textX

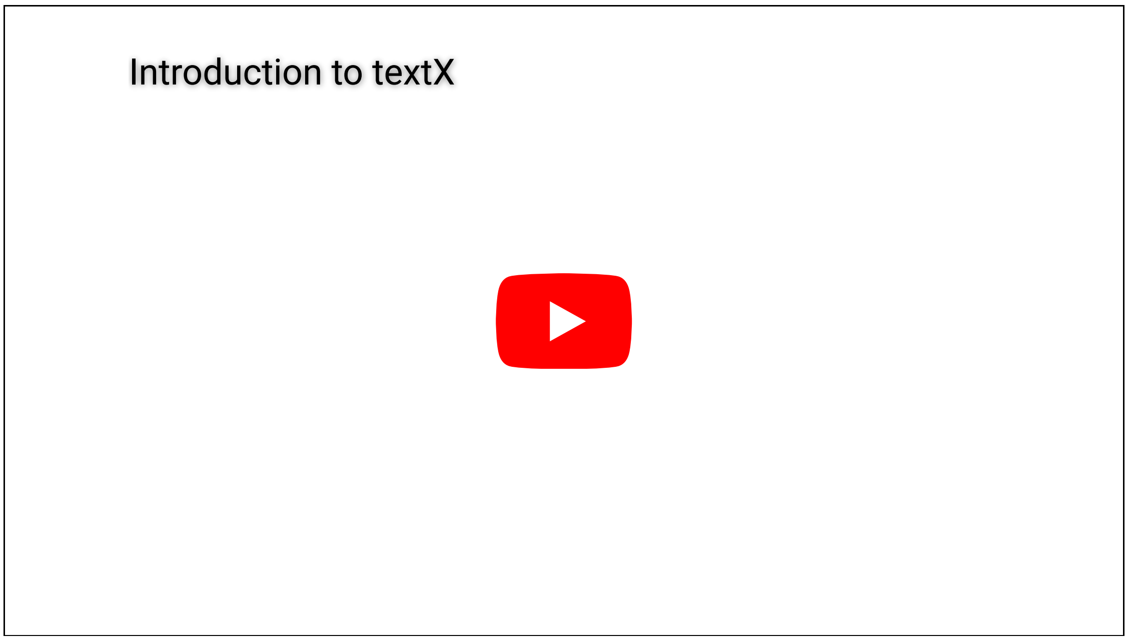
textX is a meta-language (i.e. a language for language definition) for domain-specific language (DSL) specification in Python.

In a nutshell, textX will help you build your textual language in an easy way. You can invent your own language or build a support for an already existing textual language or file format.

From a single grammar description, textX automatically builds a meta-model (in the form of Python classes) and a parser for your language. The parser will parse expressions of your language and automatically build a graph of Python objects (i.e. the model) corresponding to the meta-model.

textX is inspired by Xtext - a Java based language workbench for building DSLs with full tooling support (editors, debuggers etc.) on the Eclipse platform. If you like Java and Eclipse check it out. It is a great tool.

A video tutorial for textX installation and implementation of a simple data modeling language is below.



For a not-so-basic video tutorial check out State Machine video tutorial.

For an introduction to DSLs in general here are some references:

- Federico Tomassetti: The complete guide to (external) Domain Specific Languages.
- Pierre Bayerl: self-dsl.

For an in-depth coverage on the subject we recommend the following books:

- Voelter, Markus, et al. DSL engineering: Designing, implementing and using domain-specific languages. dslbook.org, 2013.
- Kelly, Steven, and Juha-Pekka Tolvanen. Domain-specific modeling: enabling full code generation. John Wiley & Sons, 2008.

Feature highlights

- **Meta-model/parser from a single description**

  A single description is used to define both language concrete syntax and its meta-model (a.k.a. abstract syntax). See the description of grammar and metamodel.

- **Automatic model (AST) construction**

  Parse tree will automatically be transformed to a graph of python objects (a.k.a. the model). See the model section.

  Python classes will be created by textX but, if needed, user supplied classes may be used. See custom classes.

- **Automatic linking**

  You can have references to other objects in your language and the textual representation of the reference will be resolved to the proper python reference automatically.

- **Automatic parent-child relationships**

  textX will maintain a parent-child relationships imposed by the grammar. See parent-child relationships.

- **Parser control**

  Parser can be configured with regard to case handling, whitespace handling, keyword handling etc. See parser configuration.

- **Model/object post-processing**

  A callbacks (so called processors) can be registered for models and individual classes. This enables model/object postprocessing (validation, additional changes etc.). See processors section.

- **Grammar modularization - imports**

  Grammar can be split into multiple files and then files/grammars can be imported where needed. See Grammar modularization.

- **Scope Providers**

  Scope Providers allow different types of scoping. See Scoping.

- **Multi-meta-model support**

  Different meta-models can be combined. Typically some of these meta-models extend other meta-models (grammar modularization) and reference each other. Special scope providers support file-extension-based allocation of model files to meta models. See Multi meta-model support

- **Meta-model/model visualization**

  Both meta-model and parsed models can be visulized using GraphViz software package. See visualization section.

Installation

```
$ pip install textX[cli]
```

Note

> Previous command requires pip to be installed.
>
> Also, notice the use of `[cli]` which means that we would like to use CLI `textx` command. If you just want to deploy your language most probably you won't need CLI support.

To verify that textX is properly installed run:

```
$ textx
```

You should get output like this:

```
Usage: textx [OPTIONS] COMMAND [ARGS]...

Options:
  --debug  Debug/trace output.
  --help   Show this message and exit.

Commands:
  check            Check/validate model given its file path.
  generate         Run code generator on a provided model(s).
  list-generators  List all registered generators
  list-languages   List all registered languages
  version          Print version info.
```

To install development (`master` branch) version:

```
$ pip install --upgrade https://github.com/textX/textX/archive/
master.zip
```

Python versions

textX works with Python 3.6+. Other versions might work but are not tested.

Getting started

See textX `Tutorials` to get you started:

- Hello World
- Robot
- Entity
- State Machine - video tutorial
- Toy language compiler
- self-dsl

For specific information read various `User Guide` sections.

You can also try textX in our playground. There is a dropdown with several examples to get you started.

A full example project that shows how multi-meta-modeling feature can be used is also available in a separate git repository.

To create the initial layout of your project quickly take a look at project scaffolding.

Discussion and help

For general questions and help please use StackOverflow. Just make sure to tag your question with the `textx` tag.

For issues, suggestions and feature request please use GitHub issue tracker.

Projects using textX

Here is a non-complete list of projects using textX.

- Open-source
    - pyecore - ECore implementation in Python. Vincent Aranega is doing a great work on integrating textX with pyecore. The idea is that the integration eventually gets merged to the main textX repo. For now, you can follow his work on his fork of textX.
    - pyTabs - A Domain-Specific Language (DSL) for simplified music notation
    - applang - Textual DSL for generating mobile applications
    - pyFlies - A DSL for designing experiments in psychology
    - ppci - Pure python compiler infrastructure.
    - Expremigen - Expressive midi generation
    - fanalyse - Fortran code parser/analyser
    - Silvera - A DSL for microservice based software development
    - cutevariant - A standalone and free application to explore genetics variations from VCF file. Developed by labsquare - A community for genomics software
    - osxphotos - Python app to export pictures and associated metadata from Apple Photos on macOS.
    - StrictDoc - Software for technical documentation and requirements management.
- Commercial
    - textX is used as a part of Typhoon-HIL's schematic editor for the description of power electronic and DSP schemes and components.

If you are using textX to build some cool stuff drop me a line at igor dot dejanovic at gmail. I would like to hear from you!

Editor/IDE support

Visual Studio Code support

There is currently an ongoing effort to build tooling support around Visual Studio Code. The idea is to auto-generate VCS plugin with syntax highlighting, outline, InteliSense, navigation, visualization. The input for the generator would be your language grammar and additional information specified using various DSLs.

Projects that are currently in progress are:

- textX-LS - support for Language Server Protocol and VS Code for any textX based language.
- textx-gen-coloring - a textX generator which generates syntax highlighting configuration for TextMate compatible editors (e.g. VSCode) from textX grammars.
- textx-gen-vscode - a textX generator which generates VSCode extension from textX grammar.
- viewX - creating visualizers for textX languages

Stay tuned ;)

Other editors

If you are a vim editor user check out support for vim.

For emacs there is textx-mode which is also available in MELPA.

You can also check out textX-ninja project. It is currently unmaintained.

Citing textX

If you are using textX in your research project we would be very grateful if you cite our paper [Dejanovic2017].

```
@article{Dejanovic2017,
        author = {Dejanovi\'{c}, I. and Vaderna, R. and
Milosavljevi\'{c}, G. and Vukovi\'{c}, \v{Z}.},
        doi = {10.1016/j.knosys.2016.10.023},
        issn = {0950-7051},
        journal = {Knowledge-Based Systems},
        pages = {1--4},
        title = {{TextX: A Python tool for Domain-Specific Languages
implementation}},
        url = {http://www.sciencedirect.com/science/article/pii/
S0950705116304178},
        volume = {115},
        year = {2017}
}
```

Hello World example

This is an example of very simple Hello World like language.

Note

> A `.tx` file extension is used for textX grammar. See textX grammar on what you can do inside a grammar file, including comments!

These are the steps to build a very basic Hello World - like language.

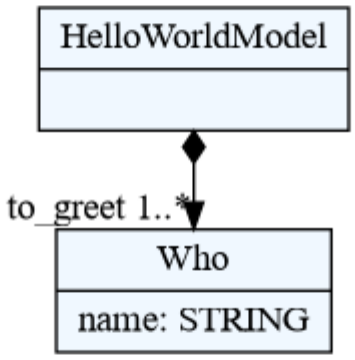
1. Write a language description in textX (file `hello.tx`):

   ```
   HelloWorldModel:
     'hello' to_greet+=Who[',']
   ;

   Who:
     name = /[^,]*/
   ;
   ```

   Description consists of a set of parsing rules which at the same time describe Python classes that will be dynamically created and used to instantiate objects of your model. This small example consists of two rules: `HelloWorldModel` and `Who`. `HelloWorldModel` starts with the keyword `hello` after which a one or more `Who` object must be written separated by commas. `Who` objects will be parsed, instantiated and stored in a `to_greet` list on a `HelloWorldModel` object. `Who` objects consists only of its names which must be matched the regular expression rule `/[^,]*/` (match non-comma zero or more times). Please see textX grammar section for more information on writing grammar rules.

2. At this point you can check and visualise meta-model using following command from the command line:

   ```
   $ textx generate hello.tx --target dot
   Generating dot target from models:
   /home/igor/repos/textX/textX/examples/hello_world/hello.tx
   -> /home/igor/repos/textX/textX/examples/hello_world/hello.dot
     To convert to png run "dot -Tpng -O hello.dot"
   ```



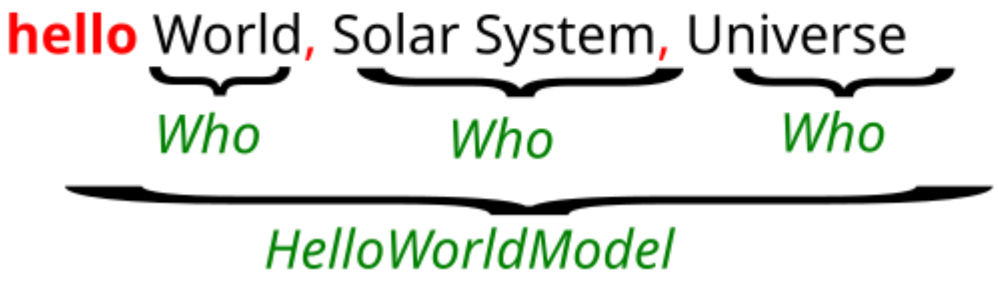
You can see that for each rule from language description an appropriate Python class has been created. A BASETYPE hierarchy is built-in. Each meta-model has it.

3. Create some content (i.e. model) in your new language (`example.hello`):

```
hello World, Solar System, Universe
```

Your language syntax is also described by language rules from step 1.

If we break down the text of the example model it looks like this:



We see that the whole line is a `HelloWorldModel` and the parts `World` , `Solar System` , and `Universe` are `Who` objects. Red coloured text is syntactic noise that is needed by the parser (and programmers) to recognize the boundaries of the objects in the text.

4. To use your models from Python first create meta-model from textX language description (file `hello.py`):

```
from textx import metamodel_from_file
hello_meta = metamodel_from_file('hello.tx')
```

5. Than use meta-model to create models from textual description:

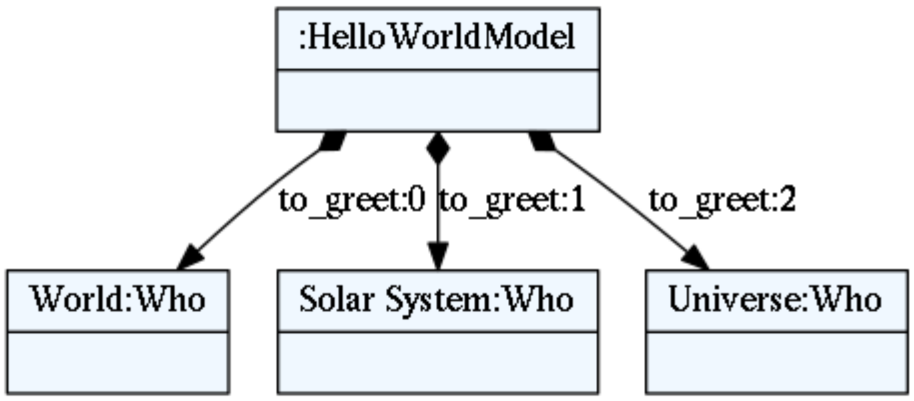
```
hello_model = hello_meta.model_from_file('example.hello')
```

Textual model `example.hello` will be parsed and transformed to plain Python objects. Python classes of the created objects are those defined by the meta-model. Returned object `hello_model` will be a reference to the root of the model, i.e. the object of class `HelloWorldModel` . You can use the model as any other Python object. For example:

```
  print("Greeting", ", ".join([to_greet.name
                               for to_greet in
 hello_model.to_greet]))
```

6. You can optionally export model to `dot` file to visualize it. Run following from the command line:

```
  $ textx generate example.hello --grammar hello.tx --target dot
  Generating dot target from models:
  /home/igor/repos/textX/textX/examples/hello_world/example.hello
  -> /home/igor/repos/textX/textX/examples/hello_world/
 example.dot
    To convert to png run "dot -Tpng -O example.dot"
```



This is an object graph automatically constructed from `example.hello` file.

We see that each `Who` object is contained in the python attribute `to_greet` of list type which is defined by the grammar.

7. Use your model: interpret it, generate code ... It is a plain Python graph of objects with plain attributes!

Note

> Try out a complete tutorial for building a simple robot language.

textX grammar

The language syntax and the meta-model are defined by the textX grammar in the form of a set of textX rules.

Rules

The basic building blocks of the textX language are rules. Each rule is written in the following form:

```
Hello:
  'hello' who=ID
;
```

This rule is called `Hello`. After the rule name, there is a colon. The body of the rule is given as a textX expression, starting at the colon and ending with a semicolon. This rule tells us that the pattern of `Hello` objects in input strings consists of the string literal `hello`, followed by the ID rule (here ID is a reference to a built-in rule, more about this in a moment).

These are valid `Hello` objects:

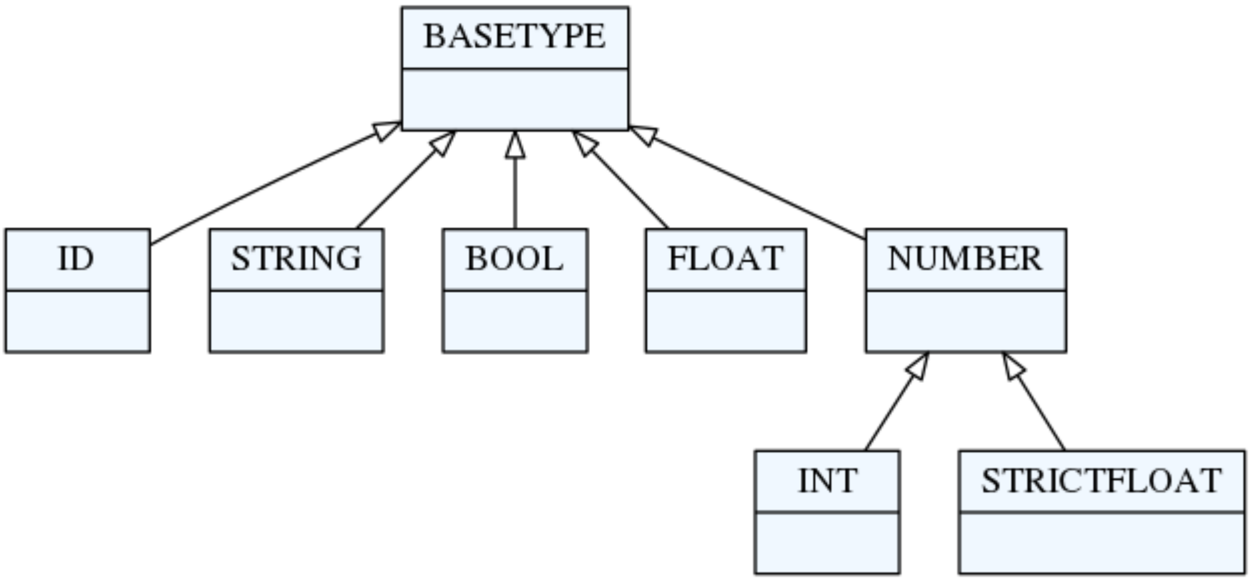
```
hello Alice
hello Bob
hello foo1234
```

Rule `Hello` at the same time defines a Python class `Hello`. When the rule is recognized in the input stream, an object of this class will get created and the attribute `who` will be set to whatever the rule `ID` has matched after the word `hello` (this is specified by the assignment `who=ID`).

Of course, there are many more rule expressions than those shown in this small example. In the next section, a detailed description of each textX expression is given.

textX base types

In the previous example you have seen an `ID` rule. This rule is one of the built-in rules that form the base of textX's type system. Base types/rules are depicted in the following figure:



- `ID` rule: matches a common identifier consisting of letters, digits and underscores. The regex pattern that describe this rule is `'[^\d\W]\w*\b'`. This match will be converted to a Python string.
- `INT` rule: matches an integer number. This match will be converted to a Python `int` instance.
- `FLOAT` rule: will match a floating point number. This match will be converted to a Python `float` instance ('FLOAT' is a direct subtype of 'BASETYPE'; in order to distinguish floats and ints, 'STRICTFLOAT' was introduced).
- `STRICTFLOAT` rule: will match a floating point number. This match will be converted to a Python `float` instance. A 'STRICTFLOAT' will not match an 'INT' (without "." or "e|E"). A 'NUMBER' is either a 'STRICTFLOAT' or an 'INT', and will, thus, be converted to a float or an int, respectively.
- `BOOL` rule: matches the words `true` or `false`. This match will be converted to a Python `bool` instance.
- `STRING` rule: matches a quoted string. This match will be converted to a Python `str` instance.

textX base types are automatically converted to python types during object instantiation. See auto-initialization for more information.

Rule expressions

Rule expressions represent the body of a rule. They is specified using basic expressions and operators.

The basic expressions are:

- Matches
    - String match (`'...'` or `"..."`)
    - Regex match (`/.../`)
- Sequence

- Ordered choice (`|`)
- Optional (`?`)
- Repetitions
    - Zero or more (`*`)
    - One or more (`+`)
    - Unordered group (`#`)
- References
    - Match reference
    - Link reference (`[..]`)
- Assignments
    - Plain (`=`)
    - Boolean (`?=`)
    - Zero or more (`*=`)
    - One or more (`+=`)
- Syntactic predicates
    - Not (`!`) - negative lookahead
    - And (`&`) - positive lookahead
- Match suppression

Matches

Match expressions are, besides base type rules, the expressions at the lowest level. They are the basic building blocks for more complex expressions. These expressions will consume input on success.

There are two types of match expressions:

- **String match** - is written as a single quoted string. It will match a literal string on the input.

  Here are a few examples of string matches:

  ```
  'blue'
  'zero'
  'person'
  ```

- **Regex match** - uses regular expression defined inside `/ /` to match the input. Therefore, it defines a whole class of strings that can be matched. Internally a python `re` module is used.

  Here are few example of regex matches:

```
/\d*/
/\d{3,4}-\d{3}/
/[-\w]*\b/
/[^}]*/
```

For more information on Regular Expression in Python see Regular Expression HOWTO.

When the metamodel has the option `use_regexp_group` set to `True`, then a regular expression with exactly one group is replaced by the group. This can be used to define multiline strings to be stored in the model without the surrounding limiters:

```
Model: 'data' '=' data=/(?ms)\"{3}(.*?)\"{3}/;
```

An example model could be

```
data = """
This is a multiline
text!
"""
```

When creating a metamodel with this grammar and the option `use_regexp_group` enabled, a multiline string delimited with `"""` is accepted: `(?ms)` activates the multiline option and the *dot matches everything* option. `\"{3}` matches the delimited `"""`. The pattern `"(.*?)` is a non-greedy variant of *get anything*.

```
metamodel = metamodel_from_str(grammar,
 use_regexp_group=True)
```

Sequence

Sequence is a textX expression that is given by just writing contained sub-expressions one after another. For example,the following rule:

```
Colors:
  "red" "green" "blue"
;
```

is defined as a sequence consisting of three string matches (`red` `green` and `blue`). Contained expressions will be matched in the exact order they are given. If some of the expressions do not match, the sequence as a whole will fail. The above rule defined by the sequence will match only the following string:

```
red green blue
```

Note

> If whitespace skipping is enabled (it is by default), arbitrary whitespaces can occur between matched words.

Ordered choice

Ordered choice is given as a set of expression separated by the `|` operator. This operator will try to match contained expression from left to right and the first match that succeeds will be used.

Example:

```
Color:
  "red" | "green" | "blue"
;
```

This will match either `red` or `green` or `blue` and the parser will try to match the expressions in that order.

Note

> In most classic parsing technologies an unordered match (alternative) is used. This may lead to ambiguous grammars where multiple parse tree may exist for the same input string.

Underlying parsing technology of textX is Arpeggio which is a parser based on PEG grammars and thus the `|` operator directly translates to Arpeggio's PEG ordered choice. Using ordered choice yields unambiguous parsing. If the text parses there is only one possible parse tree.

Optional

`Optional` is an expression that will match the contained expression if that is possible, but will not fail otherwise. Thus, optional expression always succeeds.

Example:

```
MoveUp:
  'up' INT?
;
```

`INT` match is optional in this example. This means that the `up` keyword is required, but the following integer may or may not be found.

Following lines will match:

```
up 45
up 1
up
```

Optional expressions can be more complex. For example:

```
MoveUp:
  'up' ( INT | FLOAT )?
```

Now, an ordered choice in the parentheses is optional.

Repetitions

- **Zero or more** repetition is specified by the `*` operator and will match the contained expression zero or more times. Here is an example:

  ```
  Colors:
    ("red"|"green"|"blue")*
  ;
  ```

  In this example *zero or more* repetition is applied on the *ordered choice*. In each repeated match one color will be matched, trying from left to right. Thus, `Colors` rule will match color as many times as possible, but will not fail if no color exists in the input string. The following would be matched by the `Colors` rule:

  ```
  red blue green
  ```

  but also:

  ```
  red blue blue red red green
  ```

  or an empty string.

- **One or more** repetition is specified by `+` operator and will match the contained expression one or more times. Thus, everything that is written for **zero or more** applies here except that at least one match must be found for this expression to succeed. Here is an above example modified to match at least one color:

```
Colors:
  ("red"|"green"|"blue")+
;
```

- **Unordered group** is a special kind of a sequence. Syntactically it is similar to a repetition. It is specified by the `#` operator and must be applied to either sequences or ordered choices. This operator will match each element of the sequence or the ordered choice in an arbitrary order:

  ```
  Colors:
    ("red" "green" "blue")#
  ;
  ```

  For the previous example all following lines are valid:

  ```
  red blue green
  red green blue
  blue green red
  ...
  ```

  But, the following lines are not valid:

  ```
  red blue red green
  blue green
  ```

  Consider this example:

  ```
  Modifier:
      (static?='static' final?='final' visibility=Visibility)#
  ;

  Visibility:
      'public' | 'private' | 'protected';
  ```

  We want to provide modifiers to the type declarations in our language. Furthermore, we want modifiers to be written in any order.

  The following lines will match (thanks to `?=` operator, only visibility must be specified):

```
public
public static
final protected static
...
```

You can combine unordered groups with parenthesized groups. Lets look at the following example:

```
Unordered:
  (('first' 'second')  'third')#
;
```

This will match group with sequence `first second` and `third` in arbitrary order but the sequence `first second` maintains the order. Thus, these inputs will match:

```
first second third
third first second
```

But these won't:

```
third second first
second first third
```

Alternatively, you can use ordered choice instead of grouping. This will be equivalent with the previous example:

```
Unordered:
  ('first' 'second' | 'third')#
;
```

Note

> Unordered group may also have repetition modifiers defined.

