Interpretation of natural language instructions

Translating sentences by using a grammar

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Outline

Introduction & problem description

- An alternative user interface

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- Translation

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- An alternative user interface
- Translation
- Delimitation
  - Intranet of a software development company

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- An alternative user interface
- Translation
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  - Intranet of a software development company
  - Customers, People and Projects exists

Introduction & problem description

- An alternative user interface
- Translation
- Delimitation
  - Intranet of a software development company
  - Customers, People and Projects exists
  - Limited amount of instructions

Interface definition

Sufficient for novice users

```
people who know Java
```

Interface definition

Sufficient for novice users

```
people who know Java
```

Sufficient for expert users

```
people know java
```

Solution

- Precise translation

Solution

- Precise translation
- Need mapping from natural language to query language

Solution

- Precise translation
- Need mapping from natural language to query language
  - Use a grammar

Translation with a grammar

- Structured rules for strings

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- Example: Is/Are rule

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  - Studenterna är här
  - Studenten är här

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  - Studenterna är här `===>` `((Student Def Plural) Is Here)`
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  - `((Student Def Plural) Is Here)` `===>` The students are here

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  - Studenterna är här ===> `((Student Def Plural) Is Here)`
- Use the rules again to produce a sentence
  - `((Student Def Plural) Is Here)` ===> The students are here

How can we build a grammar to translate sentences?

We will use Grammatical Framework (GF)

Introducing Grammatical Framework (GF)

- Open source development platform for natural languages

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Same technique used by programming languages

- Programmer writes source code in concrete syntax

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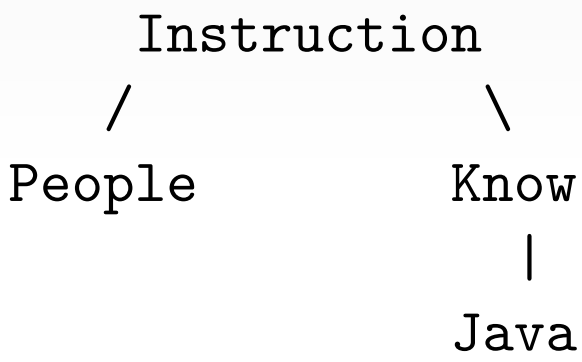
Same technique used by programming languages

- Programmer writes source code in concrete syntax
- Compiler translates concrete syntax to abstract syntax
- The rest of the compiler manipulates the abstract syntax

A simple example

Abstract syntax

```
Instruction People (Know Java)
```



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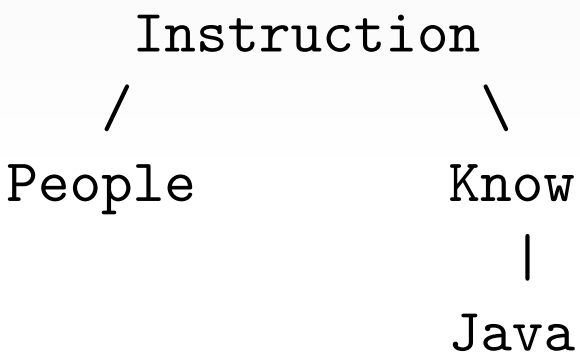

Concrete syntaxes

```
people who know Java                                  -- English
personer som kan Java                                 -- Swedish
q=object_type : Person AND expertise : Java           -- Solr
```

GF implementation: Abstract syntax

GF implementation: Abstract syntax

```
abstract Instrucs = {
  cat
    Instruction
    Subject ;
    Relation ;
    Object ;
```

GF implementation: Abstract syntax

```
abstract Instrucs = {
  cat
    Instruction
    Subject ;
    Relation ;
    Object ;
  fun
    MkInstruction : Subject -> Relation -> Instruction ;
    People : Subject ;
    Know : Object -> Relation ;
    Java : Object
}
```

GF implementation: English concrete syntax

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```
concrete InstrucsEng of Instrucs = {
  lincat
    Instruction = Str ;
    Subject = Str ;
    Relation = Str ;
    Object = Str ;
```

GF implementation: English concrete syntax

```
concrete InstrucsEng of Instrucs = {
  lincat
    Instruction = Str ;
    Subject = Str ;
    Relation = Str ;
    Object = Str ;
  lin
    MkInstruction subject relation =
                    subject ++ "who" ++ relation ;
    People = "people" ;
    Know object = "know" ++ object ;
    Java = "Java" ;
}
```

GF implementation: Solr concrete syntax

GF implementation: Solr concrete syntax

