2$ there is a directed A-edge from e_2 to $*e_1$

Also, for the sake of simplicity, there are edges labeled by $\overline{D}$ and $\overline{A}$ which corresponds to reversed D-edge and A-edge, respectively.

The grammar for may-alias problem from [20] presented on Fig. 5. It consists of two nonterminals **M** and **V**. It allows us to make two kind of queries for each of nonterminals **M** and **V**.

- **M** production shows that two l-value expression are memory aliases i.e. may stands for the same memory location.

Ontology	#tripples	Query 1				Query 2			
		#results	In memory graph (ms)	DB query time (ms)	Trails (ms)	#results	In memory graph (ms)	DB query time (ms)	Trails (ms)
atom-primitive	425	15454	174	236	2849	122	49	56	453
biomedical-mesure-primitive	459	15156	328	398	3715	2871	36	52	60
foaf	631	4118	23	42	432	10	1	2	1
funding	1086	17634	151	175	367	1158	18	23	76
generations	273	2164	9	27	9	0	0	0	0
people_pets	640	9472	68	87	75	37	2	3	2
pizza	1980	56195	711	792	7764	1262	44	56	905
skos	252	810	4	29	6	1	0	1	0
travel	277	2499	23	93	34	63	2	2	1
univ-bench	293	2540	19	74	31	81	2	3	2
wine	1839	66572	578	736	3156	133	5	7	4

Table 1: Evaluation results for In Memory Graph and Graph DB

$$M \rightarrow \overline{D}\, V\, D$$
$$V \rightarrow (M?\ A)^*\ M?\ (A\ M?)^*$$

Figure 5: Context-Free grammar for the may-alias problem in syntax

Program	Code Size (KLOC)	Count of aliases		Time (ms)
		M aliases	V aliases	
wc-5.0	0.5K	0	174	350
pr-5.0	1.7K	13	1131	532
ls-5.0	2.8K	52	5682	436
bzip2-1.0.6	5.8K	9	813	834
gzip-1.8	31K	120	4567	1585

Table 2: Running may-alias queries on Meerkat on some C open-source projects

- **V** shows that two expression are value aliases i.e. may evaluate to the same pointer value.

We made **M** and **V** queries on the code some open-source C projects. The results are presented on the Table 2

It may be usefull for tools development.

4.4 Comparison with GLL

4.5 Comparison with Trails

Trails [9] is a Scala graph combinator library which provides combinators for graph traversals. It provides traversers for describing paths in graphs in terms of parser combinators and allows to get results as a stream (maybe infinite) of all possible paths described by composition of basic traversals. Trails as well as Meerkat support parsing in memory graphs, so we compare perfomance of Trails and Meerkat on the queries from subsection 4.1. Query 1 and Query 2 in terms of Trails are on Fig. 6 and Fig 7.

Here queries made in same way as in Meerkat. `S` traversal returns pairs (*begin node*, *start node*) of S-path. Combine operators ~ and ~> in queries made in the way to get only last node from path.

```
val B = (out("type-1") ~> out("type")) |
   (out("subclassof-1") ~> B ~> out("subclassof")) |
   (out("type-1") ~> B ~> out("type")) |
   (out("subclassof-1") ~> out("subclassof"))
val S = V ~ B
```

Figure 6: Trails representation of Query 1

```
val B = out("subclassof") |
   (out("subclassof-1") ~> B ~> out("subclassof"))
val S = V ~ B
```

Figure 7: Trails representation of Query 2

The result of comparation are in table 1. Trails gives the same results as Meeerkat (column *results* in table 1) but slower than Meerkat.

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5 CONCLUSION

We propose a native way to integrate language for language-constrained path querying into general purpose programming language. We implement it and show that our implementation can be applied for real problems.

Code is available on GitHub:

Future work is

SPPF processing for debugging and results processing

Attributed grammars processing to provide mechanim for semantics calcualtion

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