Parser Combinators for Context-Free Path Querying

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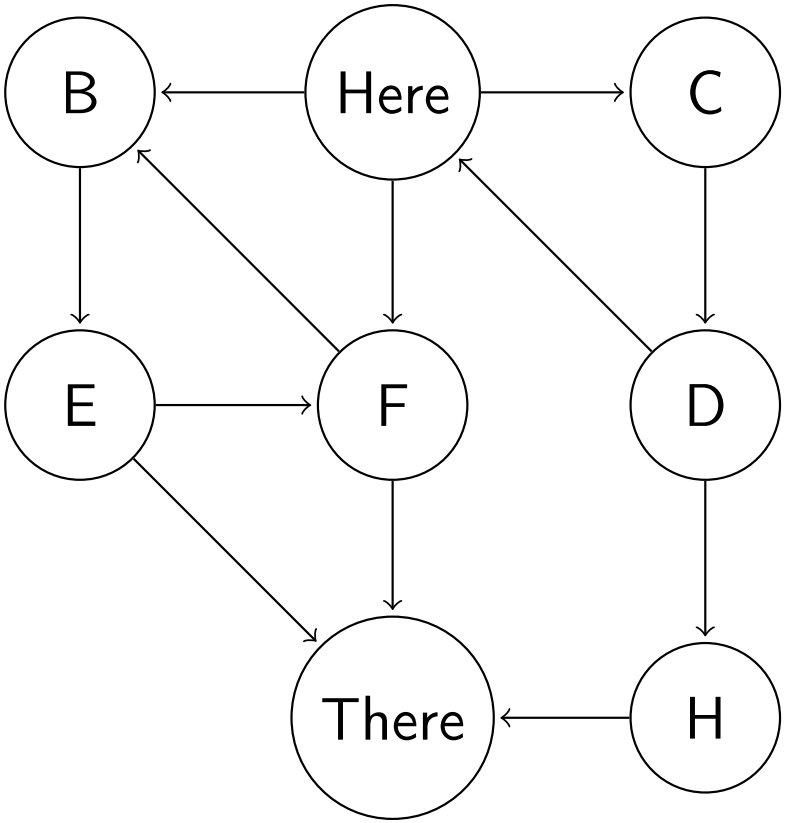
Path Querying



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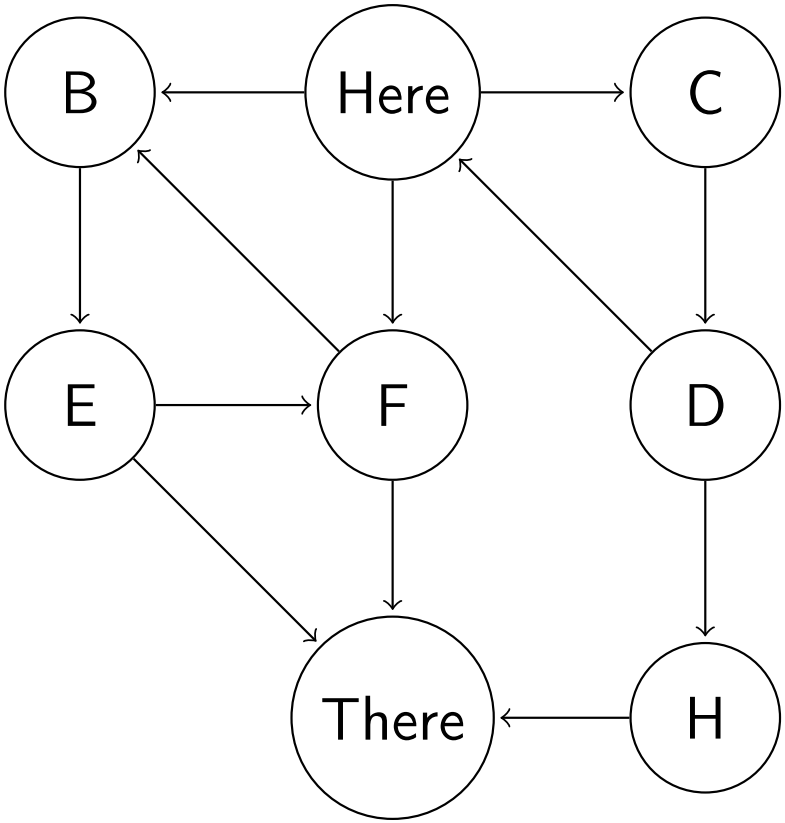