```
concrete InstrucsEng of Instrucs = {
  lincat
    Instruction = Str ;
    Subject = Str ;
    Relation = Str ;
    Object = Str ;
```

GF implementation: Solr concrete syntax

```
concrete InstrucsEng of Instrucs = {
  lincat
    Instruction = Str ;
    Subject = Str ;
    Relation = Str ;
    Object = Str ;
  lin
    MkInstruction subject relation =
                    "q=" ++ subject ++ "AND" ++ relation ;
    People = "object_type : Person" ;
    Know object = "expertise : " ++ object ;
    Java = "Java" ;
}
```

GF implementation: Translation

GF + Abstract syntax + Concrete syntax =

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Parser

```
> parse -lang=InstrucsEng "people who know Java"
MkInstruction People (Know Java)
```

GF implementation: Translation

GF + Abstract syntax + Concrete syntax =

Parser

```
> parse -lang=InstrucsEng "people who know Java"
MkInstruction People (Know Java)
```

Linearizer

```
> linearize -lang=InstrucsSolr
>                   MkInstruction People (Know Java)
"q= object_type : Person AND expertise : Java"
```

GF implementation: Translation

GF + Abstract syntax + Concrete syntax =

Parser

```
> parse -lang=InstrucsEng "people who know Java"
MkInstruction People (Know Java)
```

Linearizer

```
> linearize -lang=InstrucsSolr
>                   MkInstruction People (Know Java)
"q= object_type : Person AND expertise : Java"
```

Generator

```
> generate_trees
MkInstruction People (Know Java)
```

GF implementation: Resource Grammar Library

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  - Types for nouns, verbs, adjectives, noun phrases, verb phrases, relative sentences, phrases...

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  - Example: 'Yesterday I ate an apple'

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- Contains linguistic descriptions for natural languages
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  - Example: 'Yesterday I ate an apple'
  - Direct translation to Swedish: 'Igår jag åt ett äpple'

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- Contains linguistic descriptions for natural languages
  - Types for nouns, verbs, adjectives, noun phrases, verb phrases, relative sentences, phrases...
- Developer does not need to know linguistics
  - Example: 'Yesterday I ate an apple'
  - Direct translation to Swedish: 'Igår jag åt ett äpple'
  - Correct translation to Swedish: 'Igår åt jag ett äpple'

GF implementation: Resource Grammar Library

- Contains linguistic descriptions for natural languages
  - Types for nouns, verbs, adjectives, noun phrases, verb phrases, relative sentences, phrases...
- Developer does not need to know linguistics
  - Example: 'Yesterday I ate an apple'
  - Direct translation to Swedish: 'Igår jag åt ett äpple'
  - Correct translation to Swedish: 'Igår åt jag ett äpple'
- Only need to know the *domain*

Resource Grammar Library: English concrete syntax

Resource Grammar Library: English concrete syntax

```
concrete InstrucsEng of Instrucs =
  lincat
    Instruction = NP ;
    Subject = N ;
    Relation = RS ;
    Object = NP ;
```

Resource Grammar Library: English concrete syntax

```
concrete InstrucsEng of Instrucs =
  lincat
    Instruction = NP ;
    Subject = N ;
    Relation = RS ;
    Object = NP ;

  lin
   MkInstruction subject relation =
                    mkNP aPl_Det (mkCN subject relation) ;
   People = mkN "person" "people" ;
   Know object = mkRS' (mkVP (mkV2 (mkV "know")) object) ;
   Java = mkNP (mkPN "Java") ;
  oper
     mkRS' : VP -> RS = \vp -> mkRS (mkRCl which_RP vp) ;
```

Resource Grammar Library: Swedish concrete syntax

```
concrete InstrucsEng of Instrucs =
  lincat
    Instruction = NP ;
    Subject = N ;
    Relation = RS ;
    Object = NP ;

  lin
   MkInstruction subject relation =
                    mkNP aPl_Det (mkCN subject relation) ;
   People = mkN "person" "personer" ;
   Know object = mkRS' (mkVP (mkV2 (mkV "kan") object)) ;
   Java = mkNP (mkPN "Java") ;
  oper
     mkRS' : VP -> RS = \vp -> mkRS (mkRCl which_RP vp) ;
```

Extending the grammar

Extending the grammar: All programming languages

- Extend the grammar to support more programming languages

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- Extend the grammar to support more programming languages
- Arbitrary names instead of hard coded functions

```
fun
  Java : Object ;
lin
  Java = "Java" ;
```

Extending the grammar: All programming languages

- Extend the grammar to support more programming languages
- Arbitrary names instead of hard coded functions