Assignments

Assignments are used as a part of the meta-model deduction process. Each assignment will result in an attribute of the meta-class created by the rule.

Each assignment consists of the LHS (left-hand side) and the RHS (right-hand side).

The LHS is always a name of the meta-class attribute while the RHS can be a reference to other rules (either a match or a link reference) or a simple match (string or regex match). For example:

```
Person:
  name=Name ',' surname=Surname ',' age=INT ',' height=INT ';'
;
```

The `Name` and `Surname` rules referenced in the RHS of the first two assignments are not given in this example.

This example describes the rule and meta-class `Person`, that will parse and instantiate the `Person` objects with these four attributes:

- `name` - which will use the rule `Name` to match the input, it will be a reference to the instance of the `Name` class,
- `surname` - will use `Surname` rule to match the input,
- `age` - will use the built-in type `INT` to match a number from the input string. `age` will be converted to the python `int` type.
- `height` - the same as `age`, but the matched number will be assigned to the `height` attribute of the `Person` instance.

Notice the comma as the separator between matches and the semicolon match at the end of the rule. Those matches must be found in the input but the matched strings will be discarded. They represent a syntactic noise.

If the RHS is one of textX BASETYPEs, then the matched string will be converted to some of the plain python types (e.g. `int`, `string`, `boolean`).

If the RHS is a string or regex match like in this example:

```
Color:
  color=/\w+/
;
```

then the attribute given by the LHS will be set as the string matched by the RHS regular expression or string.

If the RHS is a reference to some other rule, then the attribute given by the LHS will be set to refer to the object created by the RHS rule.

Following strings are matched by the `Person` rule from above:

```
Petar, Petrovic, 27, 185;
John, Doe, 34, 178;
```

There are four types of assignments:

- **Plain assignment** (`=`) will match its RHS once and assign what is matched to the attribute given by the LHS. The above example uses plain assignments.

  Examples:

  ```
  a=INT
  b=FLOAT
  c=/[a-Z0-9]+/
  dir=Direction
  ```

- **Boolean assignment** (`?=`) will set the attribute to `True` if the RHS match succeeds and to `False` otherwise.

  Examples::

  ```
  cold ?= 'cold'
  number_given ?= INT
  ```

- **Zero or more assignment** (`*=`) - LHS attribute will be a `list` . This assignment will keep matching the RHS as long as the match succeeds and each matched object will be appended to the attribute. If no match succeeds, the attribute will be an empty list.

  Examples::

  ```
  commands*=Command
  numbers*=INT
  ```

- **One or more assignment** (`+=`) - same as the previous assignment, but it must match the RHS at least once. If no match succeeds, this assignment does not succeed.

Multiple assignment to the same attribute

textX allows for multiple assignments to the same attribute. For example:

```
MyRule:
    a=INT b=FLOAT a*=ID
;
```

Here `a` attribute will always be a Python list. The type of `a` will be `OBJECT` as the two assignments have declared different types for `a` (`INT` and `ID`).

Consider this example:

```
    Method:
        'func(' (params+=Parameter[','])? ')'
    ;
    Parameter:
        type=ID name=ID | name=ID
    ;
```

In `Parameter` rule, the `name` attribute assignments are part of different ordered choice alternatives and thus name will never have more than one value and thus should not be a list. The type of `name` is consistent in both assignments so it will be `ID`.

The rule of the thumb for multiple assignments is that if there is no possibility for an attribute to collect more than one value during parsing it will be a single value object, otherwise it will be a list.

###References

Rules can reference each other. References are usually used as a RHS of the assignments. There are two types of rule references:

- **Match rule reference** - will *call* another rule. When instance of the called rule is created, it will be assigned to the attribute on the LHS. We say that the referred object is contained inside the referring object (i.e. they form a parent-child relationship).

  Example::

  ```
  Structure:
    'structure' '{'
      elements*=StructureElement
    '}'
  ;
  ```

  `StructureElement` will be matched zero or more times. With each match, a new instance of the `StructureElement` will be created and appended to the `elements` python list. A `parent` attribute of each `StructureElement` will be set to the containing `Structure`.

- **Link rule reference** - is written as a referred rule name inside square brackets. It will match an identifier of some class object at the given place and convert that identifier to a Python reference to the target object. This reference resolving is done automatically by textX. By default, a `name` attribute is used as the identifier of the object. By default, all objects of the same class are in a single namespace. This can be configured by scope providers and Reference Resolving Expression Language.

  Example:

```
ScreenType:
  'screen' name=ID "{"
  '}'
;

ScreenInstance:
  'screen' type=[ScreenType]
;
```

The `type` attribute is a link to the `ScreenType` object. This is a valid usage:

```
// This is a definition of the ScreenType object
screen Introduction {

}

// And this is a reference link to the ScreenType object
defined above
// ScreenInstance instance
screen Introduction
```

`Introduction` will be matched, the `ScreenType` object with that name will be found and the `type` attribute of `ScreenInstance` instance will be set to it.

`ID` rule is used by default to match the link identifier. If you want to change that, you can use the following syntax:

```
ScreenInstance:
  'screen' type=[ScreenType:WORD]
;
```

Here, instead of `ID` a `WORD` rule is used to match the object's identifier.

Note

> Attributes with `name` names are used for reference auto-resolving. By default, a dict lookup is used, thus they must be of a hashable type. See issues #40 and #266.
>
> A usual error is to match the name in this fashion:
>
> ```
> MyObj: name+=ID['.'];
> ```
>
> Here, `name` will be a list of strings that are separated by dot and that will not work as the name must be hashable. The best way to implement this and make `name` hashable is:
>
> ```
> MyObj: name=FQN;
> FQN: ID+['.'];
> ```
>
> Now, `name` will be the string returned by the `FQN` match rule.

Syntactic predicates

Syntactic predicates are operators that are used to implement lookahead. The lookahead is used to do parsing decision based on the part of the input ahead of the current position. Syntactic predicates are written as a prefix of some textX rule expression. The rule expression will be used to match input ahead of the current location in the input string. It will either fail or succeed but will never consume any input.

There are two type of syntactic predicates:

- **Not - negative lookahead** (`!`) - will succeed if the current input doesn't match the expression given after the `!` operator.

  Example problem:

  ```
  Expression: Let | ID | NUMBER;
  Let:
      'let'
          expr+=Expression
      'end'
  ;
  ```

  In this example we have nested expressions built with indirectly recurssive `Let` rule. The problem is that the `ID` rule from `Expression` will match keyword `end` and thus will consume end of `Let` rule, so the parser will hit EOF without completing any `Let` rules. To fix this, we can specify that `ID` will match any identifier except keywords `let` and `end` like this:

```
Expression: Let | MyID | NUMBER;
Let:
    'let'
        expr+=Expression
    'end'
;
Keyword: 'let' | 'end';
MyID: !Keyword ID;
```

Now, `MyID` will match `ID` only if it is not a keyword.

- **And - positive lookahead** (`&`) - will succeed if the current input starts with the string matched by the expression given after the `&` operator.

  Example:

  ```
  Model:
      elements+=Element
  ;
  Element:
      AbeforeB | A | B
  ;
  AbeforeB:
      a='a' &'b'      // this succeeds only if 'b' follows 'a'
  ;
  A: a='a';
  B: a='b';
  ```

  Given the input string `a a a b` first two `a` chars will be matched by the rule `A`, but the third `a` will be matched by the rule `AbeforeB`. So, even when `AbeforeB` matches only `a` and is tried before any other match, it will not succeed for the first two `a` chars because they are not followed by `b`.

Match suppression

Sometimes it is necessary to define match rules that should return only parts of the match. For that we use match the suppression operator (`-`) after the expression you want to suppress.

For example:

```
FullyQualifiedID[noskipws]:
    /\s*/-
    QuotedID+['.']
    /\s*/-
;
QuotedID:
    '"'?- ID '"'?-
;
```

Because we use `noskipws` rule modifier, `FullyQualifiedID` does not skip whitespaces automatically. Thus, we have to match whitespaces ourself, but we don't want those whitespaces in the resulting string. You might wonder why we are using `noskipws`. It is because we do not want whitespaces in between each `QuotedID` match. So, for example, `first. second` shouldn't match but `first.second` should.

In the rule `FullyQualifiedID` we are suppressing whitespace matches `/\s*/-`. We also state in `QuotedID` that there are optional quotation marks around each ID, but we don't want those either `'"'?-`.

Given this input:

```
first."second".third."fourth"
```

`FullyQualifiedID` will return:

```
first.second.third.fourth
```

Repetition modifiers

Repetition modifiers are used for the modification of the repetition expressions (`*`, `+`, `#`, `*=`, `+=`). They are specified in brackets `[ ]`. If there are more modifiers, they are separated by a comma.

Currently, there are two modifiers defined:

- **Separator modifier** - is used to define separator on multiple matches. Separator is a simple match (string match or regex match).

  Example:

  ```
  numbers*=INT[',']
  ```

  Here, a separator string match is defined (`','`). This will match zero or more integers separated by commas.

```
45, 47, 3, 78
```

A regex can also be specified as a separator.

```
fields += ID[/;|,|:/]
```

This will match IDs separated by either `;` or `,` or `:`.

```
first, second; third, fourth: fifth
```

- **End-of-line terminate modifier** (`eolterm`) - used to terminate repetition on end-of-line. By default the repetition match will span lines. When this modifier is specified, repetition will work inside the current line only.

  Example:

  ```
  STRING*[',', eolterm]
  ```

  Here we have a separator as well as the `eolterm` defined. This will match zero or more strings separated by commas inside one line.

  ```
  "first", "second", "third"
  "fourth"
  ```

  If we run the example expression once on this string, it will match the first line only. `"fourth"` in the second line will not be matched.

Warning

Be aware that when `eolterm` modifier is used, its effect starts from the previous match. For example:

```
Conditions:
  'conditions' '{'
    varNames+=WORD[eolterm]    // match var names until end of
line
  '}'
```

In this example `varNames` must be matched in the same line as `conditions {` because `eolterm` effect start immediately. In this example we wanted to give the user the freedom to specify var names on the next line, even to put some empty lines if he/she wishes. In order to do that, we should modify the example like this::

```
Conditions:
  'conditions' '{'
    /\s*/
    varNames+=WORD[eolterm]    // match var names until end of
line
  '}'
```

Regex match `/\s*/` will collect whitespaces (spaces and new-lines) before the `WORD` match begins. Afterwards, repeated matches will work inside one line only.

Rule types

There are three kinds of rules in textX:

- Common rules (or just rules)
- Abstract rules
- Match rules

Common rules are rules that contain at least one assignment, i.e., they have attributes defined. For example:

```
InitialCommand:
  'initial' x=INT ',' y=INT
;
```

This rule has two defined attributes: `x` and `y`.

Abstract rules are rules that have no assignments and reference at least one abstract or common rule. They are usually given as an ordered choice of other rules and they are used to generalize other rules. For example:

```
Program:
  'begin'
    commands*=Command
  'end'
;

Command:
  MoveCommand | InitialCommand
;
```

In this example, Python objects in the `commands` list will either contain instances of `MoveCommand` or `InitialCommand`. `Command` rule is abstract. A meta-class of this rule will never be instantiated. Abstract rule can also be used in link rule references:

```
ListOfCommands:
  commands*=[Command][',']
;
```

Abstract rules may reference match rules and base types. For example:

```
Value:
    STRING | FLOAT | BOOL | Object | Array | "null"
;
```

In this example, the base types as well as the string match `"null"` are all match rules, but `Object` and `Array` are common rules and therefore `Value` is abstract.

Abstract rules can be a complex mix of rule references and match expressions as long as there is at least one abstract or common reference. For example:

```
Value:
  'id' /\d+-\d+/ | FLOAT | Object
;
```

A rule with a single reference to an abstract or common rule is also abstract:

```
Value:
  OtherRule
;
```

Abstract rules can have multiple references in a single alternative with the following rules:

- If all rule references in a single alternative are match rules the result will be a concatenation of all match rule results,
- If there is a common rule reference then it would be the result and all surrounding match rules are used only for parsing
- If there are multiple common rules then the first will be used as a result and the rest only for parsing

For example:

```
Model: STRING | ID | '#' Rule1 Sufix;  // abstract rule
Rule1: a=INT;  // common rule
Prefix: '#';
Sufix: ID | SomeOtherSufix;
SomeOtherSufix: '--' '#';
```

In this example matching `# 42 -- #` at input would yield and instance of `Rule1` with attribute `a` set to integer `42`. This comes from a third alternative `'#' Rule1 Sufix` that succeeds and the `#` and `Sufix` would be used just for parsing and the result would be discarded.

Another example:

```
Model: (STRING | ID | '#' Rule1) Sufix;
Rule1: a=INT; // common rule
Sufix: '--';
```

This is also abstract rule as we are referencing `Rule1` which is a common rule and we have no assignments. Matching `# 42 --` as input will give an instance of `Rule1` with attribute `a` set to integer `42`.

In this example:

```
Model: STRING|Rule1|ID|Prefix INT Sufix;
Rule1: a='a';  // a common rule
Prefix: '#';
Sufix: '--';
```

we see that input `# 42 --` would be recognized by the last alternative and the result will be string `#42--`, i.e. all match rule results would be concatenated. But if we give `a` as input than the result will be an instance of `Rule1` with attribute `a` set to string `'a'`.

In the following example we see what happens if we have multiple common rule references:

```
Model: STRING|Rule1|ID|Prefix Rule1 Sufix Rule2;  // Reference both
Rule1 and Rule2
Rule1: a=INT; // common rule
Rule2: a=STRING; // common rule
Prefix: '#';
Sufix: '--';
```

For input `# 42 -- "some string"` the model will be an instance of `Rule1` with attribute `a` set to `42` as it is the first common rule reference in the last alternative (the one that succeeds) but `Rule2`, despite being discarded, must also be satisfied during parsing or syntax error would be produced.

Match rules are rules that have no assignments either direct or indirect, i.e. all referenced rules are match rules too. They are usually used to specify enumerated values or some complex string matches that can't be done with regular expressions.

Examples:

```
Widget:
  "edit"|"combo"|"checkbox"|"togglebutton"
;

Name:
  STRING|/(\w|\+|-)+/
;

Value:
  /(\w|\+|-)+/ | FLOAT | INT
;
```

These rules can be used in match references only (i.e., you can't link to these rules as they don't exists as objects), and they produce objects of the base python types (`str` , `int` , `bool` , `float`).

All base type rules (e.g., `INT` , `STRING` , `BASETYPE`) are match rules.

Rule modifiers

Rule modifiers are used for the modification of the rule's expression. They are specified in brackets (`[ ]`) at the beginning of the rule's definition after the rule's name. Currently, they are used to alter parser configuration for whitespace handling on the rule level.

Rule modifiers act on the current rule and all rules referenced inside the rule (recursively): unless a refrenced rule has an explicit rule modifier, the currently active modifier state is propagated to referenced rules.

There are two rule modifiers at the moment:

- **skipws, noskipws** - are used to enable/disable whitespace skipping during parsing. This will change the global parser's `skipws` setting given during the meta-model instantiation.

  Example:

  ```
  Rule:
      'entity' name=ID /\s*/ call=Rule2;
  Rule2[noskipws]:
      'first' 'second';
  ```

  In this example `Rule` rule will use default parser behaviour set during the meta-model instantiation, while `Rule2` rule will disable whitespace skipping. This will change `Rule2` to match the word `firstsecond`, but not words `first second` with whitespaces in between.

  Note

  > Remember that whitespace handling modification will start immediately after the previous match. In the above example, additional `/\s*/` is given before the `Rule2` call to consume all whitespaces before trying to match `Rule2`.

- **ws** - used to redefine what is considered to be a whitespaces on the rule level. textX by default treats space, tab and new-line as a whitespace characters. This can be changed globally during the meta-model instantiation (see Whitespace handling) or per rule using this modifier.

  Example:

  ```
  Rule:
      'entity' name=ID /\s*/ call=Rule2;
  Rule2[ws='\n']:
      'first' 'second';
  ```

  In this example `Rule` will use the default parser behavior but the `Rule2` will alter the white-space definition to be new-line only. This means that the words `first` and `second` will get matched only if they are on separate lines or in the same line but without other characters in between (even tabs and spaces).

Note

> As in the previous example, the modification will start immediately, so if you want to consume preceding spaces you must do that explicitly, as given with `/\s*/` in the `Rule`.

Grammar comments

Syntax for comments inside a grammar is `//` for line comments and `/* ... */` for block comments.

Language comments

To support comments in your DSL use a special grammar rule `Comment`. textX will try to match this rule in between each other normal grammar match (similarly to the whitespace matching). If the match succeeds, the matched content will be discarded.

For example, in the robot language example comments are defined like this:

```
Comment:
  /\/\/.*$/
;
```

Which states that everything starting with `//` and continuing until the end of line is a comment.

Grammar modularization

Grammars can be defined in multiple files and then imported. Rules used in the references are first searched for in the current file and then in the imported files, in the order of the import.

Example:

```
import scheme

Library:
  'library' name=Name '{'
    attributes*=LibraryAttribute

    scheme=Scheme

  '}'
;
```

`Scheme` rule is defined in `scheme.tx` grammar file imported at the beginning.

Grammar files may be located in folders. In that case, dot notation is used.

Example:

```
import component.types
```

`types.tx` grammar is located in the `component` folder relatively to the current grammar file.

If you want to override the default search order, you can specify a fully qualified name of the rule using dot notation when giving the name of the referring object.

Example:

```
import component.types

MyRule:
  a = component.types.List
;

List:
  '[' values+=BASETYPE[','] ']'
;
```

`List` from `component.types` is matched/instantiated and set to `a` attribute.

Inspecting textX grammars programmatically

Since textX is a meta-language (a language for language definition) any textual language can be specified using it, even textX grammar language itself.

This definition enable loading of textX grammar as a plain Python model which can be further analyzed for various purposes. This can be used, e.g. for tooling which need to analyze the grammar beyond of just syntactic and semantic checks (e.g.

syntax highlighting may analyze grammar to discover keywords that needs to be colored).

To load grammar model first get the textX language meta-model with:

```
textx_mm = metamodel_for_language('textx')
```

and then call either `grammar_model_from_str` or `grammar_model_from_file` method on this meta-model object:

```
grammar_model = textx_mm.grammar_model_from_file(
    join(abspath(dirname(__file__)), 'pyflies.tx'))
```

Then investigate this model as you would do with any other model:

```
assert len(grammar_model.imports_or_references) == 3
assert len(grammar_model.rules) == 45

str_matches = get_children_of_type("SimpleMatch", grammar_model)
...
```

textX meta-models

textX meta-model is a Python object that knows about all classes that can be instantiated while parsing the input. A meta-model is built from the grammar by the functions `metamodel_from_file` or `metamodel_from_str` in the `textx.metamodel` module.

```
from textx import metamodel_from_file
my_metamodel = metamodel_from_file('my_grammar.tx')
```

Each rule from the grammar will result in a Python class kept in the meta-model. Besides, meta-model knows how to parse the input strings and convert them to model.

Parsing the input and creating the model is done by `model_from_file` and `model_from_str` methods of the meta-model object:

```
my_model = my_metamodel.model_from_file('some_input.md')
```

When parsing a model file or string a new parser is cloned for each model. This parser can be accessed via the model attribute `_tx_parser`.

Custom classes

For each grammar rule a Python class with the same name is created dynamically. These classes are instantiated during the parsing of the input string/file to create a graph of python objects, a.k.a. `model` or Abstract-Syntax Tree (AST).

Most of the time dynamically created classes will be sufficient, but sometimes you will want to use your own classes instead. To do so use parameter `classes` during the meta-model instantiation. This parameter is a list of your classes that should be named the same as the rules from the grammar which they represent.

```
from textx import metamodel_from_str

grammar = '''
EntityModel:
  entities+=Entity    // each model has one or more entities
;

Entity:
  'entity' name=ID '{'
    attributes+=Attribute     // each entity has one or more
attributes
  '}'
;

Attribute:
  name=ID ':' type=[Entity]   // type is a reference to an entity.
There are
                              // built-in entities registered on the
meta-model
                              // for primitive types (integer,
string)
;
'''

class Entity:
  def __init__(self, parent, name, attributes):
    self.parent = parent
    self.name = name
    self.attributes = attributes


# Use our Entity class. "Attribute" class will be created
dynamically.
entity_mm = metamodel_from_str(grammar, classes=[Entity])
```

Now `entity_mm` can be used to parse the input models where our `Entity` class will be instantiated to represent each `Entity` rule from the grammar.

When passing a list of classes (as shown in the example above), you need to have rules for all of these classes in your grammar (else, you get an exception). Alternatively, you can also pass a callable (instead of a list of classes) to return user classes given a rule name. In that case, only rule names found in the grammar are used to query user classes. See unittest.

Note

> Constructor of the user-defined classes should accept all attributes defined by the corresponding rule from the grammar. In the previous example, we have provided `name` and `attributes` attributes from the `Entity` rule. If the class is a child in a parent-child relationship (see the next section), then the `parent` constructor parameter should also be given.

Classes that use `__slots__` are supported. Also, initialization of custom classes is postponed during model loading and done after reference resolving but before object processors call (see Using the scope provider to modify a model) to ensure that immutable objects (e.g. using attr frozen feature), that can't be changed after initialization, are also supported.

Parent-child relationships

There is often an intrinsic parent-child relationship between object in the model. In the previous example, each `Attribute` instance will always be a child of some `Entity` object.

textX gives automatic support for these relationships by providing the `parent` attribute on each child object.

When you navigate model each child instance will have a `parent` attribute.

Note

> Always provide the parent parameter in user-defined classes for each class that is a child in a parent-child relationship.

Processors

To specify static semantics of the language textX uses a concept called **processor**. Processors are python callables that can modify the model elements during model parsing/instantiation or do some additional checks that are not possible to do by the grammar alone.

There are two types of processors:

- **model processors** - are callables that are called at the end of the parsing when the whole model is instantiated. These processors accept the model and meta-model as parameters.
- **object processors** - are registered for particular classes (grammar rules) and are called when the objects of the given class is instantiated.

Processors can modify model/objects or raise exception (`TextXSemanticError`) if some constraint is not met. User code that calls the model instantiation/parsing can catch and handle this exception.

Model processors

To register a model processor call `register_model_processor` on the meta-model instance.

```
from textx import metamodel_from_file

# Model processor is a callable that will accept meta-model and model
as its
# parameters.
def check_some_semantics(model, metamodel):
  ...
  ... Do some check on the model and raise TextXSemanticError if the
semantics
  ... rules are violated.

my_metamodel = metamodel_from_file('mygrammar.tx')

# Register model processor on the meta-model instance
my_metamodel.register_model_processor(check_some_semantics)

# Parse the model. check_some_semantics will be called automatically
after
# a successful parse to do further checks. If the rules are not met,
# an instance of TextXSemanticError will be raised.
my_metamodel.model_from_file('some_model.ext')
```

Object processors

The purpose of the object processors is to validate or alter the object being constructed. They are registered per class/rule.

Let's do some additional checks for the above Entity DSL example.

```
def entity_obj_processor(entity):
  '''
  Check that Ethe ntity names are capitalized. This could also be
specified
  in the grammar using regex match but we will do that check here
just
  as an example.
  '''

  if entity.name != entity.name.capitalize():
    raise TextXSemanticError('Entity name "%s" must be capitalized.'
%
                            entity.name, **get_location(entity))

def attribute_obj_processor(attribute):
  '''
  Obj. processors can also introduce changes in the objects they
process.
  Here we set "primitive" attribute based on the Entity they refer
to.
  '''
  attribute.primitive = attribute.type.name in ['integer', 'string']


# Object processors are registered by defining a map between a rule
name
# and the callable that will process the instances of that rule/
class.
obj_processors = {
    'Entity': entity_obj_processor,
    'Attribute': attribute_obj_processor,
    }

# This map/dict is registered on a meta-model by the
"register_obj_processors"
# call.
entity_mm.register_obj_processors(obj_processors)

# Parse the model. At each successful parse of Entity or Attribute,
the registered
# processor will be called and the semantics error will be raised if
the
# check does not pass.
entity_mm.model_from_file('my_entity_model.ent')
```

For another example of the usage of an object processor that modifies the objects, see object processor `move_command_processor` robot example.

If object processor returns a value that value will be used instead of the original object. This can be used to implement e.g. expression evaluators or on-the-fly model interpretation. For more information

Note

> For more information please take a look at the tests.

Object processors decorated with `textx.textxerror_wrap` will transform any exceptions not derived from `TextXError` to a `TextXError` (including line/column and filename information). This can be useful, if object processors transform values using non-textx libraries (like `datetime`) and you wish to get the location in the model file, where errors occur while transforming the data (see these tests).

Built-in objects

Often, you will need objects that should be a part of each model and you do not want users to specify them in every model they create. The most notable example are primitive types (e.g. `integer` , `string` , `bool`).