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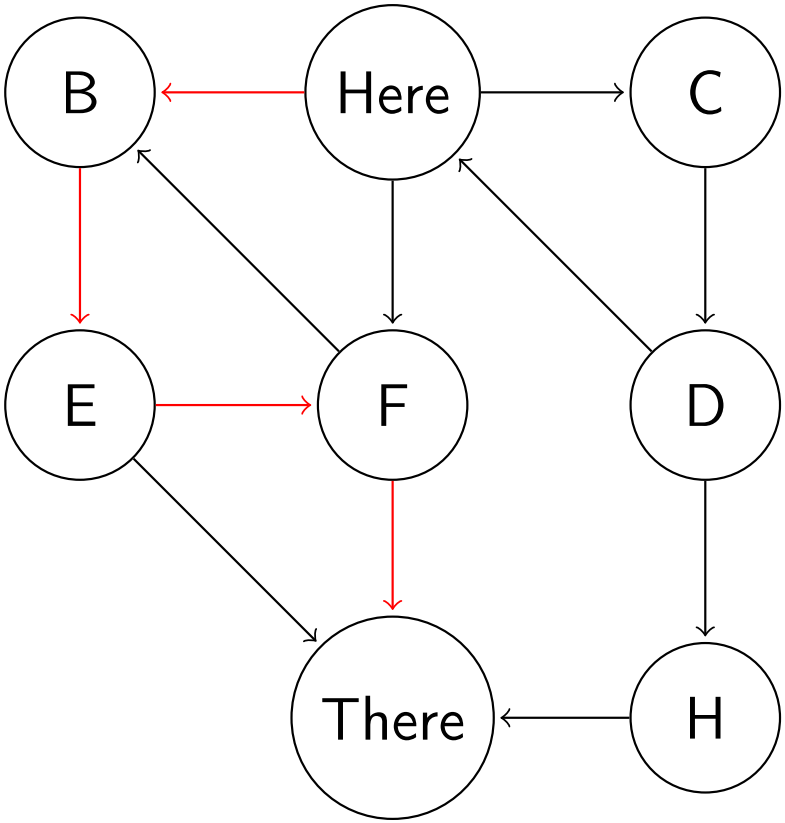

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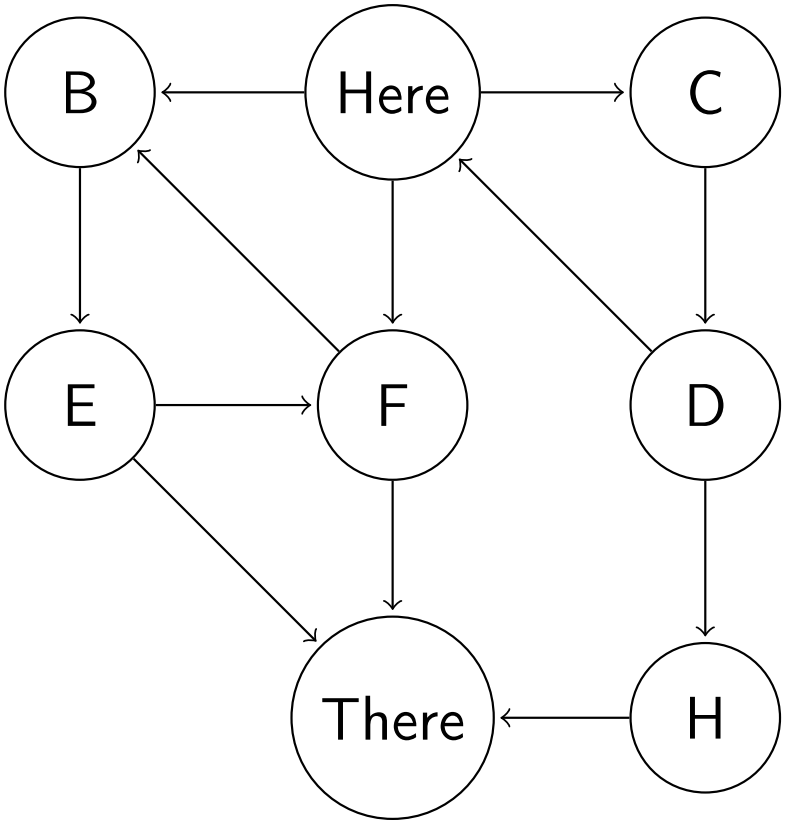

Is there a path from **Here** to **There** of length 13?

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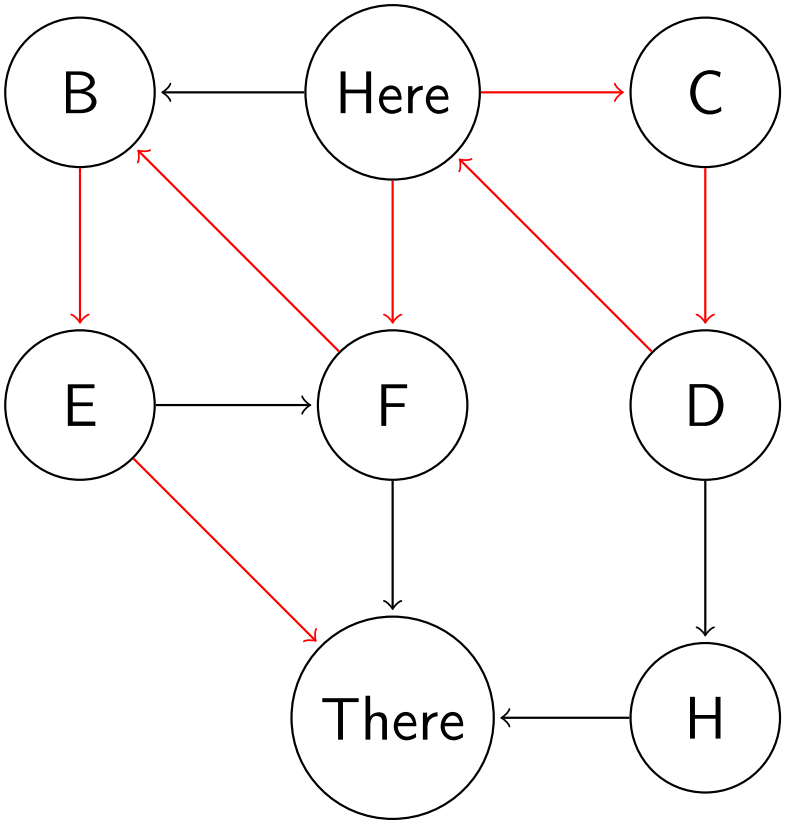