```
fun
  Java : Object ;
lin
  Java = "Java" ;

===>

fun
  MkObject : Symb -> Object ;
lin
  MkObject symb = symb.s ;
```

Extending the grammar: More instructions

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- Support **valid** sentences regarding *customers*, *people* and *projects*:

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- Extend grammar to support more instructions
- Support **valid** sentences regarding *customers*, *people* and *projects*:

```
people who know Java
people who work in London
people who work with Unicef
customers who use Solr
projects who use Solr
```

Extending the grammar: More instructions

- Extend grammar to support more instructions
- Support **valid** sentences regarding *customers*, *people* and *projects*:

```
people who know Java
people who work in London
people who work with Unicef
customers who use Solr
projects who use Solr
```

- Not support invalid sentences, for instance:

```
projects who work in London
people who use Solr
customers who work with Unicef
```

Extending the grammar: More instructions

- Resolved by adding more categories (types)

```
cat
  Internal ; External ; Resource ;
  InternalRelation ; ExternalRelation ; ResourceRelation ;
```

Extending the grammar: More instructions

- Resolved by adding more categories (types)

```
cat
  Internal ; External ; Resource ;
  InternalRelation ; ExternalRelation ; ResourceRelation ;
fun
  People   : Internal ;
  Customer : External ;
  Project  : Resource ;
```

Extending the grammar: More instructions

- Resolved by adding more categories (types)

```
cat
  Internal ; External ; Resource ;
  InternalRelation ; ExternalRelation ; ResourceRelation ;
fun
  People   : Internal ;
  Customer : External ;
  Project  : Resource ;

  Know     : Object -> InternalRelation ;
  UseExt   : Object -> ExternalRelation ;
  UseRes   : Object -> ResourceRelation ;
```

Extending the grammar: More instructions

- Resolved by adding more categories (types)

```
cat
  Internal ; External ; Resource ;
  InternalRelation ; ExternalRelation ; ResourceRelation ;
fun
  People   : Internal ;
  Customer : External ;
  Project  : Resource ;

  Know     : Object -> InternalRelation ;
  UseExt   : Object -> ExternalRelation ;
  UseRes   : Object -> ResourceRelation ;

  InstrucInternal : Internal -> InternalRelation -> Instruction
  InstrucExternal : External -> ExternalRelation -> Instruction
  InstrucResource : Resource -> ResourceRelation -> Instruction
```

Extending the grammar: Boolean operators

Extending the grammar: Boolean operators

- Extend grammar to support boolean operators
- `people who know Java and Python`

Extending the grammar: Boolean operators

- Extend grammar to support boolean operators
- `people who know Java and Python`
- `people who know Java or work in London`

Extending the grammar: Boolean operators

- Extend grammar to support boolean operators
- `people who know Java and Python`
- `people who know Java or work in London`

```
fun
  And : Object -> Object -> Object ;
  Or : Object -> Object -> Object ;

lin
  And o1 o2 = o1 ++ "and" ++ o2 ;
  Or o1 o2 = o1 ++ "or" ++ o2 ;
```

Suggestion Engine

- Narrow application grammar requires precise input

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Problem with arbitrary names

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Problem with arbitrary names

```
> generate_trees
InstrucExternal Customer (UseExt (MkObject (MkSymb "Foo")))
InstrucInternal People (Know (MkObject (MkSymb "Foo")))
InstrucInternal People (WorkIn (MkObject (MkSymb "Foo")))
InstrucInternal People (WorkWith (MkObject (MkSymb "Foo")))
InstrucResource Project (UseRes (MkObject (MkSymb "Foo")))
```

Suggestion Engine

- Narrow application grammar requires precise input
- Need to help user to find correct instructions
- Use suggestions based on partial input
- Extract possible instructions into Solr

Problem with arbitrary names

```
> generate_trees | linearize -lang=InstrucsEng
"customers who use Foo"
"people who know Foo"
"people who work in Foo"
"people who work with Foo"
"projects which use Foo"
```

Suggestion Engine

- Resolved by introducing name types

```
MkSkill : Symb -> Skill ;
MkOrganization : Symb -> Organization ;
MkModule: Symb -> Module ;
MkLocation : Symb -> Location
```

Suggestion Engine

- Resolved by introducing name types

```
MkSkill : Symb -> Skill ;
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MkModule: Symb -> Module ;
MkLocation : Symb -> Location
```