Let's provide `integer` and `string` Entities to our `Entity` meta-model in order to simplify the model creation so that the users can use the names of these two entities as the `Attribute` types.

```
class Entity:
    def __init__(self, parent, name, attributes):
        self.parent = parent
        self.name = name
        self.attributes = attributes

entity_builtins = {
        'integer': Entity(None, 'integer', []),
        'string': Entity(None, 'string', [])
}
entity_mm = metamodel_from_file(
  'entity.tx',
  classes=[Entity]            # Register Entity user class,
  builtins=entity_builtins    # Register integer and string built-in
objs
)
```

Now an `integer` and `string` `Attribute` types can be used. See model and Entitiy example for more.

Creating your own base type

Match rules by default return Python `string` type. Built-in match rules (i.e.

BASETYPEs) on the other hand return Python base types.

You can use object processors to create your type by specifying match rule in the grammar and object processor for that rule that will create an object of a proper Python type.

Example:

```
Model:
  'begin' some_number=MyFloat 'end'
;
MyFloat:
  /\d+\.(\d+)?/
;
```

In this example MyFloat rule is a match rule and by default will return Python string , so attribute some_number will be of string type. To change that, register object processor for MyFloat rule:

```
mm = metamodel_from_str(grammar)
mm.register_obj_processors({'MyFloat': lambda x: float(x)}))
```

Now, MyFloat will always be converted to Python float type.

Using match filters you can override built-in rule's conversions like this:

```
Model:
  some_float=INT
;
```

```
mm = metamodel_from_str(grammar)
mm.register_obj_processors({'INT': lambda x: float(x)}))
```

In this example we use built-in rule INT that returns Python int type. Registering object processor with the key INT we can change default behaviour and convert what is matched by this rule to some other object (float in this case).

Auto-initialization of the attributes

Each object that is recognized in the input string will be instantiated and its attributes will be set to the values parsed from the input. In the event that a defined attribute is optional, it will nevertheless be created on the instance and set to the default value.

Here is a list of the default values for each base textX type:

- ID - empty string - ''
- INT - int - 0
- FLOAT - float - 0.0 (also 0 is possible)
- STRICTFLOAT - float - 0.0 (0. or .0 or 0e1, but not 0, which is an INT)
- BOOL - bool - False
- STRING - empty string - ''

Each attribute with zero or more multiplicity (`*=`) that does not match any object from the input will be initialized to an empty list.

An attribute declared with one or more multiplicity (`+=`) must match at least one object from the input and will therefore be transformed to python list containing all matched objects.

The drawback of this auto-initialization system is that we can't be sure if the attribute was missing from the input or was matched, but the given value was the same as the default value.

In some applications it is important to distinguish between those two situations. For that purpose, there is a parameter `auto_init_attributes` of the meta-model constructor that is `True` by default, but can be set to `False` to prevent auto-initialization from taking place.

If auto-initialization is disabled, then each optional attribute that was not matched on the input will be set to `None` . This is true for the plain assignments (`=`). An optional assignment (`?=`) will always be `False` if the RHS object is not matched in the input. The multiplicity assignments (`*=` and `+=`) will always be python lists.

Optional model parameter definitions

A meta-model can define optional model parameters. Such definitions are stored in `model_param_defs` and define optional parameters, which can be specified while loading/creating a model through `model_from_str` or `model_from_file` . Details: see tx_model_params.

`metamodel.model_param_defs` can be queried (like a dict) to retrieve possible extra parameters and their descriptions for a meta-model. It is also used to restrict the additional parameters passed to `model_from_str` or `model_from_file` .

Default parameters are:

- `project_root` : this model parameter is used by the `GlobalRepo` to set a project directory, where all file patterns not referring to an absolute file position are looked up.

An example of a custom model parameter definition used to control the behavior of an object processor is given in test_reference_to_nontextx_attribute.py, (`test_object_processor_with_optional_parameter_*` ; specifying a parameter while loading) and test_reference_to_nontextx_attribute.py (defining the parameter in the metamodel).

textX models

Model is a python object graph consisting of POPOs (Plain Old Python Objects) constructed from the input string that conforms to your DSL defined by the grammar and additional model and object processors.

In a sense, this structure is an Abstract Syntax Tree (AST) known from classic parsing theory, but it is actually a graph structure where each reference is resolved to a proper python reference.

Each object is an instance of a class from the meta-model. Classes are created on-the-fly from the grammar rules or are supplied by the user.

A model is created from the input string using the `model_from_file` and `model_from_str` methods of the meta-model instance.

```
from textx import metamodel_from_file

my_mm = metamodel_from_file('mygrammar.tx')

# Create model
my_model = my_mm.model_from_file('some_model.ext')
```

Note

> The `model_from_file` method takes an optional argument `encoding` to control the input encoding of the model file to be loaded.

Let's take the Entity language used in Custom Classes section.

Content of `entity.tx` file:

```
EntityModel:
  entities+=Entity    // each model has one or more entities
;

Entity:
  'entity' name=ID '{'
    attributes+=Attribute     // each entity has one or more
attributes
  '}'
;

Attribute:
  name=ID ':' type=[Entity]   // type is a reference to an entity.
There are
                              // built-in entities registered on the
meta-model
                              // for the primitive types (integer,
string)
;
```

For the meta-model construction and built-in registration see Custom Classes and Builtins sections.

Now, we can use the `entity_mm` meta-model to parse and create Entity models.

```
person_model = entity_mm.model_from_file('person.ent')
```

Where `person.ent` file might contain this:

```
entity Person {
  name : string
  address: Address
  age: integer
}

entity Address {
  street : string
  city : string
  country : string
}
```

Model API

Functions given in this section can be imported from `textx` module.

`get_model(obj)`

`obj (model object)`

Finds the root of the model following `parent` references.

`get_metamodel(obj)`

Returns meta-model the model given with `obj` conforms to.

`get_parent_of_type(typ, obj)`

- `typ (str or class)` : the name of type of the type itself of the model object searched for.
- `obj (model object)` : model object to start search from.

Finds first object up the parent chain of the given type. If no parent of the given type exists `None` is returned.

`get_children_of_type(typ, root, children_first=False, should_follow=lambda obj: True)`

- `typ (str or python class)` : The type of the model object we are looking for.
- `root (model object)` : Python model object which is the start of the search process.
- `children_first (bool)` : indicates if children should be returned before their parents.
- `should_follow (callable)` : a predicate used to decide if the object should be traversed.

Returns a list of all model elements of type `typ` starting from model element `root` . The search process will follow containment links only. Non-containing references shall not be followed.

`get_children(selector, root, children_first=False, should_follow=lambda obj: True)`

- `selector (callable)` : a predicate returning True if the object is of interest.
- `root (model object)` : Python model object which is the start of the search process.
- `children_first (bool)` : indicates if children should be returned before their parents.
- `should_follow (callable)` : a predicate used to decide if the object should

be traversed.

Returns a list of all selected model elements starting from model element `root`. The search process will follow containment links only. Non-containing references shall not be followed.

`get_location(obj)`

Returns the location of the textX model object in the form of a dict with `line/col/nchar/filename` keys. `nchar` is a substring length of the `obj` in the input string. Filename can be `None` if the model is loaded from a string. Return value is convenient for use in TextX exceptions (e.g. `raise TextXSemanticError('Some message', **get_location(model_obj))`)

`textx_isinstance(obj, cls)`

Return `True` if `obj` is instance of `cls` taking into account textX rule/class hierarchy. For textX created classes you can get a reference to a class from meta-model by keying into it using the class name `metamodel['SomeRule']`.

Special model object's attributes

Beside attributes specified by the grammar, there are several special attributes on model objects created by textX. All special attributes' names start with prefix `_tx`.

These special attributes don't exist if the type of the resulting model object don't allow dynamic attribute creation (e.g. for Python base builtin types - str, int).

_tx_position and _tx_position_end

`_tx_position` attribute holds the position in the input string where the object has been matched by the parser. Each object from the model object graph has this attribute.

This is an absolute position in the input stream. To convert it to line/column format use `pos_to_linecol` method of the parser.

```
line, col = entity_model._tx_parser.pos_to_linecol(
    person_model.entities[0]._tx_position)
```

Where `entity_model` is a model constructed by textX.

Previous example will give the line/column position of the first entity.

`_tx_position_end` is the position in the input stream where the object ends. This position is one char past the last char belonging to the object. Thus, `_tx_position_end - _tx_position == length of the object str representation`.

If you need line, column and filename of a textX object (e.g. for raising `TextXSemanticError`) see get_location above.

_tx_filename

This attribute exists only on the root of the model. If the model is loaded from a file, this attribute will be the full path of the source file. If the model is created from a string this attribute will be `None`.

_tx_parser

This attribute represents the concrete parser instance used for the model (the attribute `_parser` of the `_tx_metamodel` is only a blueprint for the parser of each model instance and cannot be used, e.g., to determine model element positions in a file. Use the `_tx_parser` attribute of the model instead).

_tx_metamodel

This attribute exists only on the root of the model. It is a reference to the meta-model object used for creating the model.

_tx_fqn

Is the fully qualified name of the grammar rule/Python class in regard to the import path of the grammar file where the rule is defined. This attribute is used in `__repr__` of auto-generated Python classes.

_tx_model_repository

The model may have a model repository (initiated by some scope provider or by the metamodel). This object is responsible to provide and cache other model instances (see textx.scoping.providers).

_tx_model_params

This attribute always exists. It holds all additional parameters passed to `model_from_str` or `model_from_file` of a metamodel. These parameters are restricted by the `metamodel.model_param_defs` object (model and object processors), which is controlled by the metamodel designer.

Parser configuration

Case sensitivity

Parser is by default case sensitive. For DSLs that should be case insensitive use `ignore_case` parameter of the meta-model constructor call.

```
from textx import metamodel_from_file

my_metamodel = metamodel_from_file('mygrammar.tx', ignore_case=True)
```

Whitespace handling

The parser will skip whitespaces by default. Whitespaces are spaces, tabs and newlines by default. Skipping of the whitespaces can be disabled by `skipws` bool parameter in the constructor call. Also, what is a whitespace can be redefined by the `ws` string parameter.

```
from textx import metamodel_from_file
my_metamodel = metamodel_from_file('mygrammar.tx', skipws=False,
ws='\s\n')
```

Whitespaces and whitespace skipping can be defined in the grammar on the level of a single rule by rule modifiers.

Automatic keywords

When designing a DSL, it is usually desirable to match keywords on word boundaries. For example, if we have Entity grammar from the above, then a word `entity` will be considered a keyword and should be matched on word boundaries only. If we have a word `entity2` in the input string at the place where `entity` should be matched, the match should not succeed.

We could achieve this by using a regular expression match and the word boundaries regular expression rule for each keyword-like match.

```
Enitity:
  /\bentity\b/ name=ID ...
```

But the grammar will be cumbersome to read.

textX can do automatic word boundary match for all keyword-like string matches. To enable this feature set parameter `autokwd` to `True` in the constructor call.

```
from textx import metamodel_from_file
my_metamodel = metamodel_from_file('mygrammar.tx', autokwd=True)
```

Any simple match from the grammar that is matched by the regular expression `[^\d\W]\w*` is considered to be a keyword.

Memoization (a.k.a. packrat parsing)

This technique is based on memoizing result on each parsing expression rule. For some grammars with a lot of backtracking this can yield a significant speed increase at the expense of some memory used for the memoization cache.

Starting with textX 1.4 this feature is disabled by default. If you think that parsing is slow, try to enable memoization by setting `memoization` parameter to `True` during meta-model instantiation.

```
from textx import metamodel_from_file
my_metamodel = metamodel_from_file('mygrammar.tx', memoization=True)
```

textx command/tool

Executing textX related CLI commands

textX has an extensible CLI tool which is a central hub for all textX CLI commands.

When you install textX with cli dependencies (`pip install textX[cli]`) you get a CLI command `textx` which you call to execute any of the registered sub-commands.

textX registers several sub-commands:

- `check` - used to check models and meta-models for syntax and semantic validity
- `generate` - used to call registered generators and transform given models to other target languages. This command is also used to visualize models and meta-models by generating visualizations. To see how to register your own generators head over to registration/discover section.
- `list-languages` / `list-generators` - used to list registered languages and generators (see the registration/discover feature for more explanations)

Tip

We eat our own dog food so all sub-commands are registered using the same mechanism and there is no distinction between the core commands provided by the textX itself and the commands provided by third-party Python packages.

Please, see Extending textx command section bellow on how to define your own sub-commands investigate `pyproject.toml` of the textX project.

Some of development commands/tools are registered by textX-dev project which is an optional dev dependency of textX. In order to have all these commands available you can either install `textX-dev` project or install textX dev dependencies with `pip install textX[dev]` .

Using the tool

To see all available sub-commands just call the `textx` :

```
$ textx
Usage: textx [OPTIONS] COMMAND [ARGS]...

Options:
  --debug  Debug/trace output.
  --help   Show this message and exit.

Commands:
  check            Check/validate model given its file path.
  generate         Run code generator on a provided model(s).
  list-generators  List all registered generators
  list-languages   List all registered languages
```

To get a help on a specific command:

```
$ textx check --help
Usage: textx check [OPTIONS] MODEL_FILES...

  Check/validate model given its file path. If grammar is given use
it to
  construct the meta-model. If language is given use it to retrieve
the
  registered meta-model.

  Examples:

  # textX language is built-in, so always registered:
  textx check entity.tx

  # If the language is not registered you must provide the grammar:
  textx check person.ent --grammar entity.tx

  # or if we have language registered (see: text list-languages) it's
just:
  textx check person.ent

  # Use "--language" if meta-model can't be deduced by file
extension:
  textx check person.txt --language entity

  # Or to check multiple model files and deduce meta-model by
extension
  textx check *

Options:
  --language TEXT    A name of the language model conforms to.
  --grammar TEXT     A file name of the grammar used as a meta-model.
  -i, --ignore-case  Case-insensitive model parsing. Used only if
"grammar" is
                     provided.
  --help             Show this message and exit.
```

Extending textx command

`textx` command can be extended from other installed Python packages using entry points. Using command extension one can add new commands and command groups to the `textx` command.

`textx` uses click library for CLI commands processing. That makes really easy to create new commands and command groups.

To create a new command you need to provide a Python function accepting a `click` command group (in this case a top level `textx` command) and use the group to register additional commands using `click` decorators.

For example:

```
import click

def testcommand(textx):
  @textx.command()
  @click.argument('some_argument', type=click.Path())
  @click.option('--some-option', default=False, is_flag=True,
                help="Testing option in custom command.")
  def testcommand(some_argument, some_option):
      """
      This command will be found as a sub-command of `textx` command
once this
      project is installed.
      """
      click.echo("Hello sub-command test!")
```

Register new command in your project's `pyproject.toml` file under the entry point `textx_commands` (we are assuming that `testcommand` function is in package `cli`).

```
[project.entry-points.textx_commands]
testcommand = "cli:testcommand"
```

If you install now your project in the same Python environment where `textX` is installed you will see that `textx` command now has your command registered.

```
$ textx
Usage: textx [OPTIONS] COMMAND [ARGS]...

Options:
  --debug  Debug/trace output.
  --help   Show this message and exit.

Commands:
  check        Check validity of meta-model and optionally model.
  testcommand  This command will be found as a sub-command of
`textx`...
  visualize    Generate .dot file(s) from meta-model and optionally
model.


$ textx testcommand some_argument
Hello sub-command test!
```

Similarly you can create new command groups. You can have a group level options and a command level options and arguments.

Here is a full example:

```
import click

def create_testgroup(textx):
    @textx.group()
    @click.option('--group-option', default=False, is_flag=True,
                  help="Some group option.")
    def testgroup(group_option):
        """Here we write group explanation."""
        pass

    @testgroup.command()
    @click.argument('some_argument', type=click.Path())
    @click.option('--some-option', default=False, is_flag=True,
                  help="Testing option in custom command.")
    def groupcommand1(some_argument, some_option):
        """And here we write a doc for particular command."""
        click.echo("GroupCommand1: argument: {}, option:{}".format(
            some_argument, some_option))

    @testgroup.command()
    @click.argument('some_argument', type=click.Path())
    @click.option('--some-option', default=False, is_flag=True,
                  help="Testing option in custom command.")
    def groupcommand2(some_argument, some_option):
        """This is another command docs."""
        click.echo("GroupCommand2: argument: {}, option:{}".format(
            some_argument, some_option))
```

In this example we created a new group called `testgroup`. We use that group in the rest of the code to decorate new commands belonging to the group.

As usual, we have to register our function in the extension point `textx_commands` inside `pyproject.toml`:

```
[project.entry-points.textx_commands]
testgroup = "cli:create_testgroup"
```

If `MyProject` is installed in the environment where `textX` is installed you'll see that your command group is now accessible by the `textx` command:

```
$  textx
Usage: textx [OPTIONS] COMMAND [ARGS]...

Options:
  --debug  Debug/trace output.
  --help   Show this message and exit.

Commands:
  check        Check validity of meta-model and optionally model.
  testcommand  This command will be found as a sub-command of
`textx`...
  testgroup    Here we write group explanation.
  visualize    Generate .dot file(s) from meta-model and optionally
model.


$ textx testgroup
Usage: textx testgroup [OPTIONS] COMMAND [ARGS]...

  Here we write group explanation.

Options:
  --group-option  Some group option.
  --help          Show this message and exit.

Commands:
  groupcommand1  And here we write a doc for particular command.
  groupcommand2  This is another command docs.


$ textx testgroup groupcommand1 first_argument
GroupCommand1: argument: first_argument, option:False
```

For a full example please take a look at this test and this example test project.

For more information please see click documentation.

Registration and discovery

textX has an API for registration and discovery of languages and code generators. This enable developing languages and generators for others to use by simply installing from PyPI using `pip`.

textX utilizes a concept of extension point to declaratively specify the registration of language or generator. Each Python project/package may in its `pyproject.toml` declare this extensions. Once a Python package which declare the extension is installed in the environment, the extension can be dynamically found.

To make it easier to find languages and generators on PyPI we recommend the following naming scheme for the Python packages that provide a single language or generator:

- `textx-lang-<language name>` - for language package (e.g. `textx-lang-entity`)
- `textx-gen-<source language>-<target language>` - for generator package (e.g. `textx-gen-entity-java`)

With this scheme in place searching PyPI for all languages or generators can be easily achieved by `pip search` command (e.g. `pip search textx-lang` to find all languages).

textX languages

textX language consists of a meta-model which holds information of all language concepts and their relations (a.k.a. *Abstract syntax*) as well as a parser which knows how to transform textual representation of a language (a.k.a. *Concrete syntax*) to a *model* which conforms to the meta-model.

Also, each language has its unique name, a short one-line description and a file name pattern for recognizing files that contains textual representation of its models.

Registering a new language

To register a new language first you have to create an instance of `LanguageDesc` class (or its subclass) providing the name of the language, the file pattern of files using the language (e.g. `*.ent`), the description of the language and finally a callable that should be called to get the instance of the language meta-model. Alternatively, you can provide the instance of the meta-model instead of the callable.

For example:

```
from textx import LanguageDesc

def entity_metamodel():
    # Some code that constructs and return the language meta-model
    # E.g. call to metamodel_from_file

entity_lang = LanguageDesc('entity',
                           pattern='*.ent',
                           description='Entity-relationship
language',
                           metamodel=entity_metamodel)
```

The next step is to make this language discoverable by textX. To do this we have to register our `entity_lang` object in the `pyproject.toml` entry point named `textx_languages`.

```
[project.entry-points.textx_languages]
entity = "entity.metamodel:entity_lang"
```

In this example `entity.metamodel` is the Python module where `entity_lang` is defined.

When you install this project textX will discover your language and offer it through registration API (see bellow).

As a convenience there is a `language` decorator that makes creating an instance of `LanguageDesc` more convenient. Use it to decorate meta-model callable and provide the name and the file pattern as parameters. Docstring of the decorated function will be used as a language description.

The equivalent of the previous definition using the `language` decorator would be:

```
from textx import language

@language('entity', '*.ent')
def entity_lang():
    """
    Entity-relationship language
    """
    # Some code that constructs and return the language meta-model
    # E.g. call to metamodel_from_file
```

The `pyproject.toml` entry point registration would be the same.

Warning

> Language name is its unique identifier. There *must not* exist two languages with the same name. The name consists of alphanumerics, underscores (`_`) and dashes (`-`). If you plan to publish your language on PyPI choose a name that is higly unlikely to collide with other languages (e.g. by using some prefix, `mycompanyname-entity` instead of just `entity`).

Listing languages

textX provides a core command `list-languages` that lists all registered languages in the current environment. We eat our own dog food so even `textX` grammar language is registered as a language using the same mechanism.

```
$ textx list-languages
txcl (*.txcl)         textx-gen-coloring    A language for syntax
highlight definition.
textX (*.tx)          textX                 A meta-language for
language definition
types-dsl (*.etype)   types-dsl             An example DSL for simple
types definition
data-dsl (*.edata)    data-dsl              An example DSL for data
definition
flow-dsl (*.eflow)    flow-dsl              An example DSL for data
flow processing definition
```

The first column gives the language unique name and filename pattern, the second column is the Python project which registered the language and the third column is a short description.

You can get a reference to a registered language meta-model in your programs by using the registration API `metamodel_for_language` call. For example:

```
from textx import metamodel_for_language
data_dsl_mm = metamodel_for_language('data-dsl')

model = data_dsl_mm.model_from_file('my_model.data')
```

textX generators

textX generators are callables which can transform any textX model to an arbitrary (usually textual) representation. Similarly to languages, generators can be registered and discovered. They can also be called either programmatically or from

CLI using `textx` command.

Registering a new generator

To register a new generator first you have to create an instance of `GeneratorDesc` class (or its subclass) providing the name of the source language, the name of the target language, a short one-line description of the generator and finally a callable that should be called to perform code generation. The callable is if the form:

```
def generator(metamodel, model, output_path, overwrite, debug,
**custom_args)
```

where:

- `metamodel` - is the meta-model of the source language
- `model` - is the model for which the code generating is started
- `output_path` - is the root folder path where the output should be stored
- `overwrite` - a bool flag that tells us should we overwrite the target files if they exist
- `debug` - a bool flag which tells us if we are running in debug mode and should we produce more output
- `**custom_args` - additional generator-specific arguments. When the generator is called from the CLI this parameter will hold all other switches that are not recognized

For example:

```
from textx import GeneratorDesc

def entity_java_generator(metamodel, model, output_path, overwrite,
debug, **custom_args)
    # Some code that perform generation

entity_java_generator = GeneratorDesc(
    language='entity',
    target='java'
    description='Entity-relationship to Java language generator',
    generator=entity_java_generator)
```

The next step is to make this generator discoverable by textX. To do this we have to register our `entity_java_generator` object in the `pyproject.toml` entry point named `textx_generators`.

```
[project.entry-points.textx_generators]
entity_java = "entity.generators:entity_java_generator"
```

Tip

> You can also register generator programmatically using registration API. But if you want your generator to be available to `textx` command you should use `pyproject.toml` .

In this example `entity.generators` is the Python module where `entity_java_generator` is defined.

When you install this project textX will discover your generator and offer it through registration API (see bellow).

As a convenience there is a `generator` decorator that makes creating an instance of `GeneratorDesc` more convenient. Use it to decorate generator callable and provide the name and the source and target language as parameters. Docstring of the decorated function will be used as a generator description.

The equivalent of the previous definition using the `generator` decorator would be:

```
from textx import generator

@generator('entity', 'java')
def entity_java_generator(metamodel, model, output_path, overwrite,
debug, **custom_args)
    "Entity-relationship to Java language generator"
    # Some code that perform generation
```

The `pyproject.toml` would remain the same.

Here is an example of the generator of `dot` files from any textX model. This is an actual code from textX.

```
@generator('any', 'dot')
def model_generate_dot(metamodel, model, output_path, overwrite,
debug):
    "Generating dot visualizations from arbitrary models"

    input_file = model._tx_filename
    base_dir = output_path if output_path else
os.path.dirname(input_file)
    base_name, _ = os.path.splitext(os.path.basename(input_file))
    output_file = os.path.abspath(
        os.path.join(base_dir, "{}.{}".format(base_name, 'dot')))
    if overwrite or not os.path.exists(output_file):
        click.echo('-> {}'.format(output_file))
        model_export(model, output_file)
        click.echo('    To convert to png run "dot -Tpng -O {}"'
                   .format(os.path.basename(output_file)))
    else:
        click.echo('-- Skipping: {}'.format(output_file))
```

Listing generators

textX provides a core command `list-generators` that lists all registered generators in the current environment.

```
$ textx list-generators
textX -> dot          textX                  Generating dot
visualizations from textX grammars
textX -> PlantUML     textX                  Generating PlantUML
visualizations from textX grammars
any -> dot            textX                  Generating dot
visualizations from arbitrary models
flow-dsl -> PlantUML flow-codegen           Generating PlantUML
visualization from flow-dsl
```

The first column gives the generator identifier, the second column is the Python project which registered the generator and the third column is a short description.