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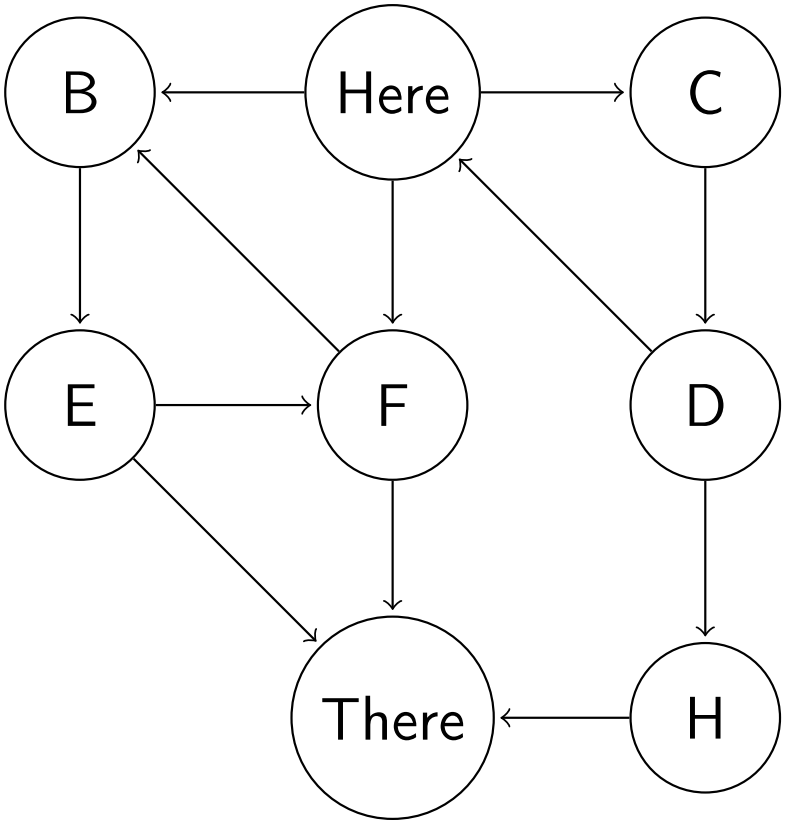

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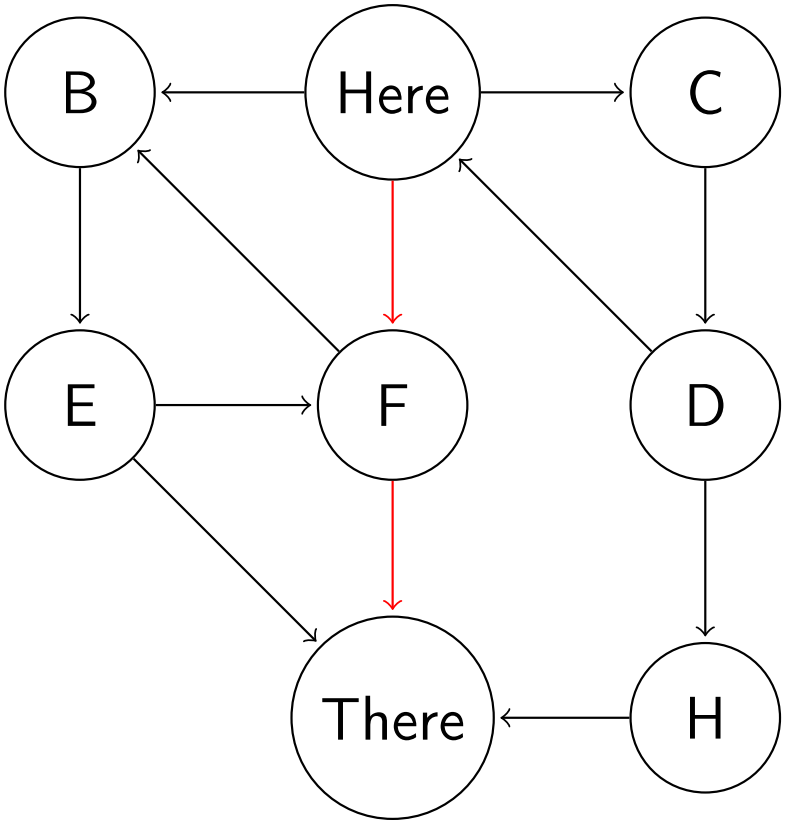