```
> generate_trees
InstrucExternal Customer (UseExt (MkModule (MkSymb "Foo")))
InstrucInternal People (Know (MkSkill (MkSymb "Foo")))
InstrucInternal People (WorkIn (MkLocation (MkSymb "Foo")))
InstrucInternal People (WorkWith (MkOrganization (MkSymb "Foo")))
InstrucResource Project (UseRes (MkModule (MkSymb "Foo")))
```

Suggestion Engine

- Resolved by introducing name types

```
MkSkill : Symb -> Skill ;
MkOrganization : Symb -> Organization ;
MkModule: Symb -> Module ;
MkLocation : Symb -> Location
```

```
> generate_trees (post processed)
InstrucExternal Customer (UseExt (MkModule (MkSymb "Module0")))
InstrucInternal People (Know (MkSkill (MkSymb "Skill0")))
InstrucInternal People (WorkIn (MkLocation (MkSymb "Location0")))
InstrucInternal People (WorkWith (MkOrganization (MkSymb "Organi..")))
InstrucResource Project (UseRes (MkModule (MkSymb "Module0")))
```

Suggestion Engine

- Resolved by introducing name types

```
MkSkill : Symb -> Skill ;
MkOrganization : Symb -> Organization ;
MkModule: Symb -> Module ;
MkLocation : Symb -> Location
```

```
> generate_trees | linearize -lang=InstrucsEng
"customers who use Module0"
"people who know Skill0"
"people who work in Location0"
"people who work with Organization0"
"projects which use Module0"
```

Suggestion Engine: Pseudocode of algorithm

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suggestions(sentence) {
    // sentence = "anyone that ever knew java"
    // names[] = {Java}
    names[] = extractNames(sentence);
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    // "anyone that ever knew java" ===>
    // "anyone that ever knew Skill0"
    sentence = replaceNamesWithTypes(sentence, names);
```

Suggestion Engine: Pseudocode of algorithm

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suggestions(sentence) {
    // sentence = "anyone that ever knew java"
    // names[] = {Java}
    names[] = extractNames(sentence);

    // "anyone that ever knew java" ===>
    // "anyone that ever knew Skill0"
    sentence = replaceNamesWithTypes(sentence, names);