Generators are identified by pair `(<source language name>, <target language name>)` . The source language must be registered in the environment for the generator to be able to parse the input. The target output is produced by the generator itself so the target language doesn't have to registered.

Note

> We eat our own dog food so even `textX` visualization is done as using the generator mechanism.

Calling a generator

You can get a reference to a generator by using the registration API. For example `generator_for_language_target` call will return the generator for the given source language name and target language name.

```
from textx import generator_for_language_target
robot_to_java = generator_for_language_target('robot', 'java')

robot_to_java(robot_mm, my_model)
```

Warning

If you are using `@generator` decorator and want to programmatically call the generator do not call the decorated fuction as it is transformed to `GeneratorDesc` instance. Instead, use `generator_for_language_target` call from the registration API as described.

A more convenient way is to call the generator from the CLI. This is done using the textX provided `generate` command.

To get a help on the command:

```
$ textx generate --help
Usage: textx generate [OPTIONS] MODEL_FILES...

  Run code generator on a provided model(s).

  For example::

  # Generate PlantUML output from .flow models
  textx generate mymodel.flow --target PlantUML

  # or with defined output folder
  textx generate mymodel.flow -o rendered_model/ --target PlantUML

  # To chose language by name and not by file pattern use --language
  textx generate *.flow --language flow --target PlantUML

  # Use --overwrite to overwrite target files
  textx generate mymodel.flow --target PlantUML --overwrite

  # In all above cases PlantUML generator must be registered, i.e.:
  $ textx list-generators
  flow-dsl -> PlantUML  Generating PlantUML visualization from flow-
dsl

  # If the source language is not registered you can use the .tx
grammar
  # file for parsing but the language name used will be `any`.
  textx generate --grammar Flow.tx --target dot mymodel.flow

Options:
  -o, --output-path PATH  The output to generate to. Default = same
as input.
  --language TEXT         A name of the language model conforms to.
Deduced
                          from file name if not given.
  --target TEXT           Target output format.  [required]
  --overwrite             Should overwrite output files if exist.
  --grammar TEXT          A file name of the grammar used as a meta-
model.
  -i, --ignore-case       Case-insensitive model parsing. Used only
if
                          "grammar" is provided.
  --help                  Show this message and exit.
```

You can pass arbitrary parameters to the `generate` command. These parameters will get collected and will be made available as `kwargs` to the generator function call.

For example:

```
textx generate mymodel.flow --target mytarget --overwrite --
meaning_of_life 42
```

Your generator function:

```
@generator('flow', 'mytarget')
def flow_mytarget_generator(metamodel, model, output_path, overwrite,
debug, **kwargs):
    ... kwargs has meaning_of_life param
```

gets `meaning_of_life` param with value `42` in `kwargs`.

If you have model parameters defined on a meta-model then any parameter passed to the generator that is registered on the meta-model will be available as `model._tx_model_params` and can be used e.g. in model processors.

Registration API

Language registration API

All classes and functions documented here are directly importable from `textx` module.

- `LanguageDesc` - a class used as a structure to hold language meta-data

  Attributes:

  - `name` - a unique language name
  - `pattern` - a file name pattern used to recognized files containing the language model
  - `description` - a short one-line description of the language
  - `metamodel` - callable that is called to get the meta-model or the instance of the meta-model

- `language_description(language_name)` - return an instance of `LanguageDesc` given the language name

- `language_descriptions()` - return a dict of `language name` -> `LanguageDesc` instances

- `register_language(language_desc_or_name, pattern=None, description='', metamodel=None)` - programmatically register language by either providing an instance of `LanguageDesc` as the first parameter or providing separate parameters

- `clear_language_registrations()` - deletes all languages registered programmatically. Note: languages registered through `pyproject.toml` won't be removed

- `metamodel_for_language(language_name, **kwargs)` - returns a meta-model for the given language name. `kwargs` are additional keyword arguments passed to meta-model factory callable, similarly to `metamodel_from_str/file`.

- `language_for_file(file_name_or_pattern)` - returns an instance of `LanguageDesc` for the given file name or file name pattern. Raises `TextXRegistrationError` if no language or multiple languages can parse the given file

- `languages_for_file(file_name_or_pattern)` - returns a list of `LanguageDesc` for the given file name or file name pattern

- `metamodel_for_file(file_name_or_pattern, **kwargs)` - returns a language meta-model for a language that can parse the given file name or file name pattern. `kwargs` are additional keyword arguments passed to meta-model factory callable, similarly to `metamodel_from_str/file`. Raises `TextXRegistrationError` if no language or multiple languages can parse the given file

- `metamodels_for_file(file_name_or_pattern)` - returns a list of meta-models for languages that can parse the given file name or file pattern

- `language` - a decorator used for language registration

Warning

> Meta-model instances are cached with a given `kwargs` so the same instance can be retrieved in further calls without giving `kwargs`. Whenever `kwargs` is given in `metamodel_for_file/language` call, a brand new meta-model will be created and cached for further use.

Generator registration API

- `GeneratorDesc` - a class used as a structure to hold generator meta-data

  Attributes:

  - `name` - a unique language name
  - `pattern` - a file name pattern used to recognized files containing the language model
  - `description` - a short one-line description of the language
  - `metamodel` - callable that is called to get the meta-model or the instance of the meta-model

- `generator_description(language_name, target_name, any_permitted=False)` - return an instance of `GeneratorDesc` with the given language and target. If `any_permitted` is `True` allow for returning generator for the same target and the source language `any` as a fallback.
- `generator_descriptions()` - return a dict of dicts where the first key is the source language name in lowercase and the second key is the target language name in lowercase. Values are `GeneratorDesc` instances.
- `generator_for_language_target(language_name, target_name, any_permitted=False)` - returns generator callable for the given language source and target. If `any_permitted` is `True` allow for returning generator for the same target and the source language `any` as a fallback.
- `register_generator(generator_desc_or_language, target=None, description='', generator=None)` - programmatically register generator by either providing an instance of `GeneratorDesc` as the first parameter or providing separate parameters
- `clear_generator_registrations` - deletes all generators registered programmatically. Note: generators registered through `pyproject.toml` won't be removed
- `generator` - a decorator used for generator registration

Visualization

A meta-model, model and parse-tree can be exported to dot files (GraphViz) for visualization. Module `textx.export` contains functions `metamodel_export` and `model_export` that can export meta-model and model to dot files respectively. But, it is usually more convenient to produce visualization using the `textx` command.

If debugging is enabled, meta-model, model and parse trees will automatically get exported to dot.

Dot files can be viewed by dot viewers. There are quite a few dot viewers freely available (e.g. xdot, ZGRViewer).

Alternatively, dot files can be converted to image formats using `dot` command. For more info see this SO thread.

In addition to GraphViz we also support PlantUML as target for our exports (see textx command/tool). You can copy-paste the exported file content online on the PlantUML website to visualize it. The PlantUML Tool is a JAR file (Java) which runs on various platforms. Many Linux distributions have this tool included (e.g. Ubuntu: `apt install platuml`).

Producing (meta)model visualizations using the `textx` command

This section describes how to use `textx` command and registered generators to produce model and meta-model visualizations.

Visualizations of models and meta-models are implemented by registering generators from `textX` (for meta-models) or `any` (for all models) to `dot` or `PlantUML` file format. Several of these generators are provided by textX. You can list them by list-generators command:

```
$ textx list-generators
textX -> dot          textX                   Generating dot
visualizations from textX grammars
textX -> PlantUML     textX                   Generating PlantUML
visualizations from textX grammars
any -> dot            textX                   Generating dot
visualizations from arbitrary models
flow-dsl -> PlantUML flow-codegen             Generating PlantUML
visualization from flow-dsl
```

You see that we have two generators from `textX` language (i.e. textX grammar language) registered by the `textX` project. The first as a target uses `dot` and the second uses `PlantUML`. These generators will produce `dot` (part of GraphViz) or `pu` (PlantUML) file respectively.

Also, you can see that there is `any` -> `dot` generator. This generator can be applied to any model and will produce `dot` output.

You can also see in this example that we have a specific visualization for language `flow-dsl` that produces `PlantUML` code. You can register visualizers for your own language by registering a generator from your language to some output that represents visual rendering. Also, you could provide rendering to some different format for all models (`any`) or for textX grammars. See the registration/discovery feature on how to do that.

Note

> Generators that produce visualization are by no means different from any other generators (e.g. those that would produce Java or Python code).

Here is an example on how to produce the same visualization described in section Visualization (see the robot example).

```
$ textx generate robot.tx --target dot
Generating dot target from models:
/home/igor/repos/textX/textX/examples/robot/robot.tx
-> /home/igor/repos/textX/textX/examples/robot/robot.dot
   To convert to png run "dot -Tpng -O robot.dot"
```

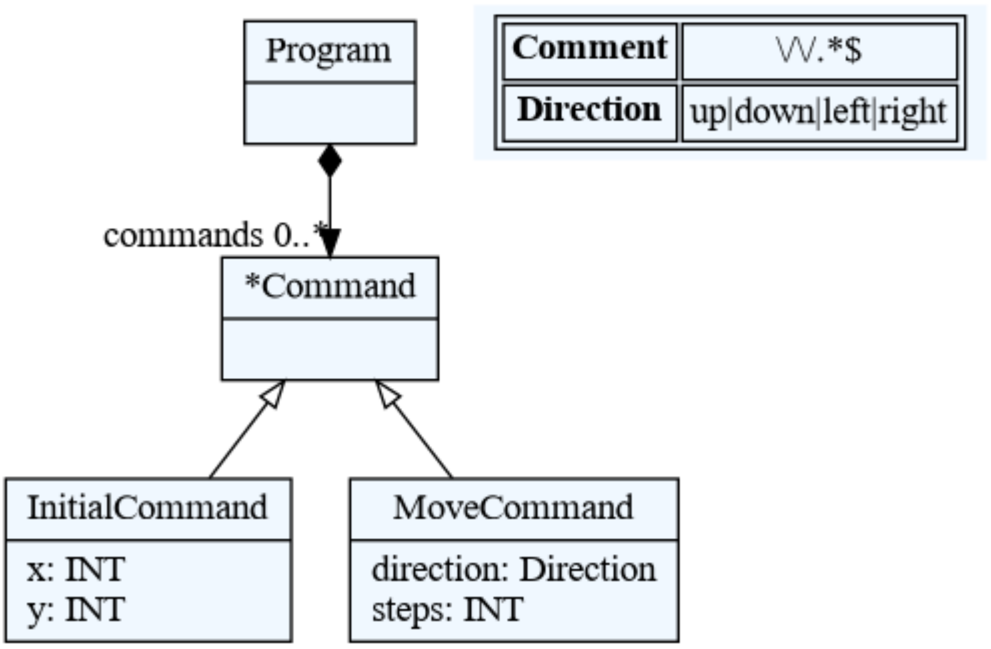
Now you can view `dot` file using some of available viewers. For example, if you install xdot:

```
$ xdot robot.dot
```

or convert it to some other graphical format (GraphViz is needed):

```
$ dot -Tpng -O robot.dot
```

and you will get `robot.dot.png` that looks like this:



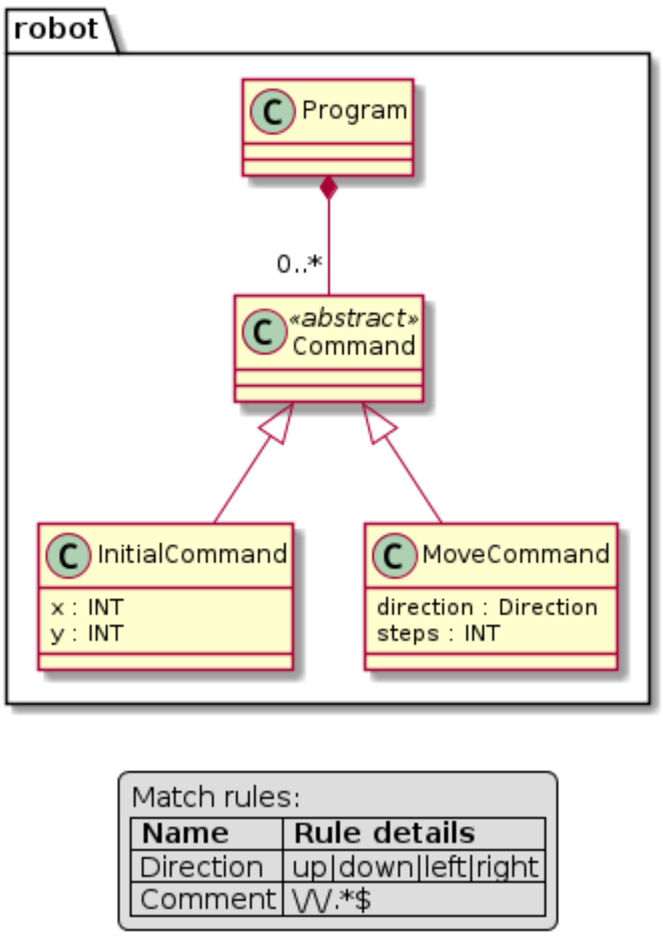
You can also generate PlantUML output from the grammar files:

```
$ textx generate robot.tx --target plantuml
Generating plantuml target from models:
/home/igor/repos/textX/textX/examples/robot/robot.tx
-> /home/igor/repos/textX/textX/examples/robot/robot.pu
To convert to png run 'plantuml /home/igor/repos/textX/textX/
examples/robot/robot.pu'
```

This will produce file `robot.pu` . Now convert it to `robot.png` by (PlantUML must be installed and accessible on path):

```
$ plantuml robot.pu
```

The produced `robot.png` image will look like this:



Match rules:

Name	Rule details
Direction	up|down|left|right
Comment	\/\/.*$

Tip

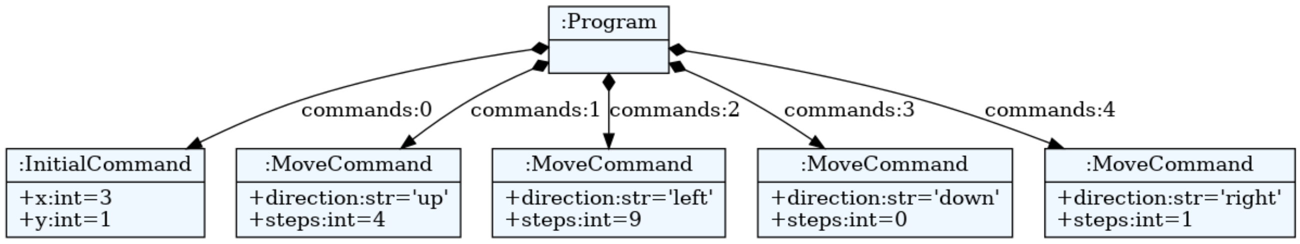
> PlantUML generator accepts additional parameter `linetype` which controls the style of lines in the diagram. Possible values are `ortho` and `polyline`. For example:
>
> ```
> $ textx generate robot.tx --target plantuml --linetype ortho
> ```

Similarly you can generate output from any model. For example:

```
$ textx generate program.rbt --grammar robot.tx --target dot
Generating dot target from models:
/home/igor/repos/textX/textX/examples/robot/program.rbt
-> /home/igor/repos/textX/textX/examples/robot/program.dot
   To convert to png run "dot -Tpng -O program.dot"
```

In this example we had to supply `--grammar` option to `generate` command as the `robot` language is not registered by the registration API. If we had the robot language registered, meta-model could be discovered by the file extension.

We could as usual visualize the `dot` file by some of the available viewers or transform it to `png` format. The produced image will look like this:



Note

> PlantUML output is not yet available for model files.

Visualize meta-models programmatically

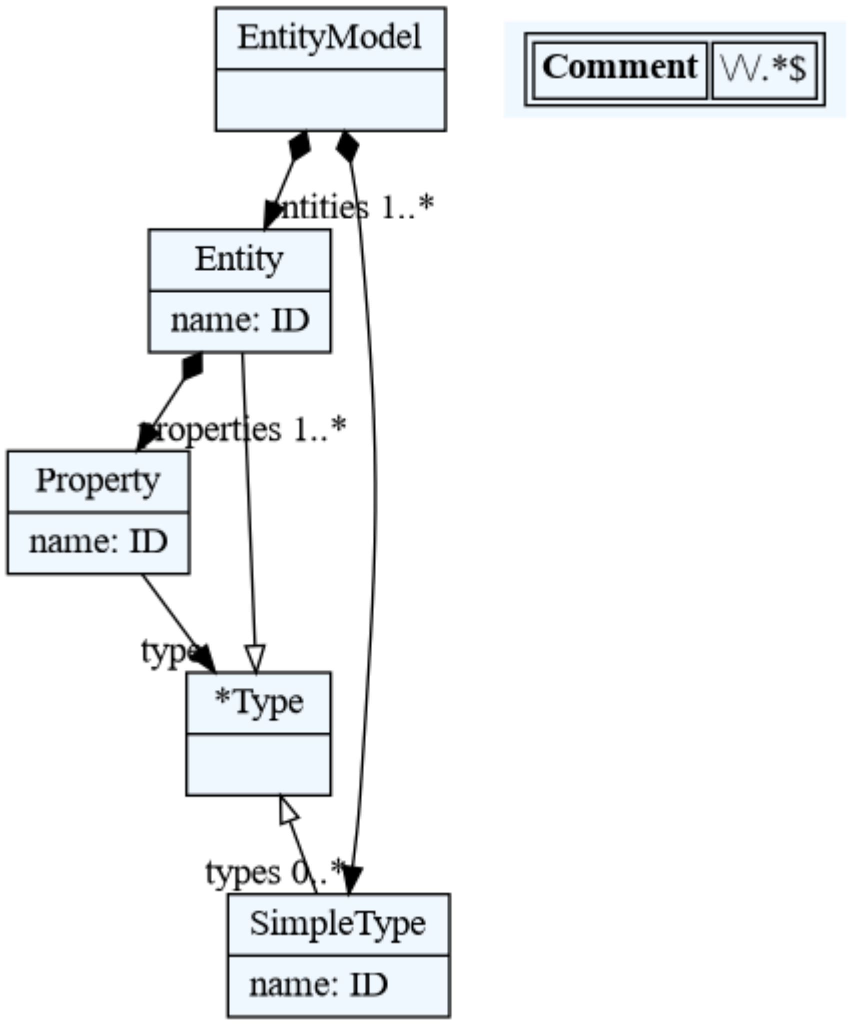
To visualize a meta-model programmatically do (see Entity example):

```
from textx import metamodel_from_file
from textx.export import metamodel_export

entity_mm = metamodel_from_file('entity.tx')

metamodel_export(entity_mm, 'entity.dot')
```

`entity.dot` file will be created. You can visualize this file by using various dot viewers or convert it to various image formats using the `dot` tool.

```
$ dot -Tpng -O entity.dot
```

The following image is generated:



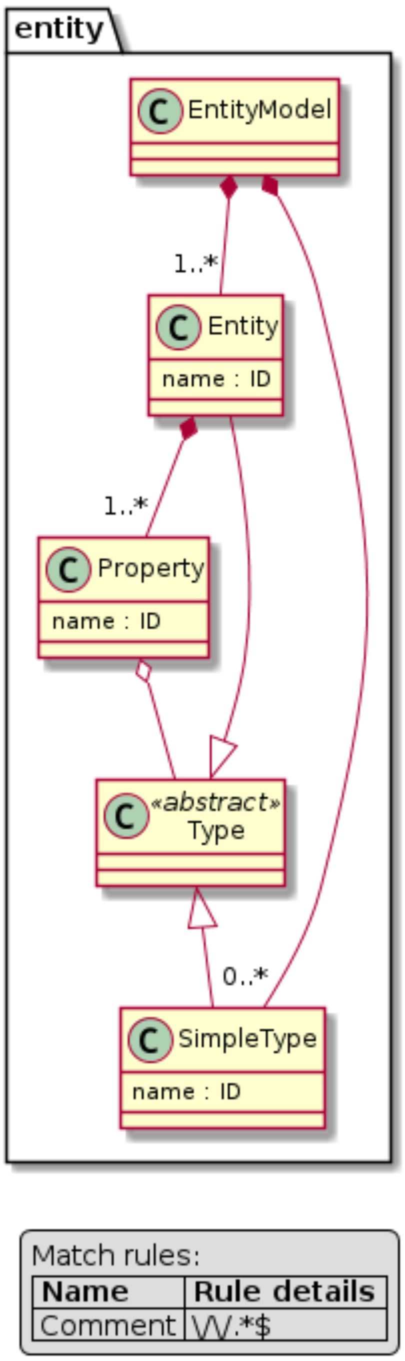
Alternatively, you can also specify an alternative renderer to export your meta model for the PlantUML tool.

```
from textx import metamodel_from_file
from textx.export import metamodel_export, PlantUmlRenderer

entity_mm = metamodel_from_file('entity.tx')

metamodel_export(entity_mm, 'entity.pu',renderer=PlantUmlRenderer())
```

`entity.pu` file will be created. You can convert it to various image formats using the `plantuml` tool.

```
$ plantuml -Tpng entity.pu
```

The following image is generated:



Match rules:

Name	Rule details
Comment	\/\/.*$

Visualize models programmatically

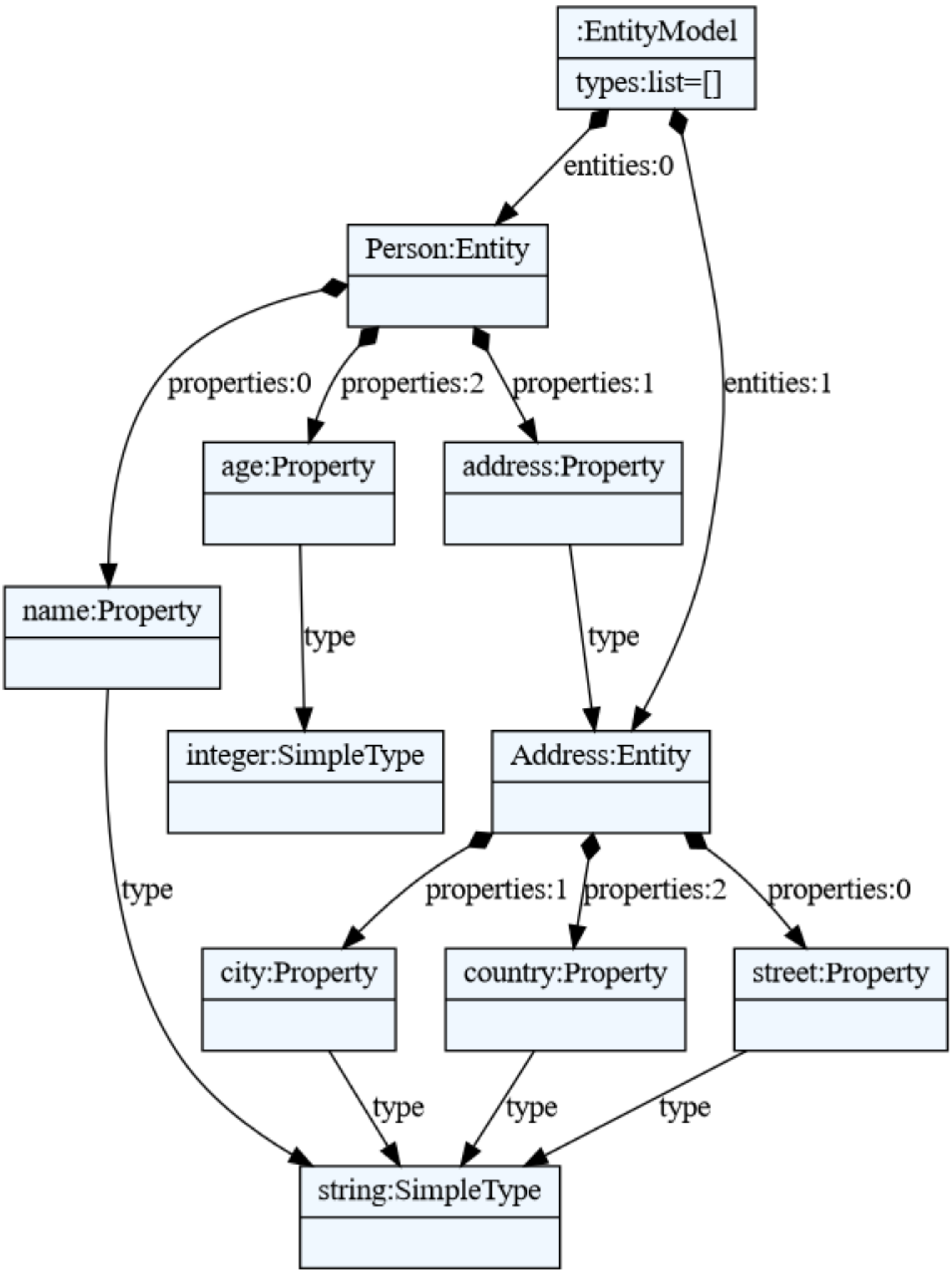
Similarly to meta-model visualization, you can also visualize your models (see Entity example).

```
from textx.export import model_export

person_model = entity_mm.model_from_file('person.ent')

model_export(person_model, 'person.dot')
```

Convert this `dot` file to `png` with:

```
$ dot -Tpng -O person.dot
```

The following image is generated:



textX projects scaffolding

Warning

`startpoject` command is provided by textX-dev project. You have to either install this project or install textX optional dev dependencies with `pip install textX[dev]`.