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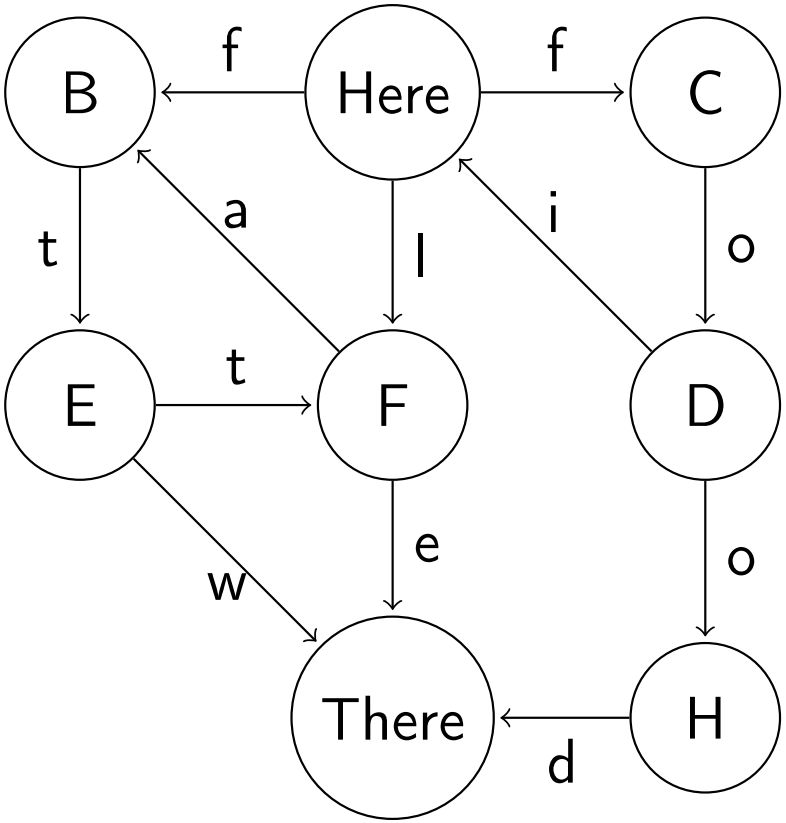
Path Querying: Regular Constraints



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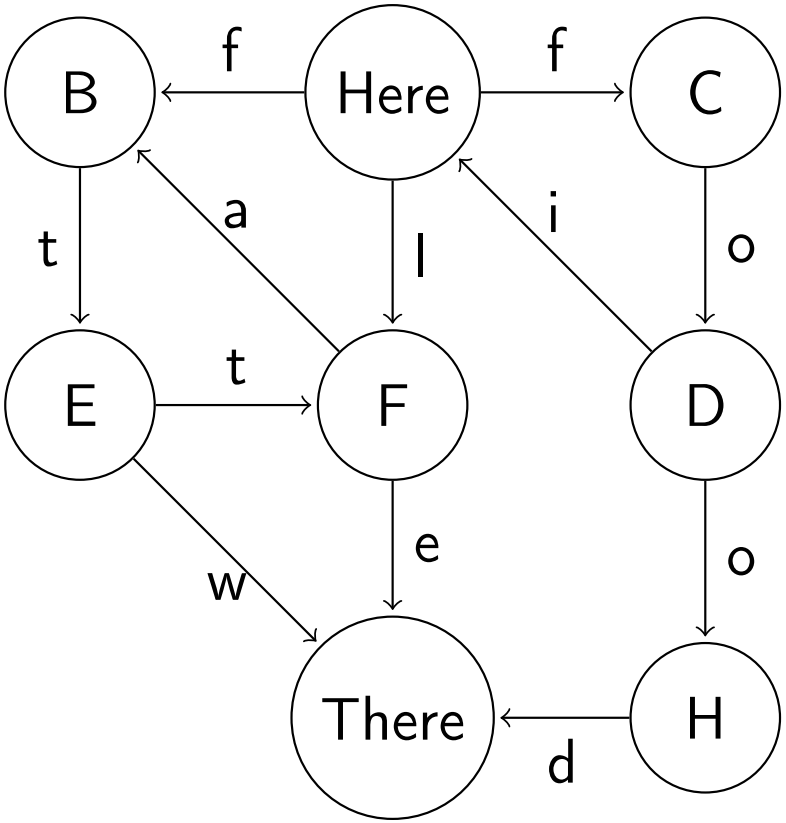