    // suggestions = { "people who know Skill0", ... }
    suggestions[] = findSentences(sentence);
```

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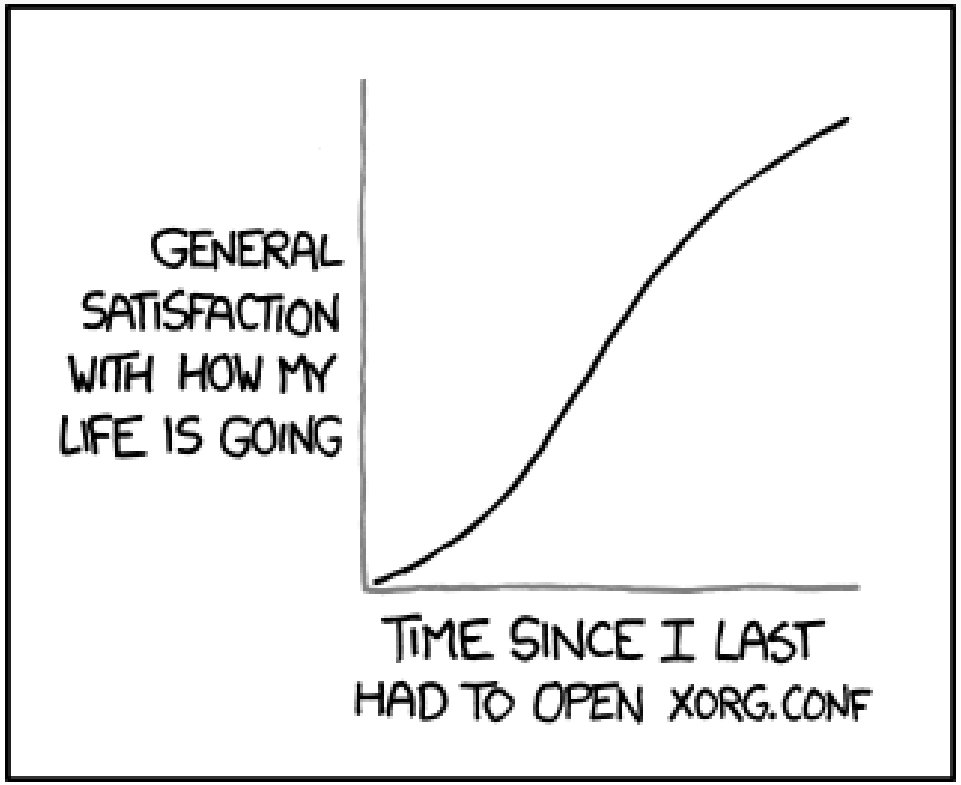
suggestions(sentence) {
    // sentence = "anyone that ever knew java"
    // names[] = {Java}
    names[] = extractNames(sentence);

    // "anyone that ever knew java" ===>
    // "anyone that ever knew Skill0"
    sentence = replaceNamesWithTypes(sentence, names);

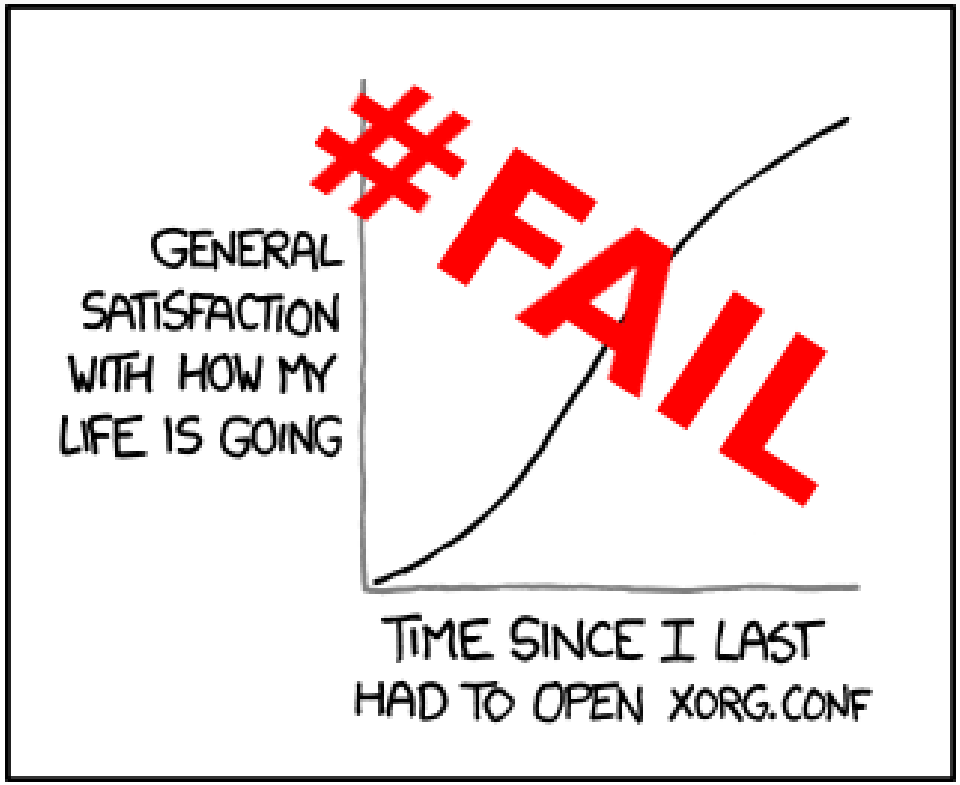
    // suggestions = { "people who know Skill0", ... }
    suggestions[] = findSentences(sentence);

    for each suggestion in suggestions {
    // "people who know Skill0" ===>
    // "people who know Java"
      suggestion = restoreNames(names, suggestion);
    }
    return suggestions;
}
```

Results


GENERAL SATISFACTION WITH HOW MY LIFE IS GOING
TIME SINCE I LAST HAD TO OPEN XORG.CONF

Results


#FAIL
GENERAL SATISFACTION WITH HOW MY LIFE IS GOING
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- Resource Grammar Library not worth the effort
  - Not possible to express a few sentences
  - For example: `people that know Java`
  - `people who know Java and work in London`

Conclusion

- Application sufficient for novice and expert users
- Resource Grammar Library not worth the effort
  - Not possible to express a few sentences
  - For example: `people that know Java`
  - `people who know Java and work in London`
  - Compare: `people who know Java and who work in London`

Conclusion

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- Resource Grammar Library not worth the effort
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  - For example: `people that know Java`
  - `people who know Java and work in London`
  - Compare: `people who know Java and who work in London`
  - Problem with constant `which_RP`

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  - For example: `people that know Java`
  - `people who know Java and work in London`
  - Compare: `people who know Java and who work in London`
  - Problem with constant `which_RP`
  - Linearizes `projects who use Solr`

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Future Work

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- Improvments of suggestions

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  - No suggestions based on empty string

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Future Work

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  - Add heuristic to auto completion
  - If invalid instruction, choose most similar suggestion
- Instructions in speech
- Proper handling of ambiguous instructions
- Use application in other context