In case you are developing many textX languages and generators and would like to do some organization we have provided a textX command `startproject` that will generate either a language or a generator project with all necessary project files to get you started quickly.

To scaffold a project just run:

```
textx startproject <folder>
```

You will be asked several questions and then the project will be generated in the given folder. After that you can:

```
pip install -e <folder>
```

to install your project in development mode.

Your language/generator will be registered in the project `setup.cfg` file and visible to textX which you can verify with:

```
textx list-languages
```

for language project or

```
textx list-generators
```

for generator project.

Answers to questions are cached in your home folder so the next time you run scaffolding you don't have to type all the answers. If the default provided answer is OK just press Enter.

Tip

Check the textX registration and discovery for details on `list-generators` and `list-languages` commands and recommended naming for language/ generator textX projects.

HowTos

Modeling hierarchical data structures: referencing attributes

The idea is to model a structure with attributes (which may again be structures).

```
struct A {
    val x
}
struct B {
    val a: A
}
struct C {
    val b: B
    val a: A
}
struct D {
    val c: C
    val b1: B
    val a: A
}

instance d: D
reference d.c.b.a.x
reference d.b1.a.x
```

- Unittest tests/functional/examples/test_hierarchical_data_structures_referencing_attributes.py

Modeling classes and objects: class inheritance

Inherited attributes or methods can be accumulated with the textx.scoping.providers.ExtRelativeName scope provider:

- Unittest (classes with pseudo inherited methods) tests/functional/test_scoping/test_metamodel_provider3.py
    - test_metamodel_provider_advanced_test3_inheritance2
    - test_metamodel_provider_advanced_test3_diamond
- Unittest (components with inherited slots) tests/functional/test_scoping/test_inheritance.py

Modeling Wiki-like texts with references inside

The idea is to model a string with an arbitrary content and links to other objects (the links are encoded with a special symbol, e.g. "[myref]" or - like in the exmample referenced below "@[myref]"):

```
ENTRY Hello:    """a way to say hello\@mail (see @[Hi])"""
ENTRY Hi:       """another way to say hello (see @[Hello])"""
ENTRY Salut:    """french "hello"
(@[Hello]@[Hi]@[Bonjour]@[Salut]@[Hallo])"""
ENTRY Hallo:    """german way to say hello (see ""@[Hello]"")"""
ENTRY Bonjour:  """another french "\@@[Hello]", see @[Salut]"""
ENTRY NoLink:   """Just text"""
ENTRY Empty:    """"""
```

- Unittest tests/functional/examples/test_free_text_with_references.py

Referencing a JSON database from within a textX model

Here, we link a textX model with a non textX database (could be any database or data structure available in python). If you have, e.g., a DOORS binding, you could also reference such information sources.

- JSON-File "data.json":

```
{
  "name": "pierre",
  "gender": "male"
}
```

- TextX-model:

```
import "data.json" as data
access A1 data.name
access A2 data.gender
```

- Unittest tests/functional/test_scoping/test_reference_to_nontextx_attribute.py

Referencing global data using full qualified names

- Example model:

  ```
  package P1 {
      class Part1 {
      }
  }
  package P2 {
      class Part2 {
          attr C2 rec;
      }
      class C2 {
          attr P1.Part1 p1;
          attr Part2 p2a;
          attr P2.Part2 p2b;
      }
  }
  ```

- Unittest tests/functional/test_scoping/test_full_qualified_name.py

Multi-file models

- Unittest (global import) tests/functional/test_scoping/test_global_import_modules.py
- Unittest (explicit import, "importURI") tests/functional/test_scoping/test_import_module.py
- Unittest (explicit import, "importURI" with custom search path) tests/functional/test_scoping/test_import_module_search_path_issue66.py

Multi-metamodel multi-file models

Here, we focus on referencing model elements from models based on other textX meta models. These other meta models are typically imported from other python modules (e.g. deployed separately).

In the example referenced below, we simulate three modules with three classes in the unittest. Each class take the role of one module and defines one concrete DSL. These DLS reference each other.

- Model example (types.type) - "Type"-DSL

```
type int
type string
```

- Model example (data_structures.data) - "Data"-DSL

```
#include "types.type"

data Point { x: int y: int}
data City { name: string }
data Population { count: int}
```

- Model example (data_flow.flow) - "Flow"-DSL

```
#include "data_structures.data"
#include "types.type" // double include, loaded 1x only

algo A1 : Point -> City
algo A2 : City -> Population
connect A1 -> A2
```

- Model example (data_flow.flow) - "Flow"-DSL with validation error

```
#include "data_structures.data"

algo A1 : Point -> City
algo A2 : City -> Population
connect A2 -> A1 // Error, must be A1 -> A2
```

- Unittest tests/functional/test_metamodel/test_multi_metamodel_refs.py

Enable and distinguish float and int values for attributes

- Model text:

```
x1 = 1
x2 = -1
y1 = 1.0
y2 = 1.1e-2
y3 = -1.1e+2
```

- Unittest tests/functional/examples/test_modeling_float_int_variables.py

Parsing structures inside arbitrary surrounding text

See this StackOverflow question.

Optimizing grammar performance

When it comes to parsing very large files with textX, the performance issues may arise. In certain cases, a good performance improvement can be achieved by optimizing the grammar.

Investigating the grammar with the parse trace option enabled (`debug=true`) helps to reveal the excessive backtrackings (unsuccessful matches) that are essentially the wasted computations. By investigating these backtrackings, valuable clues can be obtained regarding possible inefficiencies in the grammar design.

Known optimization techniques:

- Reorder OrderedChoice to put first those members that occur more often in inputs.
- If a grammar has a hot path that is called out very often and this path contains negative assertions (see this example), these negative assertions can be optimized by merging them all together in a single regex. Regex engine is implemented in C and is much faster to handle the negative assertions in one go compared to when the negative matching is done by Arpeggio on the Python level.

Caching parsed content to speed up processing

Parsing a single text file with textX can be fast. However, when dealing with multiple files that need to be re-parsed every time a program is invoked, it is worth considering the option of caching the parsed content.

One straightforward solution, using Python, involves utilizing Python's pickle module. After running a textX job, a set of Python objects is created based on the textX grammar. The Pickle module allows storing these objects in a file on the file system. Consequently, when the program is executed again, instead of parsing the textX grammar from scratch, the program can efficiently recreate the Python objects from the cached file.

To ensure that the cache remains valid, the modification date of the original text file can be compared with that of the cached file. If the cached file is found to be older than the original text file, it indicates that the textX parser needs to be called again to obtain the latest result and subsequently update the cached file.

textX Scoping

Motivation and Introduction to Scoping

Assume a grammar with references as in the following example (grammar snippet).

```
MyAttribute:
        ref=[MyInterface:FQN] name=ID ';'
;
```

The scope provider is responsible for the reference resolution of such a reference.

The default behavior (default scope provider) is looking for the referenced name globally (not taking any nested model structures into account, such as nested model-packages, model-namespaces or similar).

Other scope providers will take namespaces into account, support references to parts of the model stored in different files or even models defined by other metamodels (imported into the current metamodel). Moreover, scope providers exist that allow to reference model elements relative to other referenced model elements. For example, this can be a referenced method defined in a referenced class of an instance (with a metamodel defining classes, methods and instances of classes).

Usage

The scope providers are registered with a metamodel and can be bound to specific attributes of grammar rules:

- e.g., `my_meta_model.register_scope_providers({"*.*": scoping.providers.FQN()})` bounds `FQN` provider to all attributes of all grammar rules due to `*.*`
- or: `my_meta_model.register_scope_providers({"MyAttribute.ref": scoping.providers.FQN()})` bounds `FQN` provider to attribute `ref` of grammar rule `MyAttribute`
- or: `my_meta_model.register_scope_providers({"*.ref": scoping.providers.FQN()})` bounds `FQN` provider to `ref` attribute of all grammar rules.
- or: `my_meta_model.register_scope_providers({"MyAttribute.*": scoping.providers.FQN()})` bounds `FQN` provider to all attributes of `MyAttribute` grammar rule

Example (from tests/test_scoping/test_local_scope.py):

```
# Grammar snippet (Components.tx)
Component:
    'component' name=ID ('extends' extends+=[Component:FQN][','])?
'{'
        slots*=Slot
    '}'
;
Slot: SlotIn|SlotOut;
# ...
Instance:
    'instance' name=ID ':' component=[Component:FQN] ;
Connection:
    'connect'
      from_inst=[Instance:ID] '.' from_port=[SlotOut:ID]
    'to'
      to_inst=[Instance:ID] '.' to_port=[SlotIn:ID]
;
```

```
# Python snippet
my_meta_model = metamodel_from_file(
    os.path.join(abspath(dirname(__file__)), 'components_model1',
'Components.tx')

my_meta_model.register_scope_providers({
    "*.*": scoping_providers.FQN(),
    "Connection.from_port": scoping_providers.RelativeName(
        "from_inst.component.slots"),
    "Connection.to_port": scoping_providers.RelativeName(
        "to_inst.component.slots"),
})
```

This example selects the fully qualified name provider as default provider (`"*.*"`). Moreover, for special attributes of a `Connection` a relative name lookup is specified: here the `path` from the rule `Connection` containing the attribute of interest (e.g. `Connection.from_port`) to the referenced element is specified (the slot contained in `from_inst.component.slots`). Since this attribute is a list, the list is searched to find the referenced name.

Note

> Special rule selections (e.g., `Connection.from_port`) are preferred to wildcard selection (e.e, `"*.*"`).

Scope Providers defined in Module "textx.scoping.providers"

Note

> The scope provider implementations presented here assume that the `name` attribute of named elements has a string type (e.g. ´name=ID´).

We provide some standard scope providers:

- `textx.scoping.providers.PlainName` : This is the **default provider** of textX. It implements global naming within one model (model file/string) without namespaces.
- `textx.scoping.providers.FQN` : This is a **provider similar to Java or Xtext name loopup** within one model (model file/string). Example: see tests/test_scoping/test_full_qualified_name.py.

  A central feature of this scope provider is, that it **traverses the model tree and searches for a matching sequence of named objects** (objects with an attribute `name` matching parts of the full qualified name separated by dots). You can also provide a **callback** (`scope_redirection_logic`) to specify that certain named objects are not searched recursively, but are replaced by a list of objects instead, which are searched in place of the current object. With this feature you can create, e.g., **namespace/package aliases** in your language. You can also activate a **python like module import behavior** for your language (with `textx.scoping.providers.FQNImportURI`), which is based on this callback. Example: see tests/functional/regressions/test_issue103_python_like_import.py.

  ```
  package p1 {
      package p2 {
          class a {};
      }
  }
  using p1.p2 as main
  var x = new p1.p2.a()
  var y = new main.a()
  ```

  Note

  > Except in the context of the `scope_redirection_logic` (see above), the FQN does not take Postponed (unresolved) references into account. The reason is that this would create a much more complex decision logic to decide which reference needs to be resolved first. The purpose of the FQN is to identify direct instances of model objects, and no references.

- `textx.scoping.providers.ImportURI` : This a provider which **allows to load additional modules** for lookup. You need to define a rule with an attribute `importURI` as string (like in Xtext). This string is then used to load other models. Moreover, you need to provide another scope provider to manage the concrete lookup, e.g., the `scope_provider_plain_names` or the `scope_provider_fully_qualified_names` . Model objects formed by the rules with an `importURI` attribute get an additional attribute `_tx_loaded_models` which is a list of the loaded models by this rule instance. Example: see tests/test_scoping/test_import_module.py.

  - `FQNImportURI` (decorated scope provider)
  - `PlainNameImportURI` (decorated scope provider)

  You can use ***globbing*** (e.g. `import "*.data"`) with the ImportURI feature. This is implemented via the Python `glob` module. Arguments can be passed to the `glob.glob` function (`glob_args`), e.g., to enable recursive globbing. Alternatively, you can also specify a list of ***search directories***. In this case globbing is not allowed and is disabled (reason: it is unclear if the user wants to glob over all search path entries or to stop after the first match). Example: see tests/test_scoping/test_import_module_search_path_issue66.py.

- `textx.scoping.providers.GlobalRepo` : This is a provider where **you initially need to specifiy the model files to be loaded and used for lookup**. Like for `ImportURI` you need to provide another scope provider for the concrete lookup. Example: see tests/test_scoping/test_global_import_modules.py.

  - `textx.scoping.providers.FQNGlobalRepo` (decorated scope provider)

    Here, you can also activate the "importAs" feature to allow to make imported models not visible in your root namespace, but related to a named importURI element (tests/test_scoping/importURI_variations/test_importURI_variations.py)

    You can also transform the importURI attribute to a filename: see (tests/test_scoping/importURI_variations/test_importURI_variations.py.

  - `textx.scoping.providers.PlainNameGlobalRepo` (decorated scope provider)

- `textx.scoping.providers.RelativeName` : This is a scope provider to **resolve relative lookups**: e.g., model-methods of a model-instance, defined by the class associated with the model-instance. Typically, another reference (the reference to the model-class of a model-instance) is used to determine the concrete referenced object (e.g. the model-method, owned by a model-class). Example: see tests/test_scoping/test_local_scope.py.

- `textx.scoping.providers.ExtRelativeName` : The same as `RelativeName`

allowing to model inheritance or chained lookups. Example: see tests/test_scoping/test_local_scope.py.

Note on Uniqueness of Model Elements (global repository)

Two different models created using one single meta-model (not using a scope provider like `GlobalRepo`, but by directly loading the models from file) have different instances of the same model elements. If you need two such models to share their model element instances, you can specify this, while creating the meta model (`global_repository=True` or `global_repository=instance_of_a_global_repo`). Then, the meta model will store an own instance of a `GlobalModelRepository` as a base for all loaded models.

Model elements in models including other parts of the model (possibly circular) have unique model elements (no double instances).

Examples see tests/test_scoping/test_import_module.py.

Included model retrieval

When a model includes or references other model (model files), the scope providers in `textx.scoping.providers` use the field `_tx_model_repository` of the model object to keep track of the included models.

- You can get a list of all included model objects of a model and the model itself with `textx.scoping.providers.get_all_models_including_attached_models`.
- You can check if a model file is included by a model with `textx.scoping.providers.is_file_included_by_model`.

Builtin models

Similarly to builtin objects that are searched by their names, as a fallback you can provide model repository using `builtin_models` parameter during meta-model construction. These models will be searched by scoping providers based on `ImportURI` scoping provider after searching into a local model and all loaded models fails.

This is handy to provide builtin models of the language that are pre-loaded and don't need to be imported by each user model.

Here is a full example that demonstrates this feature:

```
from textx import metamodel_from_str, metamodel_for_language,
register_language
from textx.scoping import ModelRepository

types_mm = metamodel_from_str(r'''
Model: types+=BaseType;
BaseType: 'type' name=ID;
''')

# We register `types` language to be available by `reference`
# statement in the main meta-model
register_language('types', '*.type', 'Simple types language',
types_mm)

# Now in the main meta-model we use `references` to access the
# type language. We also use RREL for `Property.type` (+m:types) to
# specify where instances of `BaseType` can be found.
entity_mm_str = r'''
reference types as t
Model: entities+=Entity;
Entity: 'entity' name=ID '{'
              properties*=Property
        '}'
;
Property: name=ID ':' type=[t.BaseType:ID|+m:types];
'''

# Get `types` language meta-model
types_mm = metamodel_for_language('types')

builtin_models = ModelRepository()

# Construct types model and add it to the repository.
# We instantiate the types model with two BaseType instances: `int`
and `bool`
builtin_models.add_model(types_mm.model_from_str('type int type
bool'))

# BaseType object `int` and `bool` will now be available to the
# entity meta-model. Standard RREL search mechanism will be used to
find the
# referenced model object
entity_mm = metamodel_from_str(entity_mm_str,
builtin_models=builtin_models)

# In this model `bool` type is accessible despite not being
explicitly imported.
model = entity_mm.model_from_str(r'''
entity First {
    first : bool
}
''')

assert model.entities[0].properties[0].type.name == 'bool'
assert model.entities[0].properties[0].type.__class__.__name__ ==
'BaseType'
''')
```

Technical aspects and implementation details

The scope providers are Python callables accepting `obj, attr, obj_ref`:

- `obj` : the object representing the start of the search (e.g., a rule, like `MyAttribute` in the example above, or the model)
- `attr` : a reference to the attribute (e.g. `ref` in the first example above)
- `obj_ref` : a `textx.model.ObjCrossRef` - the reference to be resolved

The scope provider return the referenced object (e.g. a `MyInterface` object in the example illustrated in the `Motivation and Introduction` above (or `None` if nothing is found; or a `Postponed` object, see below).

The scope provider is responsible to check the type and throw a `TextXSemanticError` if the type is not OK.

Scope providers shall be stateless or have unmodifiable state after construction: this means they should allow to be reused for different models (created using the same meta-model) without interacting with each other. This means, they must save their state in the corresponding model, if they need to store data (e.g., if they load additional models from files *during name resolution*, they are not allowed to store them inside the scope provider.

Models with references being resolved have a temporary attribute `_tx_reference_resolver` of type `ReferenceResolver`. This object can be used to resolve the object. It contains information, such as the parser in charge for the model (file) being processed.

Note

> Scope providers as normal functions (`def <name>(...):...`), not accessing global data, are safe per se. The reason to be stateless, is that no side effects (beside, e.g., loading other models) should influence the name lookup.

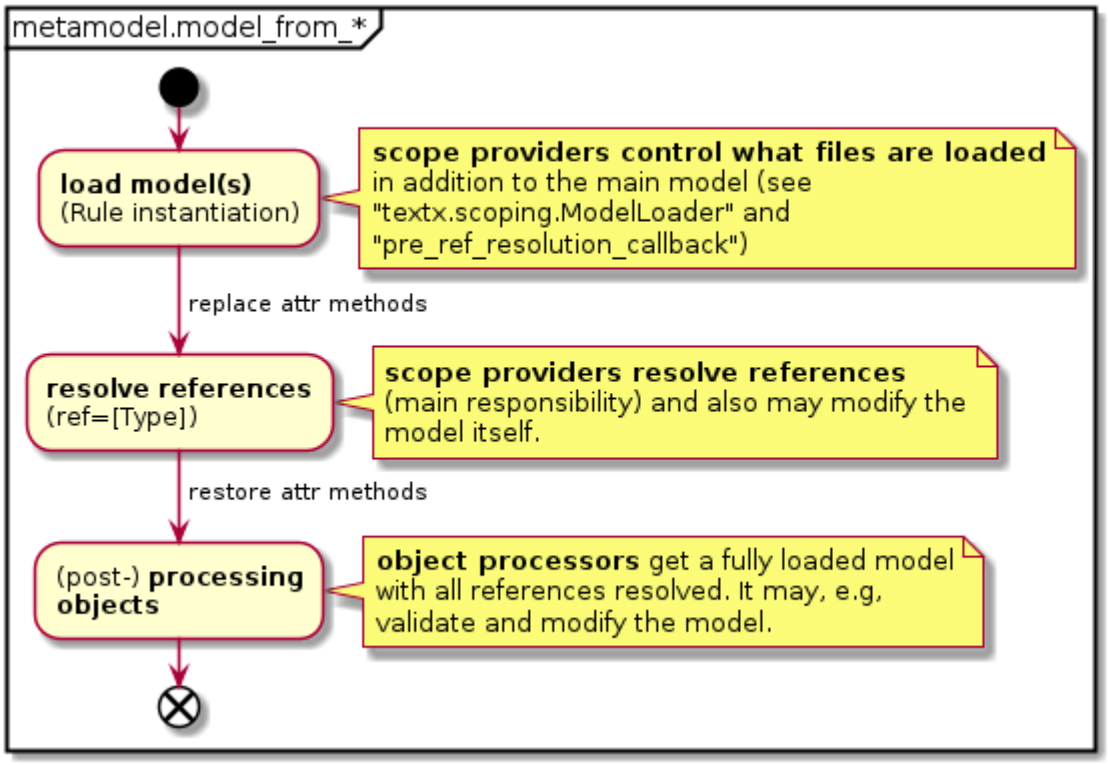
The state of model resolution should mainly consist of models already loaded. These models are stored in a `GlobalModelRepository` class. This class (if required) is stored in the model. An included model loaded from another including model "inherits" the part of the `GlobalModelRepository` representing all loaded models. This is done to (a) cache already loaded models and (b) guarantee, that every referenced model element is instantiated exactly once. Even in the case of circular inclusions.

Scope providers may return an object of type `Postponed` , if they depend on another event to happen first. This event is typically the resolution of another reference. The resolution process will repeat multiple times over all unresolved references to be resolved until all references are resolved or no progress regarding the resolution is observed. In the latter case an error is raised. The control flow responsibility of the resolution process is allocated to the `model.py` module.

Using the scope provider to modify a model

Model creation by the metamodel (loading the model) is divided into a set of strictly ordered activities. Understanding that order makes it clear where in the metamodel and its configuration (e.g., scope providers or object processors) it is allowed to modify the model itself and what has to be taken into account.

The following image sketches these ordered activities:


metamodel.model_from_*
load model(s)
(Rule instantiation)
scope providers control what files are loaded
in addition to the main model (see
"textx.scoping.ModelLoader" and
"pre_ref_resolution_callback")
replace attr methods
resolve references
(ref=[Type])
scope providers resolve references
(main responsibility) and also may modify the
model itself.
restore attr methods
(post-) processing
objects
object processors get a fully loaded model
with all references resolved. It may, e.g,
validate and modify the model.

The image illustrates that, while **resolving references**, all directly modeled objects are already loaded and instantiated. Scoping takes place after the model is completely parsed. Thus, while resolving references you can rely on the assumption that all model elements already exist.

It also shows, that **objects processors** kick in when all references are resolved. That means that no references are resolved any more after or while the first object processor has been executed. One **exception** is when calling **object processors for match rules** (e.g. regular expressions or rules like 'ID'): these processors are *called bottom up* during model construction. Those object processors should generally be a very simple, usually just a type conversions so they don't need a fully constructed model. **Other object processors** (i.e. those operating on common rules) are called, as depicted above, on a constructed model, *in bottom up* fashion.

Note

> While resolving references, user classes have modified attr-methods (`__setattr__`, `__getattr__`, `__delattr__`, and `__getattribute__`) in order to enable user classes with modified/restricted attribute access, like classes employing `__slots__` (see Custom classes).

Use case: reference data in non-textx models

If you want to **reference an element not directly modelled** (instantiated), you need to instantiate or load this element or information somewhere. This information can be, e.g., information from a non-textx model, such as a JSON file (see: test_reference_to_nontextx_attribute.py). Since you need to resolve a reference (e.g. to an `[OBJECT]` in the given example), you cannot rely on object processors, since they are executed *after* reference resolution. Thus, scope providers need to take care of that (e.g., take care of loading the JSON data).

Use case: reference data "defined by references"

You may have the use case, that you want to define/instantiate objects by referencing them (on the fly). This may happen, if your meta model allows to define a model element by referencing it (like PlantUML is doing for, e.g., classes). In that case **your scope provider creates (invents) model elements**.

If you then require to reference these model elements "defined by a reference" by another "non-inventing reference", you must take into account that these elements may have not yet been created. This can be achieved in the same way as handling unresolved references in a scope provider (with the `Postponed` mechanism). This use case was motivated by #167.

An example of such a meta model is given in tests/test_model_modification_through_scoping.py: Here you can

- **define** Persons explicitly (existence) and
- **reference** two persons which **know** each other (relationship). Moreover, **referencing a nonexistent persons** (all person explicitly defined by the grammar have been created at the time of reference resolving) will **create an additional (new) person** (and, thus, modify the model).

In an extension of the grammar we then also allow

- to **greet** persons. This also happens by referencing a person (like for the "knows"-relationship). But this time, **nonexistent persons shall not be created**, but should yield a referencing error.

  Implementation: Since it is unclear if a nonexistent person may be created by a not yet resolved "knows"-relationship reference, we have to postpone the resolution of a failed greeting (return `Postponed`). The reference resolution mechanism will detect if a state is reached with only postponed references and will then raise an error, as expected.

Reference resolving expression language (RREL)

RREL allows to specify scope provider (lookup) specification in the grammar itself (grammar example and an example test).

The idea is to support all current builtin scoping providers (e.g., `FQN`, `RelativeName` etc.; see scoping) while the user would have to resort to Python only to support some very specific cases or referring to models not handled by textX.

A RREL expression is written as a third part of the textX link rule reference.