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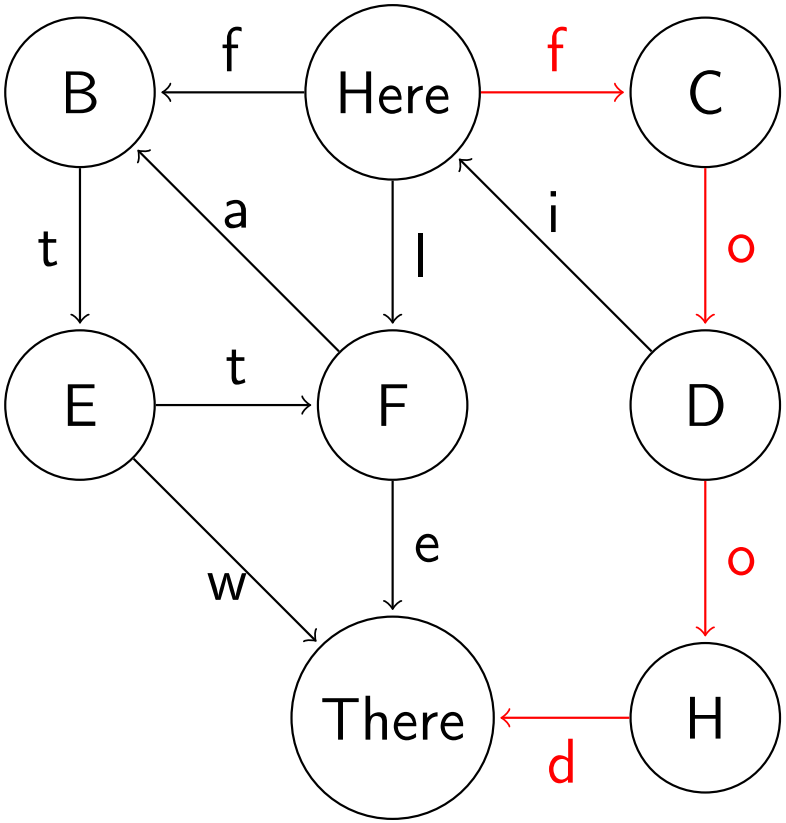

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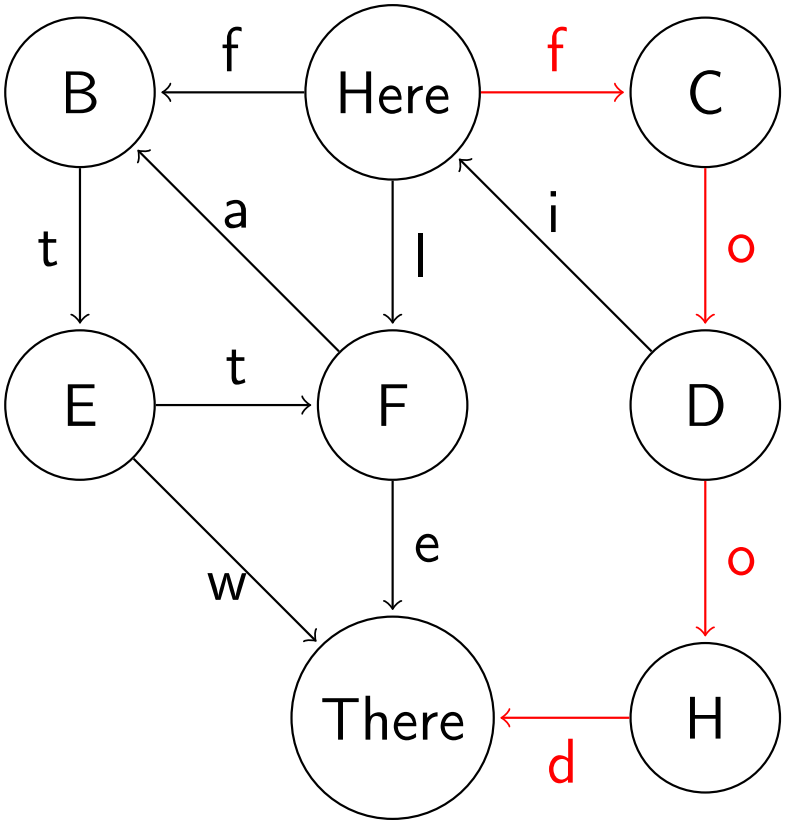

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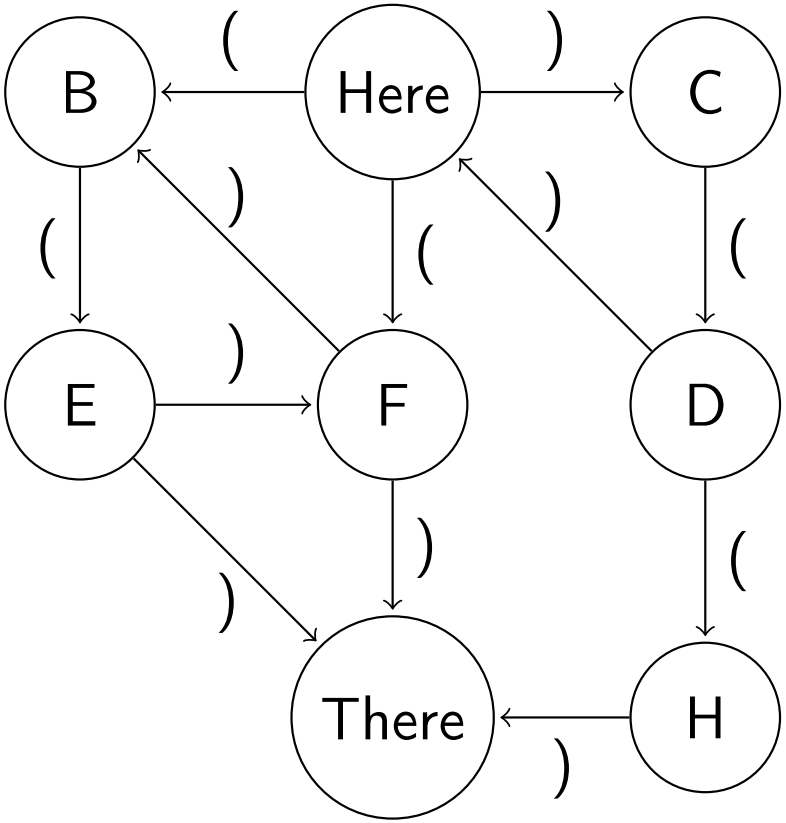
Constraints are a regular language