For example:

```
Attribute: 'attr' ref=[Class:FQN|^packages*.classes] name=ID ';';
```

This grammar rule has a `ref` attribute which is a reference to the `Class` rule. This is a link rule reference as it is enclosed inside of square brackets. It consists of three parts where first two parts are separated by `:` while the second and the third are separated by `|`. The first part defines the target object type or its grammar rule. The second part defines what will parser match at the place of the reference. It would be a fully qualified name of the target object (thus `FQN`). The third part of the reference is RREL expression (`^packages*.classes`). Second and third part of the reference are optional. If second part is not given `ID` is assumed. If RREL expression is not given the default resolver, which search the reference in the global scope, will be used.

Each reference in the model, by default, forms a dot separated name, which is matched by the second part of the link rule reference in the grammar, where a plain ID is just a special case. For example, a reference could be `package1.component4` or just `component4`. We could further generalize this by saying that a reference is a sequence of names where a plain ID is just a sequence of length 1. It doesn't have to be dot separated. A user could provide a custom match rule (like `FQN` in the above example) and a match processor to convert the matched string to a sequence of names. There is also the possibility to define the separator sequence (by default a dot), as demonstrated in sub-section "RREL reference name deduction" bellow.

For reference resolving as an input we have:

- A dot separated name matched by the parser, where ID is a special case
- A RREL expression

We evaluate RREL expression using the name in the process and we yield referenced object or an error.

RREL operators

Reference resolving expression language (RREL) consists of several operators (see test):

- `.` Dot navigation. Search for the attribute in the current AST context. Can be used for navigation up the parent chain, e.g. `.` is this object, `..` is parent, `...` is a parent of a parent. If the expression starts with a `.` than we have a relative path starting from the current AST context. Otherwise we have an absolute path starting from the root of the model unless `^` is used (see below). For example, `.a.b` means search for `a` attribute at the current level (`.`) and than search for `b` attribute. Expression `a.b` would search starting from the root of the model.

- `parent(TYPE)` - navigate up the parent chain until the exact type is found.

- `~` This is a marker applied to a path element to inform resolver that the current collection should not be searched by the current name part but that all elements should be processed. For example, to search for a method in the inheritance hierarchy one would write `~extends*.methods` which (due to `*` , see below) first searches `methods` collection of the current context object, if not found, all elements of the current `extends` collection are iterated in the order of defintion without consuming name part, and then name would be searched in the `methods` collection of each object from the `extends` collection. If not found `*` would expand `extends` to `extends.extends` if possible and the search would continue.

- `'name-value'~` The `~` operator takes an additional optional string to indicate that the part of the name is not consumed, but is expected to be the value indicated by the passed string: `'myname'~myattribute` means *follow attribute `myattribute`, if it is named `'myname'`*.

  The following example sketches parts of a meta-model, where the lookup rules indicate a fallback to some `types_collection` entry with the name `'builtin'` (of course such an object must be present to successfully resolve such references, e.g., by adding a builtin model with that information (see tests/test_scoping/test_rrel.py, test_rrel_with_fixed_string_in_navigation):

```
        Using: 'using' name=ID "=" type=[Type:ID|+m:
              ~active_types.types,                // "regular
    lookup"
              'builtin'~types_collection.types    // "default
    lookup" - name "builtin"
                                                  // hard coded in
    grammar
          ];
```

- `*` - Repeat/expand. Used in expansion step to expand sub-expression by 0+ times. First expansion tried will be 0, then once, then twice etc. For example, `~extends*.methods` would search in `methods` collection in the current context object for the current name part. If not found expansion of `*` would took place and we would search in `~extends.methods` by iterating over `extends` collection without consuming part name (due to `~`) and searching by ref. name part inside `methods` collection of each iterated object. The process would continue (i.e. `~extends.~extends.methods` ...) until no more expansion is possible as we reach the end of inheritance chain.

- `^` - Bottom-up search. This operator specifies that the given path should be expanded bottom-up, up the parent chain. The search should start at the current AST context and go up the parent chain for the number of components in the current expanded path. Then the match should be tried. See the components example above using `^` in `extends`. For example, `^a.b.c` would start from the current AST level and go to the parent of the parent, search there for `a`, then would search for `b` in the context of the previous AST search result, and finally would search for attribute `c`. `^` is a marker applied to path search subexpression, i.e. it doesn't apply to the whole sequence (see below).

- `,` - Defines a sequence, i.e. a sequence of RREL expressions which should tried in order.

Priorities from highest to lowest: `*`, `.`, `,`.

`~` and `^` are regarded as markers, not operators.

RREL evaluation

Evaluation goes like this:

1. Expand the expression. Expand `*` starting from 0 times.
2. Match/navigate the expression (consume part names in the process)
3. Repeat

The process stops when either:

- all possibilities are exhausted and we haven't find anything -> error.
- in `*` we came to a situation where we consume all part names before we finished with the RREL expression -> error.
- We have consumed all path name elements, finished with RREL expression and found the object. If the type is not the same as the type given in the grammar reference we report an error, else we found our object.

RREL reference name deduction

The name of a referenced object is transformed into a list of non-empty name parts, which is processed by a RREL expression to navigate through the model. Possible names are defined in the grammar, e.g. `FQN` in the following example (used in rule `Attribute` to reference a model class:

```
Model:     packages*=Package;
Package:   'package' name=ID '{' classes*=Class '}';
Class:     'class' name=ID '{' attributes*=Attribute '}';
Attribute: 'attr' ref=[Class:FQN|^packages*.classes] name=ID ';';
Comment:   /#.*/;
FQN:       ID('.'ID)*;
```

The name of a reference (`Attribute.ref`) could then be, e.g., `P1.Part1` (the package `P1` and the class `Part1`), separated by a dot. The **dot is the default separator** (if no other separator is specified).

```
package P1 {
    class Part1 {
    }
}
package P2 {
    class Part2 {
        attr C2 rec;
    }
    class C2 {
        attr P1.Part1 p1;
        attr Part2 p2a;
        attr P2.Part2 p2b;
    }
}
```

The match rule used to specify possible reference names (e.g., `FQN`) can **specify a separator used to split the reference name into individual name parts**. Use the rule parameter `split` , which must be a non-empty string (e.g. `split='/'` ; note that the match rule itself should produce names, for which the given separator makes sense):

```
Model:           packages*=Package;
Package:         'package' name=ID '{' classes*=Class '}';
Class:           'class' name=ID '{' attributes*=Attribute '}';
Attribute:       'attr' ref=[Class:FQN|^packages*.classes] name=ID
';';
Comment:         /#.*/;
FQN[split='/']: ID('/'ID)*;  // separator split='/'
```

Then the RREL scope provider (using the match rule with the extra rule parameter `split`) automatically uses the given split character to process the name.

RREL and multi files model

Use the prefix `+m:` for an RREL expression to activate a multi file model scope provider. Then, in case of no match, other loaded models are searched. When using this extra prefix the importURI feature is activated (see scoping and grammar example).

Accessing the RREL 'path' of a resolved reference

Use the prefix `+p:` for an RREL expression to access the complete path of named elements for a resolved reference. For that, the resolved reference is represented by a proxy which is transparent to the user is terms of attribute access and `textx_instanceof` semantics.

The proxy (`textx.scoping.rrel.ReferenceProxy`) provides two extra fields: `_tx_obj` and `_tx_path` . `_tx_obj` represent the referenced object itself and `_tx_path` is a list with all named elements traversed during scope resolution. The last entry of the list is `_tx_obj` .

The following model shows how to employ the `+p:` flag and is used in the unittest referenced for the following use case:

```
Model:
    structs+=Struct
    instances+=Instance
    references+=Reference;
Struct:
    'struct' name=ID '{' vals+=Val '}';
Val:
    'val' name=ID (':' type=[Struct])?;
Instance:
    'instance' name=ID (':' type=[Struct])?;
Reference:
    'reference' ref=[Val:FQN|+p:instances.~type.vals.(~type.vals)*];
FQN: ID ('.' ID)*;
```

The **use case** for that feature is that you sometimes need to access all model elements specified in a model reference. Consider a reference to a hierarchically modelled data element like in this unittest example, e.g. `reference d.c.b.a.x`:

```
struct A {
    val x
}
struct B {
    val a: A
}
struct C {
    val b: B
    val a: A
}
struct D {
    val c: C
    val b1: B
}
instance d: D
reference d.c.b.a.x
reference d.b1.a.x
```

In this example you need all referenced intermediate model elements to accurately identify the modelled data for, e.g., code generation because `reference d.c.b.a.x` is not distinguishable from `reference d.b1.a.x` without the path (both point to the field `x` in `A`).

Using RREL from Python code

RREL expression could be used during registration in place of scoping provider. For example:

```
my_meta_model.register_scope_providers({
        "*.*": scoping_providers.FQN(),
        "Connection.from_port": "from_inst.component.slots"  # RREL
        "Connection.to_port": "from_inst.component.slots"      # RREL
    })
```

RREL processing (internal)

RREL expression are parsed when the grammar is loaded and transformed to AST consisting of RREL operator nodes (each node could be an instance of `RREL` prefixed class, e.g `RRELSequence`). The expressions ASTs are stateless and thus it is an important possibility to define the same expression for multiple attributes by using wildcard as the same expression tree would be used for the evaluation.

In the process of evaluation the root of the expression tree is given the sequence of part names and the current context which represent the parent object of the reference in the model AST. The evaluation is then carried out by recursive calls of the RREL AST nodes. Each node gets the AST context consisting of a collection of objects from the model and a current unconsumed part names collection, which are the result of the previous operation or, in the case of the root expression AST node, an initial input. Each operator object should return the next AST context and the unconsumed part of the name. At the end of the successful search AST context should be a single object and the names parts should be empty.

Multi meta-model support

There are different ways to combine meta models: **(1)** a meta model can use another meta model to compose its own structures (extending a meta model) or **(2)** a meta model can reference elements from another meta model. **(3)** Moreover, we also demonstrate, that we can combine textX metamodels with arbitrary non-textX metamodels/models available in python.

(1) Extending an existing meta model can be realized in textX by defining a grammar extending an existing grammar. All user classes, scope providers and processors must be manually added to the new meta model. Such extended meta models can also reference elements of models created with the original meta model. Although the meta classes corresponding to inherited rules are redefined by the extending meta model, scope providers match the object types correctly. This is implemented by comparing the types by their name (see textx.textx_isinstance). Simple examples: see tests/functional/test_scoping/test_metamodel_provider*.py.

(2) Referencing elements from another meta model can be achieved without having the original grammar, nor any other details like scope providers, etc. Such references can, thus, be enabled by using just a referenced language name in a `reference` statement of referring grammar. Target language meta-model may originate from a library installed on the system (without sources, like the grammar). The referencing grammar can reference the types (rules) of the referenced meta model. Rule lookup takes care of choosing the correct types. Simple examples: see tests/functional/test_metamodel/test_multi_metamodel_refs.py.

To identify a referenced grammar you need to register the grammar to be referenced with the registration API.

Tip

> When designing a domain model (e.g., from the software test domain) to reference elements of another domain model (e.g., from the interface/communication domain), the second possibility (see **(2) referencing**) is probably a **cleaner way** to achieve the task than the first possibility (see **(1)** extending).

Note

> A full example project that shows how multi-meta-modeling feature can be used is also available in a separate git repository.

Use Case: meta model referencing another meta model

Note

> The example in this section is based on the tests/functional/test_metamodel/test_multi_metamodel_refs.py.

We have two languages/grammars (grammar `A` and `B`). `grammarA` string defines named elements of type `A`:

```
Model: a+=A;
A:'A' name=ID;
```

`GrammarBWithImportURI` string defines named elements of type `B` referencing elements of type `A` (from `grammarA`). This is achieved by using `reference` statement with alias. It also allows importing other model files by using `importURI`.

```
reference A as a
Model: imports+=Import b+=B;
B:'B' name=ID '->' a=[a.A];
Import: 'import' importURI=STRING;
```

We now proceed by registering languages using registration API:

```
global_repo = scoping.GlobalModelRepository()
global_repo_provider = scoping_providers.PlainNameGlobalRepo()

def get_A_mm():
    mm_A = metamodel_from_str(grammarA,
global_repository=global_repo)
    mm_A.register_scope_providers({"*.*": global_repo_provider})
    return mm_A

def get_BwithImport_mm():
    mm_B = metamodel_from_str(grammarBWithImport,
                              global_repository=global_repo)

    # define a default scope provider supporting the importURI
feature
    mm_B.register_scope_providers(
        {"*.*": scoping_providers.FQNImportURI()})
    return mm_B

register_language('A',
                  pattern="*.a",
                  metamodel=get_A_mm)

register_language('BwithImport',
                  pattern="*.b",
                  metamodel=get_BwithImport_mm)
```

Note that we are using a global repository and `FQNImportURI` scoping provider for `B` language to support importing of `A` models inside `B` models and referencing its model objects.

Tip

> In practice we would usually register our languages using declarative extension points. See the registration API docs for more information.

After the languages are registered we can access the meta-models of registered languages using the registration API. Given the model in language `A` in file `myA_model.a`:

```
A a1 A a2 A a3
```

and model in language `B` (with support for `ImportURI`) in file `myB_model.b`:

```
import 'myA_model.a'
B b1 -> a1 B b2 -> a2 B b3 -> a3
```

we can instantiate model `myB_model.b` like this:

```
mm_B = metamodel_for_language('BwithImport')
model_file_name = os.path.join(os.path.dirname(__file__),
'myB_model.b')
model = mm_B.model_from_file(model_file_name)
```

In another way we could use a global model repository directly to instantiate models directly from Python code without resorting to `ImportURI` machinery. For this we shall modify the grammar of language `B` to be:

```
reference A
Model: b+=B;
B:'B' name=ID '->' a=[A.A];
```

Notice that we are not using the `ImportURI` functionality to load the referenced model here. Since both meta-models share the same global repository, we can directly add a model object to the `global_repo_provider` (`add_model`) of language A. This model object will then be visible to the scope provider of the second model and make the model object available. We register this language as we did above. Now, the code can look like this:

```
mm_A = metamodel_for_language('A')
mA = mm_A.model_from_str('''
A a1 A a2 A a3
''')
global_repo_provider.add_model(mA)

mm_B = metamodel_for_language('B')
mB = mm_B.model_from_str('''
B b1 -> a1 B b2 -> a2 B b3 -> a3
''')
```

See how we explicitly added model `mA` to the global repository. This enabled model `mB` to find and resolve references to objects from `mA` .

Note

It is crucial to use a scope provider which supports the global repository, such as the `ImporUri` or the `GlobalRepo` based providers, to allow the described mechanism to add a model object directly to a global repository.

Use Case: Recipes and Ingredients with global model sharing

Note

> The example in this section is based on the test_metamodel_provider2.py.

In this use case we define recipes (food preparation) including a list of ingredients. The ingredients of a recipe model element are defined by:

- a count (e.g. 100),
- a unit (e.g. gram),
- and an ingredient reference (e.g. sugar).

In a separate model the ingredients are defined: Here we can define multiple units to be used for each ingerdient (e.g. `60 gram of sugar` or `1 cup of sugar`). Moreover some ingredients may inherit features of other ingredients (e.g. salt may have the same units as sugar).

Here, two meta-models are defined:

- `Ingredient.tx` , to handle ingredient definitions (e.g. `fruits.ingredient` model) and
- `Recipe.tx` , for recipe definitions (e.g. `fruit_salad.recipe` model).

The registration API is utilized to bind the file extensions to the meta-models (see test_metamodel_provider2.py). Importantly, a common model repository (`global_repo`) is defined to share all model elements among both meta models:

```
i_mm = get_meta_model(
    global_repo, join(this_folder, "metamodel_provider2",
"Ingredient.tx"))
r_mm = get_meta_model(
    global_repo, join(this_folder, "metamodel_provider2",
"Recipe.tx"))

clear_language_registrations()
register_language(
    'recipe-dsl',
    pattern='*.recipe',
    description='demo',
    metamodel=r_mm
)
register_language(
    'ingredient-dsl',
    pattern='*.ingredient',
    description='demo',
    metamodel=i_mm
)
```

Tip

> In practice we would usually register our languages using declarative extension points. See the registration API docs for more information.

Use Case: meta model sharing with the ImportURI-feature

Note

> The example in this section is based on the test_metamodel_provider.py.

In this use case we have a given meta-model to define components and instances of components. A second model is added to define users which use instances of components defined in the first model.

The grammar for the user meta-model is given as follows (including the ability to import a component model file).

```
import Components

Model:
    imports+=Import
    users+=User
;

User:
    "user" name=ID "uses" instance=[Instance:FQN] // Instance, FQN
from other grammar
;

Import: 'import' importURI=STRING;
```

The registration API is utilized to bind a file extension to the corresponding meta-model:

```
register_language(
    'components-dsl',
    pattern='*.components',
    description='demo',
    metamodel=mm_components  # or a factory
)
register_language(
    'users-dsl',
    pattern='*.users',
    description='demo',
    metamodel=mm_users  # or a factory
)
```

With this construct we can define a user model referencing a component model:

```
import "example.components"
user pi uses usage.action1
```

Tip

> In practice we would usually register our languages using declarative extension points. See the registration API docs for more information.

Use Case: referencing non-textX meta-models/models

Note

> The example in this section is based on the test_reference_to_buildin_attribute.py.

You can reference an arbitrary python object using the `OBJECT` rule (see: test_reference_to_buildin_attribute.py)

```
Access:
    'access' name=ID pyobj=[OBJECT] ('.' pyattr=[OBJECT])?
```

In this case the referenced object will be a python dictionary referenced by `pyobj` and the entry of such a dictionary will be referenced by `pyattr`. An example model will look like:

```
access AccessName1 foreign_model.name_of_entry
```

`foreign_model` in this case is a plain Python dictionary provided as a custom built-in and registered during meta-model construction:

```
foreign_model = {
    "name": "Test",
    "value": 3
}
my_metamodel = metamodel_from_str(metamodel_str,
                                  builtins={
                                      'foreign_model':
foreign_model})
```

A custom scope provider is used to achieve mapping of `pyobj/pyattr` to the entry in the `foreign_model` dict:

```
def my_scope_provider(obj, attr, attr_ref):
    pyobj = obj.pyobj
    if attr_ref.obj_name in pyobj:
        return pyobj[attr_ref.obj_name]
    else:
        raise Exception("{} not found".format(attr_ref.obj_name))
```

The scope provider is linked to the `pyattr` attribute of the rule `Access`:

```
my_metamodel.register_scope_providers({
    "Access.pyattr": my_scope_provider,
})
```

With this, we can reference non-texX data elements from within our language. This can be used to, e.g., use a non-textX AST object and reference it from a textX model.

Use Case: referencing non-textX meta-models/ models with a json file

Note

> The example in this section is based on the test_reference_to_nontextx_attribute.py.

In test_reference_to_nontextx_attribute.py we also demonstrate how such an external model can be loaded with our own language (using a json file as external model).

We want to access elements of JSON file from our model like this:

```
import "test_reference_to_nontextx_attribute/othermodel.json" as data
access A1 data.name
access A2 data.gender
```

Where the json file `othermodel.json` consists of:

```
{
  "name": "pierre",
  "gender": "male"
}
```

We start with the following meta-model:

```
Model:
    imports+=Json
    access+=Access
;
Access:
    'access' name=ID pyobj=[Json] '.' pyattr=[OBJECT]?
;

Json: 'import' filename=STRING 'as' name=ID;
Comment: /\/\/.*$/;
```

Now when resolving `pyobj/pyattr` combo of the `Access` rule we want to search in the imported JSON file. To achieve this we will write and register a scope provider that will load the referenced JSON file first time it is accessed and that lookup for the `pyattr` key in that file:

```
def generic_scope_provider(obj, attr, attr_ref):
    if not obj.pyobj:
        from textx.scoping import Postponed
        return Postponed()
    if not hasattr(obj.pyobj, "data"):
        import json
        obj.pyobj.data = json.load(open(
            join(abspath(dirname(__file__)), obj.pyobj.filename)))
    if attr_ref.obj_name in obj.pyobj.data:
        return obj.pyobj.data[attr_ref.obj_name]
    else:
        raise Exception("{} not found".format(attr_ref.obj_name))

# create meta model
my_metamodel = metamodel_from_str(metamodel_str)
my_metamodel.register_scope_providers({
    "Access.pyattr": generic_scope_provider,
})
```

Conclusion

We provide a pragmatic way to define meta-models that use other meta-models. Mostly, we focus on textX meta-models using other textX meta-models. But scope providers may be used to also link a textX meta model to an arbitrary non-textX data structure.

Error handling

textX will raise an error if a syntax or semantic error is detected during meta-model or model parsing/construction.

For a syntax error `TextXSyntaxError` is raised. For a semantic error `TextXSemanticError` is raised. Both exceptions inherit from `TextXError`. These exceptions are located in `textx.exceptions` module.

All exceptions have `message` attribute with the error message, and `line`, `col` and `nchar` attributes which represent line, column and substring length where the error was found.

Note

- You can also raise `TextXSemanticError` during semantic checks (e.g. in object processors. These error classes accepts the message and location information (`line`, `col`, `nchar`, `filename`) which can be produced from any textX model object using `get_location`:

```
from textx import get_location, TextXSemanticError
...
def my_processor(entity):
    ... check something
    raise TextXSemanticError('Invalid entity',
**get_location(entity))
...
```

Note

See also textx command/tool for (meta)model checking from command line.

Debugging

textX supports debugging on the meta-model (grammar) and model levels. If debugging is enabled, textX will print various debugging messages.

If the `debug` parameter of the meta-model construction is set to `True`, debug messages during grammar parsing and meta-model construction will be printed. Additionally, a parse tree created during the grammar parsing as well as meta-model (if constructed successfully) dot files will be generated:

```
form textx.metamodel import metamodel_from_file

robot_metamodel = metamodel_from_file('robot.tx', debug=True)
```

If `debug` is set in the `model_from_file/str` calls, various messages during the model parsing and construction will be printed. Additionally, parse tree created from the input as well as the model will be exported to dot files.

```
   robot_program = robot_metamodel.model_from_file('program.rbt',
debug=True)
```

Alternatively, you can use textx check or generate command in debug mode.

```
$ textx --debug generate --grammar robot.tx program.rbt --target dot

*** PARSING LANGUAGE DEFINITION ***
New rule: grammar_to_import -> RegExMatch
New rule: import_stm -> Sequence
New rule: rule_name -> RegExMatch
New rule: param_name -> RegExMatch
New rule: string_value -> OrderedChoice
New rule: rule_param -> Sequence
Rule rule_param founded in cache.
New rule: rule_params -> Sequence
...

>> Matching rule textx_model=Sequence at position 0 => */* This ex
  >> Matching rule ZeroOrMore in textx_model at position 0 => */*
This ex
      >> Matching rule import_stm=Sequence in textx_model at position
0 => */* This ex
        ?? Try match rule StrMatch(import) in import_stm at position
0 => */* This ex
        >> Matching rule comment=OrderedChoice in import_stm at
position 0 => */* This ex
            ?? Try match rule comment_line=RegExMatch(//.*?$) in
comment at position 0 => */* This ex
            -- NoMatch at 0
            ?? Try match rule comment_block=RegExMatch(/\*(.|\n)*?
\*/) in comment at position 0 => */* This ex

...


Generating 'robot.tx.dot' file for meta-model.
To convert to png run 'dot -Tpng -O robot.tx.dot'
Generating 'program.rbt.dot' file for model.
To convert to png run 'dot -Tpng -O program.rbt.dot'
```

This command renders parse trees and parser models of both textX and your language to dot files. Also, a meta-model and model of the language will be rendered if parsed correctly.

Note

By default all debug messages will be printed to stdout. You can provide `file` parameter to `metamodel_from_file/str` to specify file-like object where all messages should go.

Generator framework based on Jinja template engine

Warning

> This framework is implemented in textX-jinja project. You have to install it with `pip install textX-jinja` to be able to use it.

You can roll your own code generation approach with textX but sometimes it is good to have a predefined framework which is easy to get started with and only if you need something very specific later you can create your own code generator.

Here, we describe a little framework based on Jinja template engine.

The idea is simple. If you want to generate a set of files from your textX model(s) you create a folder which resembles the outline of the file tree you want to generate. Each file in your template folder can be a Jinja template (with `.jinja` extension, e.g. `index.html.jinja`), in which case target file will be created by running the template through the Jinja engine. If the file doesn't end with `.jinja` extension it is copied as is to the target folder.

To call Jinja generator you use `textx_jinja_generator` function:

```
...
from textxjinja import textx_jinja_generator
...

@generator('mylang', 'mytarget')
def mygenerator(metamodel, model, output_path, overwrite, debug):
    "Generate MyTarget from MyLang model."

    # Prepare context dictionary
    context = {}
    context['some_param'] = "Some value"

    template_folder = os.path.join(THIS_FOLDER, 'template')

    # Run Jinja generator
    textx_jinja_generator(template_folder, output_path, context,
overwrite)
```

In this example we have our templates stored in `template` folder.

You can use variables from `context` dict in your templates as usual, but also you can use them in filenames. If file name has a variable name in the format `__<variablename>__` it will be replaced by the value of the variable from the `context` dict. If variable by the given name is not found the `variablename` is treated as literal filename. For example __package__ in the template file names will be replaced by package name from `context` dict.

Boolean values in file names are treated specially. If the value is of a bool type the file will be skipped entirely if the value is `False` but will be used if the value is `True`. This makes it easy to provide templates/files which should be generated only under certain conditions (for example see `__lang__` and `__gen__` variable usage in template names)

If a variable from context is iterable, then the generator will produce a file for each element of the iterable.

Parameter `transform_names` is a callable that is used to transform model variables and return a string that will be used instead. It is applied to both iterable and non-iterable model objects. This test is an example usage of iterables and name tranformation.

To see a full example of using `textX-jinja` you can take a look at the implementation of `startproject` textX command in textX-dev project. This textX command will run a questionnaire based on the Questionnaire DSL and with run a project scaffolding generation by calling textx_jinja_generate with the templates for the project.

Hello World example

This is an example of very simple Hello World like language.

Note

> A `.tx` file extension is used for textX grammar. See textX grammar on what you can do inside a grammar file, including comments!

These are the steps to build a very basic Hello World - like language.

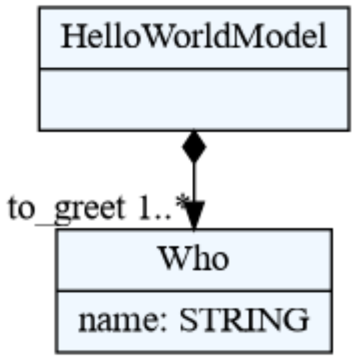
1. Write a language description in textX (file `hello.tx`):

   ```
   HelloWorldModel:
     'hello' to_greet+=Who[',']
   ;

   Who:
     name = /[^,]*/
   ;
   ```

   Description consists of a set of parsing rules which at the same time describe Python classes that will be dynamically created and used to instantiate objects of your model. This small example consists of two rules: `HelloWorldModel` and `Who`. `HelloWorldModel` starts with the keyword `hello` after which a one or more `Who` object must be written separated by commas. `Who` objects will be parsed, instantiated and stored in a `to_greet` list on a `HelloWorldModel` object. `Who` objects consists only of its names which must be matched the regular expression rule `/[^,]*/` (match non-comma zero or more times). Please see textX grammar section for more information on writing grammar rules.

2. At this point you can check and visualise meta-model using following command from the command line:

   ```
   $ textx generate hello.tx --target dot
   Generating dot target from models:
   /home/igor/repos/textX/textX/examples/hello_world/hello.tx
   -> /home/igor/repos/textX/textX/examples/hello_world/hello.dot
     To convert to png run "dot -Tpng -O hello.dot"
   ```



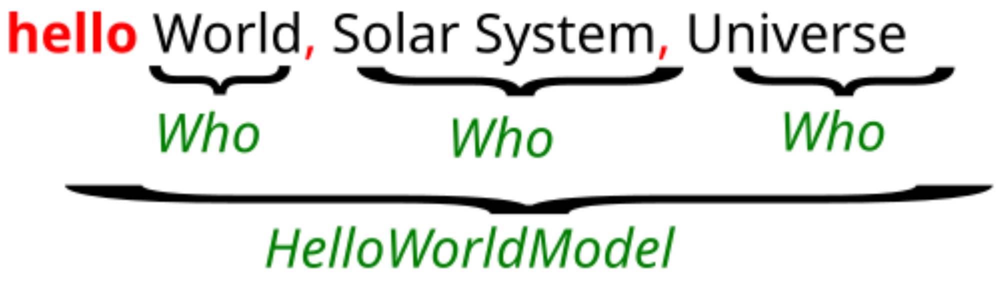
You can see that for each rule from language description an appropriate Python class has been created. A BASETYPE hierarchy is built-in. Each meta-model has it.

3. Create some content (i.e. model) in your new language (`example.hello`):

   ```
   hello World, Solar System, Universe
   ```

   Your language syntax is also described by language rules from step 1.

   If we break down the text of the example model it looks like this:



   We see that the whole line is a `HelloWorldModel` and the parts `World` , `Solar System` , and `Universe` are `Who` objects. Red coloured text is syntactic noise that is needed by the parser (and programmers) to recognize the boundaries of the objects in the text.

4. To use your models from Python first create meta-model from textX language description (file `hello.py`):

   ```
   from textx import metamodel_from_file
   hello_meta = metamodel_from_file('hello.tx')
   ```

5. Than use meta-model to create models from textual description:

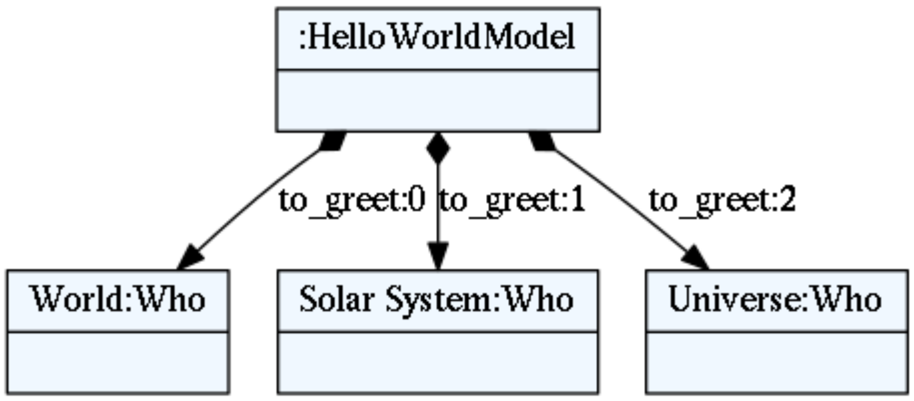
   ```
   hello_model = hello_meta.model_from_file('example.hello')
   ```

   Textual model `example.hello` will be parsed and transformed to plain Python objects. Python classes of the created objects are those defined by the meta-model. Returned object `hello_model` will be a reference to the root of the model, i.e. the object of class `HelloWorldModel` . You can use the model as any other Python object. For example:

```
 print("Greeting", ", ".join([to_greet.name
                             for to_greet in
hello_model.to_greet]))
```

6. You can optionally export model to `dot` file to visualize it. Run following from the command line:

```
 $ textx generate example.hello --grammar hello.tx --target dot
 Generating dot target from models:
 /home/igor/repos/textX/textX/examples/hello_world/example.hello
 -> /home/igor/repos/textX/textX/examples/hello_world/
example.dot
   To convert to png run "dot -Tpng -O example.dot"
```



   This is an object graph automatically constructed from `example.hello` file.

   We see that each `Who` object is contained in the python attribute `to_greet` of list type which is defined by the grammar.

7. Use your model: interpret it, generate code … It is a plain Python graph of objects with plain attributes!

Note

> Try out a complete tutorial for building a simple robot language.

Robot tutorial

In this tutorial we will build a simple robot language to demonstrate the basic workflow when working with textX.

Robot language

When building a DSL we should first do a domain analysis, to see what concepts do we have and what are their relationships and constraints. In the following paragraph a short analysis is done. Important concepts are emphasized.

In this case we want an imperative language that should define `robot` movement on the imaginary grid. Robot should `move` in four base `direction`. We will call these directions `up`, `down`, `left` and `right` (you could use north, south, west and east if you like). Additionally, we shall have a robot coordinate given in x, y `position`. For simplicity, our robot can move in discrete `steps`. In each movement robot can move by 1 or more steps but in the same direction. Coordinate is given as a pair of integer numbers. Robot will have an `initial position`. If not given explicitly it is assumed that position is `(0, 0)`.

So, lets build a simple robot language.

Grammar

First, we need to define a grammar for the language. In textX the grammar will also define a meta-model (a.k.a. abstract syntax) for the language which can be visualized and be used as a part of the documentation.

Usually we start by outlining some program in the language we are building.

Here is an example *program* on robot language:

```
begin
    initial 3, 1
    up 4
    left 9
    down
    right 1
end
```

We have `begin` and `end` keywords that define the beginning and end of the program. In this case we could do without these keywords but lets have it to make it more interesting.

In between those two keywords we have a sequence of instruction. First instruction will position our robot at coordinate `(3, 1)`. After that robot will move `up 4 steps`, `left 9 steps`, `down 1 step` (1 step is the default) and finally `1 step to the right`.

Lets start with grammar definition. We shall start in a top-down manner so lets first define a program as a whole.

```
Program:
  'begin'
    commands*=Command
  'end'
;
```

Here we see that our program is defined with sequence of:

- string match (`'begin'`),
- zero or more assignment to `commands` attribute,
- string match (`'end'`).

String matches will require literal strings given at the begin and end of program. If this is not satisfied a syntax error will be raised. This whole rule (`Program`) will create a class with the same name in the meta-model. Each program will be an instance of this class. `commands` assignment will result in a python attribute `commands` on the instance of `Program` class. This attribute will be of Python `list` type (because `*=` assignment is used). Each element of this list will be a specific command.

Now, we see that we have different types of commands. First command has two parameters and it defines the robot initial position. Other commands has one or zero parameters and define the robot movement.

To state that some textX rule is specialised in 2 or more rules we use an abstract rule. For `Command` we shall define two specializations: `InitialCommand` and `MoveCommand` like this:

```
Command:
  InitialCommand | MoveCommand
;
```

Abstract rule is given as ordered choice of other rules. This can be read as *Each command is either a InitialCommand or MoveCommand*.

Lets now define command for setting initial position.

```
InitialCommand:
  'initial' x=INT ',' y=INT
;
```

This rule specifies a class `InitialCommand` in the meta-model. Each initial position command will be an instance of this class.

So, this command should start with the keyword `initial` after which we give an integer number (base type rule `INT` - this number will be available as attribute `x` on the `InitialCommand` instance), than a separator `,` is required after which we have `y` coordinate as integer number (this will be available as attribute `y`). Using base type rule `INT` matched number from input string will be automatically converted to python type `int` .

Now, lets define a movement command. We know that this command consists of direction identifier and optional number of steps (if not given the default will be 1).

```
MoveCommand:
  direction=Direction (steps=INT)?
;
```

So, the movement command model object will have two attributes. `direction` attribute will define one of the four possible directions and `steps` attribute will be an integer that will hold how many steps a robot will move in given direction. Steps are optional so if not given in the program it will still be a correct syntax. Notice, that the default of 1 is not specified in the grammar. The grammar deals with syntax constraints. Additional semantics will be handled later in model/object processors (see below).

Now, the missing part is `Direction` rule referenced from the previous rule. This rule will define what can be written as a direction. We will define this rule like this:

```
Direction:
  "up"|"down"|"left"|"right"
;
```

This kind of rule is called a *match rule*. This rule does not result in a new object. It consists of ordered choice of simple matches (string, regex), base type rules (INT, STRING, BOOL...) and/or other match rule references.

The result of this match will be assigned to the attribute from which it was referenced. If base type was used it will be converted in a proper python type. If not, it will be a python string that will contain the text that was matched from the input.

In this case a one of 4 words will be matched and that string will be assigned to the `direction` attribute of the `MoveCommand` instance.

The final touch to the grammar is a definition of the comment rule. We want to comment our robot code, right?

In textX a special rule called `Comment` is used for that purpose. Lets define a C-style single line comments.

```
Comment:
  /\/\/.*$/
;
```

Our grammar is done. Save it in `robot.tx` file. The content of this file should now be:

```
Program:
  'begin'
    commands*=Command
  'end'
;

Command:
  InitialCommand | MoveCommand
;

InitialCommand:
  'initial' x=INT ',' y=INT
;

MoveCommand:
  direction=Direction (steps=INT)?
;

Direction:
  "up"|"down"|"left"|"right"
;

Comment:
  /\/\/.*$/
;
```

Notice that we have not constrained initial position command to be specified just once on the beginning of the program. This basically means that this command can be given multiple times throughout the program. I will leave as an exercise to the reader to implement this constraint.

Next step during language design is meta-model visualization. It is usually easier to comprehend our language if rendered graphically. To do so we use excellent GraphViz software package and its DSL for graph specification called *dot*. It is a textual language for visual graph definition.

Lets check our meta-model and export it to the dot language.

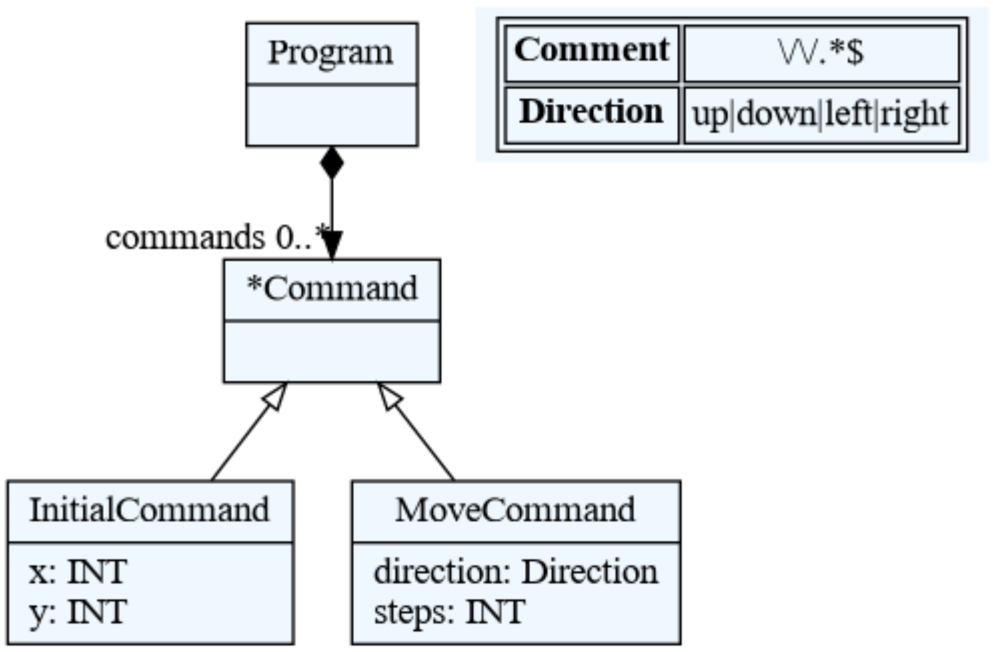
```
$ textx generate robot.tx --target dot
Generating dot target from models:
/home/igor/repos/textX/textX/examples/robot/robot.tx
-> /home/igor/repos/textX/textX/examples/robot/robot.dot
   To convert to png run "dot -Tpng -O robot.dot"
```

`dot` file can be opened with dot viewer (there are many to choose from) or transformed with `dot` tool to raster or vector graphics.

For example:

```
$ dot -Tpng -O robot.dot
```

This command will create `png` image out of `dot` file.



Instantiating meta-model

In order to parse our models we first need to construct a meta-model. A textX meta-model is a Python object that contains all classes that can be instantiated in our model. For each grammar rule a class is created. Additionally, meta-model contains a parser that knows how to parse input strings. From parsed input (parse tree) meta-model will create a model.

Meta-models are created from our grammar description, in this case `robot.tx` file. Open `robot.py` Python file and write following:

```
from textx import metamodel_from_file
robot_mm = metamodel_from_file('robot.tx')
```

Note

> This meta-model can be used to parse multiple models.

Instantiating model

Now, when we have our meta-model we can parse models from strings or external textual files. Extend your `robot.py` with:

```
robot_model = robot_mm.model_from_file('program.rbt')
```

This command will parse the file `program.rbt` and construct our robot model. If this file does not match our language a syntax error will be raised on the first error encountered.

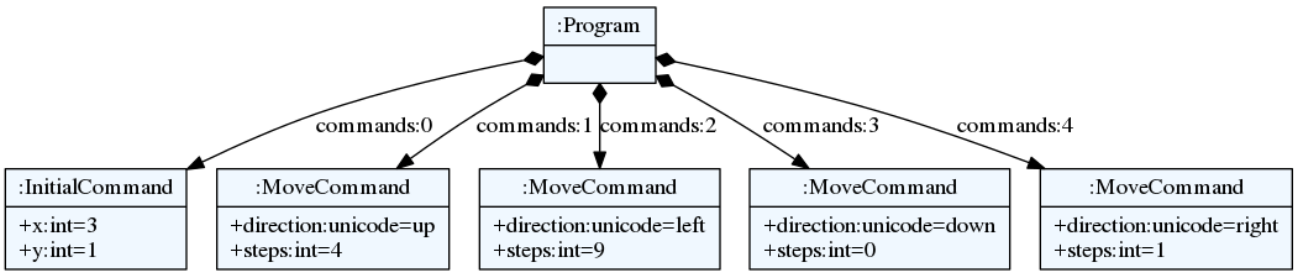
In the same manner as meta-model visualization we can visualize our model too.

```
$ textx generate program.rbt --grammar robot.tx --target dot
Generating dot target from models:
/home/igor/repos/textX/textX/examples/robot/program.rbt
-> /home/igor/repos/textX/textX/examples/robot/program.dot
   To convert to png run "dot -Tpng -O program.dot"
```

This will create `program.dot` file that can be visualized using proper viewer or transformed to image.

```
$ dot -Tpng -O program.dot
```

For the robot program above we should get an image like this:



Interpreting model

When we have successfully parsed and loaded our model/program (or mogram or prodel ;)) we can do various stuff. Usually what would you like to do is to translate your program to some other language (Java, Python, C#, Ruby,...) or you could build an interpreter that will evaluate/interpret your model directly. Or you could analyse your model, extract informations from it etc. It is up to you to decide.

We will show here how to build a simple interpreter that will start the robot from the initial position and print the position of the robot after each command.

Lets imagine that we have a robot that understands our language. In your `robot.py` file add:

```
class Robot:

    def __init__(self):
        # Initial position is (0,0)
        self.x = 0
        self.y = 0

    def __str__(self):
        return f"Robot position is {self.x}, {self.y}."
```

Now, our robot will have an `interpret` method that accepts our robot model and runs it. At each step this method will update the robot position and print it.

```
def interpret(self, model):

    # model is an instance of Program
    for c in model.commands:

        if c.__class__.__name__ == "InitialCommand":
            print(f"Setting position to: {c.x}, {c.y}")
            self.x = c.x
            self.y = c.y
        else:
            print(f"Going {c.direction} for {c.steps} step(s).")

            move = {
                "up": (0, 1),
                "down": (0, -1),
                "left": (-1, 0),
                "right": (1, 0)
            }[c.direction]

            # Calculate new robot position
            self.x += c.steps * move[0]
            self.y += c.steps * move[1]

        print(self)
```

Now lets give our `robot_model` to `Robot` instance and see what happens.

```
robot = Robot()
robot.interpret(robot_model)
```

You should get this output:

```
Setting position to: 3, 1
Robot position is 3, 1.
Going up for 4 step(s).
Robot position is 3, 5.
Going left for 9 step(s).
Robot position is -6, 5.
Going down for 0 step(s).
Robot position is -6, 5.
Going right for 1 step(s).
Robot position is -5, 5.
```

It is *almost* correct. We can see that down movement is for 0 steps because we have not defined the steps for `down` command and haven't done anything yet to implement default of 1.

The best way to implement default value for step is to use so called object processor for `MoveCommand`. Object processor is a callable that gets called whenever textX parses and instantiates an object of particular class. Use `register_obj_processors` method on meta-model to register callables/processors for classes your wish to process in some way immediately after instantiation.

Lets define our processor for `MoveCommand` in `robot.py` file.

```
def move_command_processor(move_cmd):

  # If steps is not given, set it do default 1 value.
  if move_cmd.steps == 0:
    move_cmd.steps = 1
```

Now, register this processor on meta-model. After meta-model construction add a line for registration.

```
robot_mm.register_obj_processors({'MoveCommand':
move_command_processor})
```

`register_obj_processors` accepts a dictionary keyed by class name. The values are callables that should handle instances of the given class.

If you run robot interpreter again you will get output like this:

```
Setting position to: 3, 1
Robot position is 3, 1.
Going up for 4 step(s).
Robot position is 3, 5.
Going left for 9 step(s).
Robot position is -6, 5.
Going down for 1 step(s).
Robot position is -6, 4.
Going right for 1 step(s).
Robot position is -5, 4.
```

And now our robot behaves as expected!

Note

> The code from this tutorial can be found in the examples/robot folder.
>
> Next, you can read the Entity tutorial where you can see how to generate source code from your models.

Entity tutorial

A tutorial for building ER-like language and generating Java code.

Entity language

In this example we will see how to make a simple language for data modeling. We will use this language to generate Java source code (POJO classes).

Our main concept will be `Entity` . Each entity will have one or more `properties` . Each property is defined by its `name` and its `type` .

Let's sketch out a model in our language.

```
entity Person {
  name : string
  address: Address
  age: integer
}

entity Address {
  street : string
  city : string
  country : string
}
```

The grammar

In our example we see that each entity starts with a keyword `entity` . After that, we have a name that is the identifier and an open bracket. Between the brackets we have properties. In textX this is written as:

```
Entity:
    'entity' name=ID '{'
        properties+=Property
    '}'
;
```

We can see that the `Entity` rule references `Property` rule from the assignment. Each property is defined by the `name` , colon (`:`) and the type's name. This can be written as:

```
Property:
    name=ID ':' type=ID
;
```

Now, grammar defined in this way will parse a single `Entity`. We haven't stated yet that our model consists of many `Entity` instances.

Let's specify that. We are introducing a rule for the whole model which states that each entity model contains one or more `entities`.

```
EntityModel:
    entities+=Entity
;
```

This rule must be the first rule in the textX grammar file. First rule is always considered a `root rule`.

This grammar will parse the example model from the beginning.

At any time you can check and visualize entity meta-model and person model using commands:

```
$ textx generate entity.tx --target dot
$ textx generate person.ent --grammar entity.tx --target dot
```

Given grammar in file `entity.tx` and example Person model in file `person.ent`.

These commands will produce `entity.dot` and `person.dot` files which can be viewed by any dot viewer or converted to e.g. PNG format using command:

```
$ dot -Tpng -O *.dot
```

Note that GraphViz must be installed to use dot command line utility.

Meta-model now looks like this:

Entity metamodel 1

While the example (Person model) looks like this:

Person model 1

What you see on the model diagram are actual Python objects. It looks good, but it would be even better if a reference to `Address` from properties was an actual Python reference, not just a value of `str` type.

This resolving of object names to references can be done automatically by textX. To do so, we shall change our `Property` rule to be:

```
Property:
    name=ID ':' type=[Entity]
;
```

Now, we state that type is a reference (we are using `[]`) to an object of the `Entity` class. This instructs textX to search for the name of the `Entity` after the colon and when it is found to resolve it to an `Entity` instance with the same name defined elsewhere in the model.

But, we have a problem now. There are no entities called `string` and `integer` which we used for several properties in our model. To remedy this, we must introduce dummy entities with those names and change `properties` attribute assignment to be `zero or more` (`*=`) since our dummy entities will have no attributes.

Although, this solution is possible it wouldn't be elegant at all. So let's do something better. First, let's introduce an abstract concept called `Type` which as the generalization of simple types (like `integer` and `string`) and complex types (like `Entity`).

```
Type:
  SimpleType | Entity
;
```

This is called abstract rule, and it means that `Type` is either a `SimpleType` or an `Entity` instance. `Type` class from the meta-model will never be instantiated.

Now, we shall change our `Property` rule definition:

```
Property:
    name=ID ':' type=[Type]
;
```

And, at the end, there must be a way to specify our simple types. Let's do that at the beginning of our model.

```
EntityModel:
    simple_types *= SimpleType
    entities += Entity
;
```

And the definition of `SimpleType` would be:

```
SimpleType:
  'type' name=ID
;
```

So, simple types are defined at the beginning of the model using the keyword `type` after which we specify the name of the type.

Our person model will now begin with:

```
type string
type integer

entity Person {
...
```

Meta-model now looks like this:

Entity metamodel 2

While the example (Person model) looks like this:

Person model 2

But, we can make this language even better. We can define some built-in simple types so that the user does not need to specify them for every model. This has to be done from python during meta-model instantiation. We can instantiate `integer` and `string` simple types and introduce them in every model programmatically.

The first problem is how to instantiate the `SimpleType` class. textX will dynamically create a Python class for each rule from the grammar but we do not have access to these classes in advance.

Luckily, textX offers a way to override dynamically created classes with user supplied ones. So, we can create our class `SimpleType` and register that class during meta-model instantiation together with two of its instances (`integer` and `string`).

```
class SimpleType:
  def __init__(self, parent, name):  # remember to include parent
param.
    self.parent = parent
    self.name = name
```

Now, we can make a dict of builtin objects.

```
myobjs =  {
  'integer': SimpleType(None, 'integer'),
  'string': SimpleType(None, 'string')
}
```

And register our custom class and two builtins on the meta-model:

```
meta = metamodel_from_file('entity.tx',
                           classes=[SimpleType],
                           builtins=myobjs)
```

Now, if we use `meta` to load our models we do not have to specify `integer` and `string` types. Furthermore, each instance of `SimpleType` will be an instance of our `SimpleType` class.