Path Querying: Context-Free Constraints



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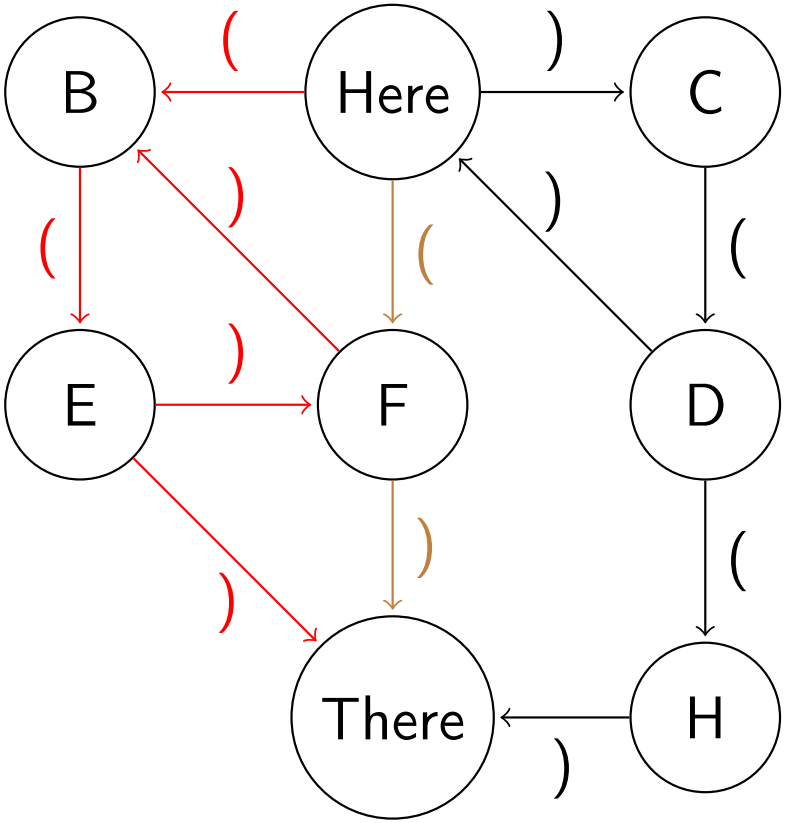
Path Querying: Context-Free Constraints



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(())() () ()()

Context-Free Path Querying

Given:

- an input graph
- a context-free language specification

Construct the set of paths in the graph which are in the language

Applications of Context-Free Path Querying

- Querying graph databases
- Static code analysis
- Network analysis

Parsing for Path Querying

We need to parse strings along the paths

Can we generalize parsing to work on graphs instead of strings?

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Can we generalize parsing to work on graphs instead of strings?

Yes, we can!

Goals

Writing queries should be user friendly!
It should be liberated from the particularities of parsing

- Transparent integration of the query language
- Work with any context-free constraint
- Work with any input graph

Parser Combinators as a Way of Transparent Integration

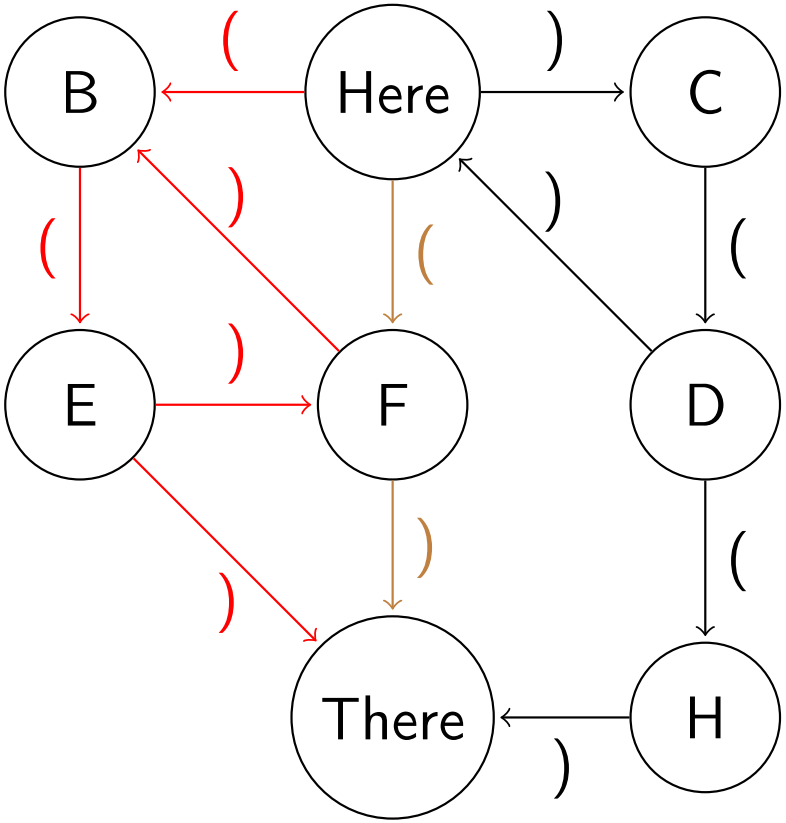
- Encode the query in the programm itself
- Types work for us: harder to write nonsensical grammar
- Composability
- Natural representation of the result

Meerkat

- Generic parser combinator library in Scala
- CPS-parsing with memoization
- Supports any context-free grammar (left recursive, ambiguous)
- Semantics calculation

```
val E: Nonterminal
= syn ( E ~ "^" ~ E
      | "_" ~ E
      | E ~ "*" ~ E
      | E ~ "/" ~ E
      | E ~ "+" ~ E
      | E ~ "_" ~ E
      | "(" ~ E ~ ")"
      | "[0-9]".r
      )
```

CFPQ in Meerkat



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

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Supported Combinators

Combinator	Description
a ~ b	sequential parsing: a then b
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a *	repetition of zero or more a
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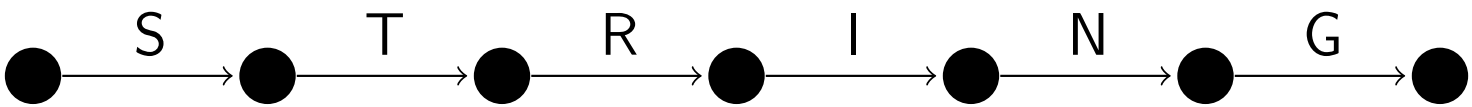
a ^ f	apply f function to a if a is a token
a ^^	capture output of a if a is a token
a & f	apply f function to a if a is a parser
a &&	capture output of a if a is a parser

How is it Done? Input

String = linear graph



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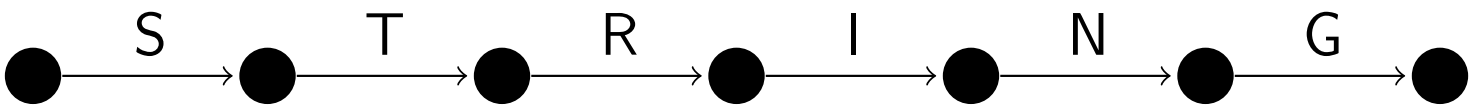

What makes a graph **not** a string?

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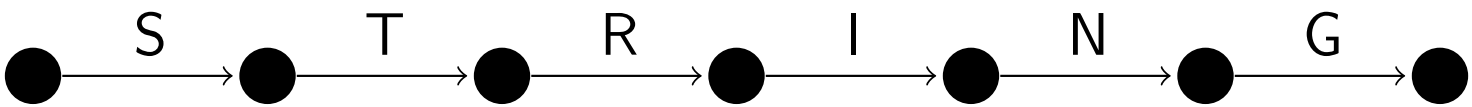

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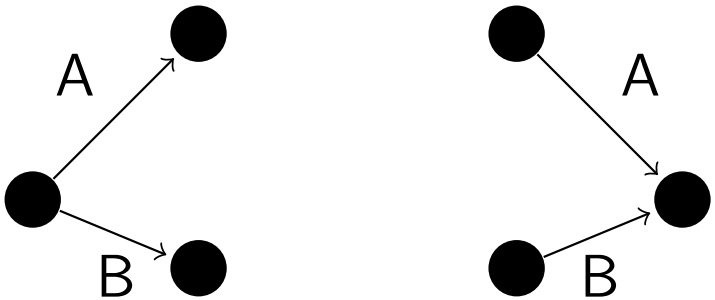

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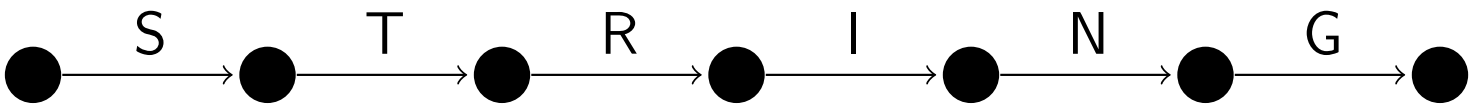

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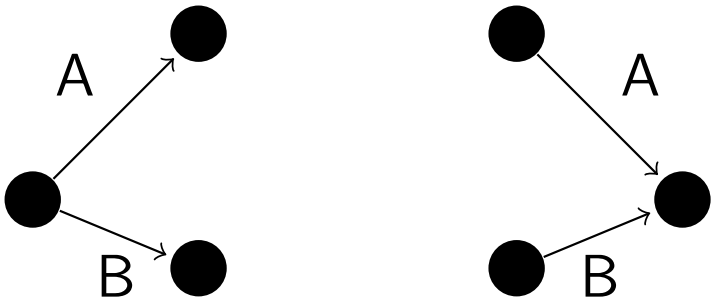
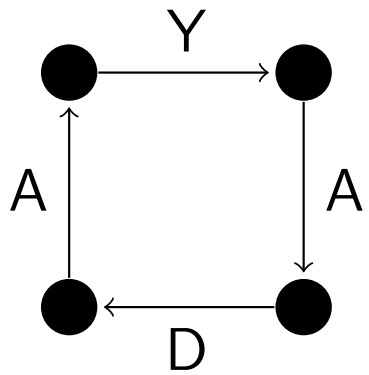


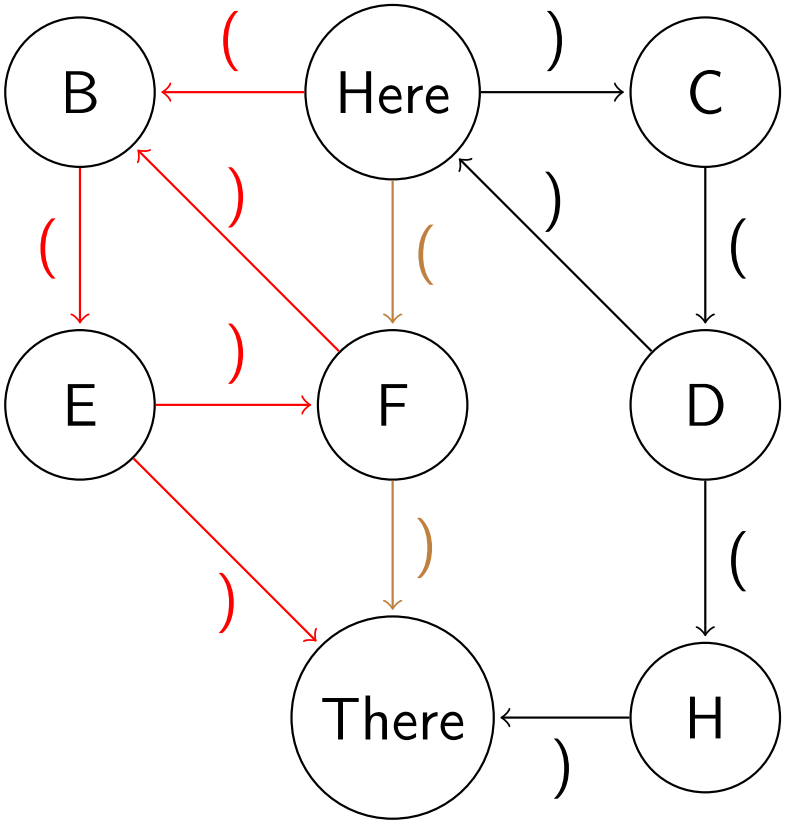
Cycles



How is it Done? General Idea

- Each input position corresponds to a set of intermidiate parsing results
- Continue parsing along each branch independently
- Merge the sets of intermidiate results whenever two paths lead to the same input position
- Continue parsing only from the **new** results
- Memoize the results obtained

Peeking into Vertices



Is there a path from **Here** to **There** which is a string of balanced brackets?

```
val Query : Nonterminal
= syn (LV("Here") ~ S ~
       LV("There"))

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

(())() () ()()

Input abstraction

```
trait Input[+E, +N] {
  def checkNode(nodeId: Int,
      predicate: N => Boolean): Option[N] }
  def filterEdges(nodeId: Int,
      predicate: E => Boolean): Seq [(E, Int)]
```

We provide the integration for GraphX and Neo4j

Example

```
val query =
  syn((
    syn(LV("Actor") ^^) ~ outLE("ACTS_IN") ~
    LV("Movie")) & (a => (a.name, a.toInt)))
executeQuery(query, input)
  .groupBy{ case(a, i) => i }
  .toIndexedSeq
  .map{ case(i, ms) => (ms.head._1, ms.length) }
  .sortBy{ case(a, mc) => -mc }}
  .take (10)
```

Evaluation

- Ontology querying
  - About 3 times faster than GLL-based solution
- Static code analysis: may-alias relations
  - Up to 5 times faster than Trails
- Movies database queries
  - Up to 10 times slower than Neo4j + Cypher
  - All queries are regular constraints

Limitations

- Overhead for the regular constraints
- Not exactly clear how to compute arbitrary semantics for the paths
  - Paths can be lazily extracted, but in what order?
  - Is it possible to compute some semantics in case of cycles?

Future work

- Reduce overhead for regular queries and improve performance
- Apply the library for static analysis of code
- Go beyond context-free constraints (ex. conjunctive grammars)

Summary

Parser combinators for CFPQ:

- Transparent integration of the query language
- Any context-free constraints
- Any input graph

Contacts

- Semyon Grigorev: s.v.grigoriev@spbu.ru
- Kate Verbitskaia: kajigor@gmail.com

- Meerkat for CFPQ: https://github.com/YaccConstructor/Meerkat