We, can use this custom classes support to implement any custom behaviour in our object graph.

Generating source code

textX doesn't impose any specific library or process for source code generation. You can use anything you like. From the `print` function to template engines.

I highly recommend you to use some of the well-established template engines.

Here, we will see how to use Jinja2 template engine to generate Java source code from our entity models.

First, install jinja2 using pip:

```
$ pip install Jinja2
```

Now, for each entity in our model we will render one Java file with a pair of getters and setters for each property.

Let's write Jinja2 template (file `java.template`):

```
// Autogenerated from java.template file
class {{entity.name}} {

  {% for property in entity.properties %}
  protected {{property.type|javatype}} {{property.name}};
  {% endfor %}

  {% for property in entity.properties %}
  public {{property.type|javatype}} get{{property.name|capitalize}}()
{
    return this.{{property.name}};
  }

  public void set{{property.name|capitalize}}({{property.type|
javatype}} new_value){
    this.{{property.name}} = new_value;
  }

  {% endfor %}
}
```

Templates have static parts that will be rendered as they are, and variable parts whose content depends on the model. Variable parts are written inside `{{}}`. For example `{{entity.name}}` from the second line is the name of the current entity.

The logic of rendering is controlled by `tags` written in `{%...%}` (e.g. loops, conditions).

We can see that this template will render a warning that this is auto-generated code (it is always good to do that!). Then it will render a Java class named after the current entity and then, for each property in the entity (please note that we are using textX model so all attribute names come from the textX grammar) we are rendering a Java attribute. After that, we are rendering getters and setters.

You could notice that for rendering proper Java types we are using `|javatype` expression. This is called `filter` in Jinja2. It works similarly to `unix` pipes. You have an object and you pass it to some filter. Filter will transform the given object to some other object. In this case `javatype` is a simple python function that will transform our types (`integer` and `string`) to proper Java types (`int` and `String`).

Now, let's see how we can put this together. We need to initialize the Jinja2 engine, instantiate our meta-model, load our model and then iterate over the entities from our model and generate a Java file for each entity:

```python
from os import mkdir
from os.path import exists, dirname, join
import jinja2
from textx import metamodel_from_file

this_folder = dirname(__file__)


class SimpleType:
    def __init__(self, parent, name):
        self.parent = parent
        self.name = name

    def __str__(self):
        return self.name


def get_entity_mm():
    """
    Builds and returns a meta-model for Entity language.
    """
    type_builtins = {
            'integer': SimpleType(None, 'integer'),
            'string': SimpleType(None, 'string')
    }
    entity_mm = metamodel_from_file(join(this_folder, 'entity.tx'),
                                    classes=[SimpleType],
                                    builtins=type_builtins)

    return entity_mm


def main(debug=False):

    # Instantiate the Entity meta-model
    entity_mm = get_entity_mm()

    def javatype(s):
        """
        Maps type names from SimpleType to Java.
        """
        return {
                'integer': 'int',
                'string': 'String'
        }.get(s.name, s.name)

    # Create the output folder
    srcgen_folder = join(this_folder, 'srcgen')
    if not exists(srcgen_folder):
        mkdir(srcgen_folder)

    # Initialize the template engine.
    jinja_env = jinja2.Environment(
        loader=jinja2.FileSystemLoader(this_folder),
        trim_blocks=True,
        lstrip_blocks=True)

    # Register the filter for mapping Entity type names to Java type
names.
    jinja_env.filters['javatype'] = javatype

    # Load the Java template
    template = jinja_env.get_template('java.template')

    # Build a Person model from person.ent file
    person_model = entity_mm.model_from_file(join(this_folder,
'person.ent'))

    # Generate Java code
    for entity in person_model.entities:
        # For each entity generate java file
        with open(join(srcgen_folder,
                       "%s.java" % entity.name.capitalize()), 'w') as
f:
            f.write(template.render(entity=entity))


if __name__ == "__main__":
    main()
```

And the generated code will look like this:

```java
// Autogenerated from java.template file
class Person {

  protected String name;
  protected Address address;
  protected int age;

  public String getName(){
    return this.name;
  }

  public void setName(String new_value){
    this.name = new_value;
  }

  public Address getAddress(){
    return this.address;
  }

  public void setAddress(Address new_value){
    this.address = new_value;
  }

  public int getAge(){
    return this.age;
  }

  public void setAge(int new_value){
    this.age = new_value;
  }

}
```

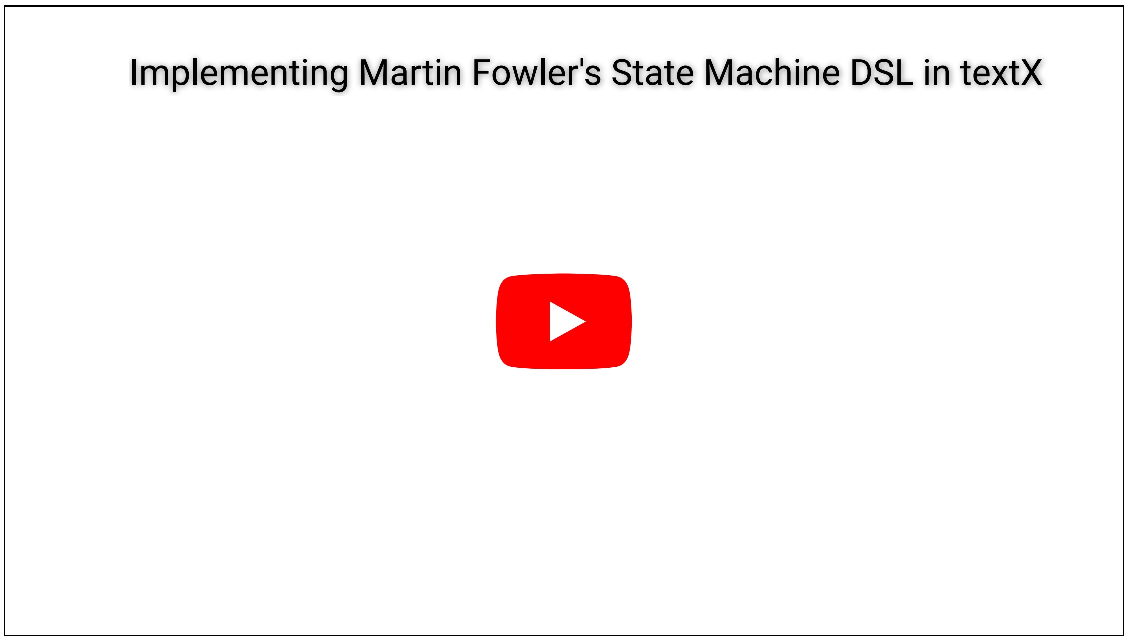
Note

> The code from this tutorial can be found in the examples/Entity folder.

State machine language

This is a video tutorial that explains the implementation of the StateMachine example.

See the blog post about this language implementation.



Toy language compiler

A toy language compiler tutorial

Windel Bouwman wrote an excellent tutorial for using textX and ppci to write a compiler for a simple language.

self-dsl

A tutorial site on creation of Domain-Specific Languages.

Pierre Bayerl is maintaining an excellent tutorial site on writing DSL for both Xtext and textX. Check out his tutorial for textX.

Turtle graphics language

A turtle graphics language interpreter with VS Code support

Allesio Stalla from Strumenta wrote an excellent tutorial on building a Turtle graphics language, an interpreter and a plugin for VS Code using textX-LS project. This is a complete step-by-step tutorial on how to create a textX language project and a supporting VS Code plugin.

Contributing

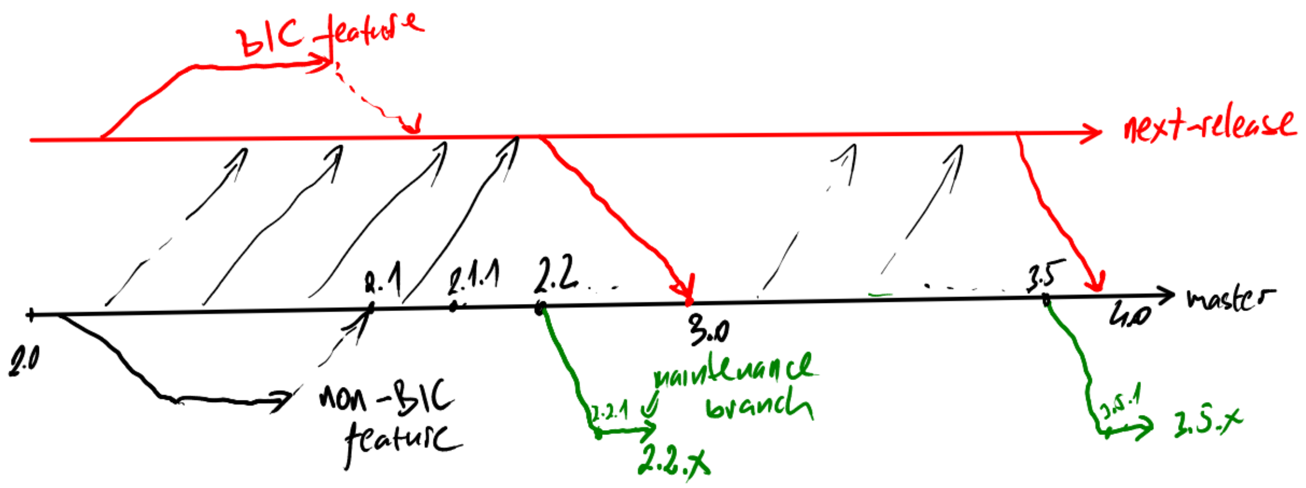
See this document.

textX release process

Note

> For the background see here.

- We are using semantic versioning and a standard format to keep changelogs (see CHANGELOG.md).
- We develop features on feature branches. Feature branches are named `feature/<feature name>`.
- We fix bugs on bugfix branches named as `bugfix/<issue no>-<name>`
- We have a branch for the upcoming major release -- `next-release` (red in the picture bellow).
- If the feature is backward incompatible (BIC) the PR is made against the `next-release` branch (not against the `master` branch)
- If the feature is backward compatible PR is made against the `master`.
- Thus, `Unreleased` section in the changelog on the `master` branch will never have any BIC change. All BIC changes should go to the changelog on the `next-release` branch.
- We constantly merge `master` branch to `next-release` branch. Thus, `next-release` branch is the latest and greatest version with **all** finished features applied.
- When the time for minor release come we follow textX release checklist defined bellow.
- When the time for major release come we merge `next-release` branch to `master` and follow textX release checklist defined bellow.



textX release checklist

1. If minor/major version increase, create maintenance/support branch from the current master. The name is `support/v<previous major.minor.x>` (e.g.

support/v2.0.x).

2. Create a temporary branch for preparing the next release called release-preparation and switch to that branch.
3. Update version in the textX/__init__.py .
4. Update CHANGELOG (create new section for the release, update github links, give credits to contributors).
5. Push release branch and create PR. Wait for tests to pass. Wait for the review process to complete.
6. Delete all previous distributions in the dist folder.
7. Create whl/tar.gz packages

   ```
   python setup.py bdist_wheel sdist
   ```

8. Release to PyPI testing

   ```
   python setup.py publishtest
   ```

9. Release to PyPI

   ```
   python setup.py publish
   ```

10. In case of errors repeat steps 3-10.
11. Create git tag in the form of v<version> (e.g. v2.1.0). Push the tag.
12. Merge PR and delete PR branch (release-preparation).
13. Change the version in textX/__init__.py to next minor version with .dev0 addition (e.g. v2.2.0.dev0).
14. Merge master to next-version to keep it up-to-date.

Note

For supporting previous versions only bugfix releases will be made. The process is similar. The difference for support release would be that release process would be based of the support branch instead of the master branch as is done for regular releases. Thus, for support release, we would skip step 1, in step 5 we would create PR against the support branch, and we won't do steps 13-15.

Comparing textX to other tools

There are generally two classes of textual DSL tools textX could be compared to.

The first class comprises tools that use traditional parsing technologies, i.e. given a grammar (usually a context-free grammar) they produce program code capable of recognizing whether a given textual input conforms to the given grammar. Furthermore, they enable either transformation of textual input to a tree structure (i.e. parse tree), that is processed afterwards, or definition of actions that should be executed during parsing if a particular pattern is recognized. Most popular representatives in this class are lex and yacc, ANTLR, GNU bison, These kind of tools are generally known by the name Parser Generators.

textX's differences in regard to this first class are following:

- textX works as grammar interpreter i.e. parser code is not generated by the tool but the tools is configured by the grammar to recognize textual input on the language specified by the grammar. You can even embed your grammar as a Python string. This enables faster round-trip from grammar to the working parsers as the parser don't need to be regenerated but only reconfigured.
- Most of the classical parsing tools use context-free grammars while textX uses PEG grammars. The consequences are that lookahead is unlimited and there are no ambiguities possible as the alternative operator is ordered. Additionally, there is no need for a separate lexer.
- textX uses a single textual specification (grammar) to define not only the syntax of the language but also its meta-model (a.k.a. abstract syntax). The textX's meta-language is inspired by Xtext. This is very important feature which enables automatic construction of the model (a.k.a. abstract semantic graph - ASG or semantic model) without further work from the language designer. In traditional parsing tools transformation to the model usually involves coding of parse actions or manually written parse tree transformation.

The second class of textual DSL tools are more powerful tools geared especially towards DSL construction. These kind of tools are generally known by the name **Language Workbenches** coined by Martin Fowler. Most popular representatives of this class are Xtext, Spoofax and MPS. These tools are much more complex, highly integrated to the particular development environment (IDE) but provide powerful tooling infrastructure for language development, debugging and evolving. These tools will build not only parser but also a language-specific editor, debugger, validator, visualiser etc.

textX is positioned between these two classes of DSL tools. The goal of textX project is not a highly sophisticated DSL engineering platform but a simple DSL Python library that can be used in various Python applications and development environment. It can also be used for non-Python development using code generation from textX models (see Entity tutorial). Tooling infrastructure, editor support etc. will be developed as independent projects (see for example textx-tools).

Difference to Xtext grammar language

textX grammar language is inspired by Xtext and thus there are a lot of similarities between these tools when it come to grammar specification. But, there are also differences in several places. In this section we shall outline those differences to give users already familiar with Xtext a brief overview.

Lexer and terminal rules

textX uses PEG parsing which doesn't needs separate lexing phase. This eliminate the need to define lexemes in the grammar. Therefore, there is no `terminal` keyword in the textX nor any of special terminal definition rules used by Xtext.

Types used for rules

Xtext integrates tightly with Java and Ecore typing system providing keyword `returns` in rule definition by which language designer might define a class used to instantiate objects recognized by the parser.

textX integrates with Python typing system. In textX there is no keyword `returns`. The class used for the rule will be dynamically created Python class for all non-match rules. Language designer can provide class using user classes registration on meta-model. If the rule is of [match type] than it will always return Python string or some of base Python types for BASETYPES inherited rules.

Assignments

In textX there are two types of `many` assignments (`*=` - zero or more, `+=` - one or more) whereas in Xtext there is only one (`+=`) which defines the type of the inferred attribute but doesn't specify any information for the parser. Thus, if there should be zero or more matched elements you must additionally wrap your expression in `zero or more` match:

In Xtext:

```
Domainmodel :
    (elements+=Type)*;
```

In textX:

```
Domainmodel :
    elements*=Type;
```

Similarly, optional assignment in Xtext is written as:

```
static?='static'?
```

In textX a '?' at the end of the expression is implied, i.e. rhs of the assignment will be optional:

```
static?='static'
```

Regular expression match

In Xtext terminal rules are described using EBNF.

In textX there is no difference between parser and terminal rules so you can use the full textX language to define terminals. Furthermore, textX gives you the full power of Python regular expressions through regular expression match. Regex matches are defined inside `/ /`. Anything you can use in Python re module you can use here. This gives you quite powerful sublanguage for pattern definition.

In Xtext:

```
terminal ASCII:
    '0x' ('0'..'7') ('0'..'9'|'A'..'F');
```

In textX:

```
ASCII:
    /0x[0-7](\d|[A-F])/;
```

Literal Regex match can be used anywhere a regular match rule can be used.

For example:

```
Person:
    name=/[a-zA-Z]+/ age=INT;
```

Repetition modifiers

textX provides a syntactic construct called repetition modifier which enables parser to be altered during parsing of a specific repetition expression.

For example, there is often a need to define a separated list of elements.

To match a list of integers separated by comma in Xtext you would write:

```
list_of_ints+=INT (',' list_of_ints+=INT)*
```

In textX the same expression can be written as:

```
list_of_inst+=INT[',']
```

The parser is instructed to parse one or more INT with commas in between. Repetition modifier can be a regular expression match too.

For example, to match one or more integer separated by comma or semi-colon:

```
list_of_ints+=INT[/,|;/]
```

Inside square brackets more than one repetition modifier can be defined. See section in the docs for additional explanations.

We are not aware of the similar feature in Xtext.

Rule modifiers

Similarly to repetition modifiers, in textX parser can be altered at the rule level too. Currently, only white-space alteration can be defined on the rule level:

For example:

```
Rule:
    'entity' name=ID /\s*/ call=Rule2;
Rule2[noskipws]:
    'first' 'second';
```

Parser will be altered for `Rule2` not to skip white-spaces. All rules down the call chain inherit modifiers.

There are hidden rules in Xtext which can achieve the similar effect, even define different kind of tokens that can be hidden from the semantic model, but the rule modifier in textX serve different purpose. It is a general mechanism for parser alteration per rule that can be used in the future to define some other alteration (e.g. case sensitivity).

Unordered groups

Xtext support unordered groups using `&` operator.

For example:

```
Modifier:
    static?='static'? & final?='final'? & visibility=Visibility;

enum Visibility:
    PUBLIC='public' | PRIVATE='private' | PROTECTED='protected';
```

In textX unordered groups are specified as a special kind of repetitions. Thus, repetition modifiers can be applied also:

```
Modifier:
    (static?='static' final?='final' visibility=Visibility)#[',']

Visibility:
    'public' | 'private' | 'protected';
```

Previous example will match any of the following:

```
private, static, final
static, private, final
...
```

Notice the use of `,` separator as a repetition modifier.

Syntactic predicates

textX is based on PEG grammars. Unlike CFGs, PEGs can't be ambiguous, i.e. if an input parses it has exactly one parse tree. textX is backtracking parser and will try each alternative in predetermined order until it succeeds. Thus, textX grammar can't be ambiguous. Nevertheless, sometimes it is not possible to specify desired parse tree by reordering alternatives. In that case syntactic predicates are used. textX implements both and- and not- syntactic predicates.

On the other hand, predictive non-backtracking parsers (as is ANTLR used by Xtext) must make a decision which alternative to chose. Thus, grammar might be ambiguous and additional specification is needed by a language designer to resolve ambiguity and choose desired parse tree. Xtext uses a positive lookahead syntactic predicates (=> and ->). See here.

Hidden rules

Xtext uses hidden terminal symbols to suppress non-important parts of the input from the semantic model. This is used for comments, whitespaces etc. Terminal rules are referenced from the `hidden` list in the parser rules. All rules called from the one using hidden terminals inherits them.

textX provides support for whitespaces alteration on the parser level and rule level and a special Comment match rule that can be used to describe comments pattern which are suppressed from the model. Comment rule is currently defined for the whole grammar, i.e. can't be altered on a per-rule basis.

Parent-child relationships

textX will provide explicit `parent` reference on all objects that are *contained* inside some other objects. This attribute is a plain Python attribute. The relationship is imposed by the grammar.

Xtext, begin based on Ecore, provides similar mechanism through Ecore API.

Enums

Xtext support Enum rules while textX does not. In textX you use match rule with ordered choice to mimic enums.

Scoping

Scoping in textX is done either by using Python through registration of scope providers, or declaratively using Reference Resolving Expression Language.

Xtext provides a Scoping API which can be used by the Xtend code to specify scoping rules.

Additional differences in the tool usage

Some of the differences in tools usage are outlined here.

REPL

textX is Python based, thus it is easy to interactively play with it on the Python console.

Example ipython session:

```
In [1]: from textx import metamodel_from_str

In [2]: mm = metamodel_from_str("""
...: Model: points+=Point;
...: Point: x=INT ',' y=INT ';';
...: """)

In [3]: model = mm.model_from_str("""
...: 34, 45; 56, 78; 88, 12;""")

In [4]: model.points
Out[4]:
[<textx:Point object at 0x7fdfb4cda828>,
<textx:Point object at 0x7fdfb4cdada0>,
<textx:Point object at 0x7fdfb4cdacf8>]

In [5]: model.points[1].x
Out[5]: 56

In [6]: model.points[1].y
Out[6]: 78
```

Xtext is Java based and works as generator thus it is not possible, as far as we know, to experiment in this way.

Post-processing

textX provide model objects post processing by registering a Python callable that will receive object as it is constructed. Post-processing is used for all sorts of things, from model semantic validation to model augmentation.

An approach to augment model after loading in Xtext is given here.

Parser control

In textX several aspect of parsing can be controlled:

- Whitespaces
- Case sensitivity
- Keyword handling

These settings are altered during meta-model construction. Whitespaces can be further controlled on a per-rule basis.

Xtext enable hidden terminal symbols which can be used for whitespace handling. Case sensitivity can be altered for parser rules but not for lexer rules.

Mapping to host language types

textX will dynamically create ordinary Python classes from the grammar rules. You can register your own classes during meta-model construction which will be used instead. Thus, it is easy to provide your domain model in the form of Python classes.

Xtext is based on ECore model, thus all concepts will be instances of ECore classes. Additionally, there is an API which can be used to dynamically build JVM types from the DSL concepts providing tight integration with JVM.

Built-in objects

In textX you can provide objects that will be available to every model. It is used to provide, e.g. built-in types of the language. For more details see built-in objects section in the docs.

An approach to augment model after loading in Xtext is given here.

Additional languages

Xtext use two additional DSLs:

- Xbase - a general expression language
- Xtend - a modern Java dialect which can be used in various places in the Xtext framework

textX uses RREL for the declarative specification of reference resolving in the grammar.

Template engines

textX doesn't impose a particular template engine to be used for code generation. Although we use Jinja2 in some of the examples, there is nothing in textX that is Jinja2 specific. You can use any template engine you like.

Xtext provide it's own template language as a part of Xtend DSL. This language nicely integrates in the overall platform.

IDE integration

Xtext is integrated in Eclipse and InteliJ IDEs and generates full language-specific tool-chain from the grammar description and additional specifications.

textX does not provide IDE integrations. There is textx-tools project which provide pluggable platform for developing textX languages and generators with project scaffolding. Integration for popular code editors is planned. There is some basic support for vim and emacs at the moment. There is a support for visualization of grammars (meta-models) and models but the model visualization is generic, i.e. it will show you the object graph of your model objects. We plan to develop language-specific model visualization support.

License

See here.

Frequently Asked Questions

Your question is not here? Please use stackoverflow. Just make sure your question is tagged with `textx` .

Is TextX suitable to generate Django model code ?

Yes, textX is perfectly suitable for the task. Actually, that is something it is created for. To make a clean little language that fits your needs in describing your requirements/solution and than generate a bunch of stuff for various target platforms. See the Entity example is the docs. It's very simplistic but would provide you a good starting point.

I see the success of Django and similar frameworks (like ROR for example) mainly due to use of internal DSLs (django models is a DSL that is interpreted on-the-fly to provide ORM etc., or admin is interpreted on the fly to provide CRUDS interface). With textX you can go further by having an external DSL where you can fully control your syntax and you can generate the rest of the stuff. Down the road, if you decide to leave Django, just change your generators and regenerate for the new platform.

Note

> Taken from #121.

What is an idiomatic way to test models generated by a grammar ?

Exact comparison of models is probably not a good idea : differences in the model may be unsignificant from the semantic point of view.

A more practical and sensible approach is to construct the model using textX and then to traverse the model, asserting various facts about it, duck typing style.

You may want to look at property-oriented testing, with frameworks as hypothesis.

Note

> Inspired by #116.

How to parse whitespace sensitive grammar (like Python) ?

There is no direct support for whitespace sensitive languages at the moment. An incoming work is going to deal with this.

> **Note**
>
> Taken from #44.

How to use line terminator as EOL token (like Python) ?

You can disable whitespace skipping using `ws` parser parameter to redefine whitespaces or disable whitespace entirely using `skipws` param.

You can also do that per rule. This way you can catch whitespaces in your grammar. For your particular case, when you should match inside single line only, there is even simpler solution by using `eolterm` repetition modifier.

See for example implementation of pyFlies conditions. In this DSL each state is a separate line.

> **Note**
>
> Taken from #44.

TextX allows to get AST from code. How to convert the AST back to code ?

This feature is not implemented for the moment. It will be made possible by an incoming frontend for TextX based on another parsing method.

For the moment, the closest thing you have is the Entity example showing how to generate source code from models.

Note

> Taken from #36.

Is the `.dot` output fully deterministic ?

No, because internally the `id()` function is used when generating the `.dot` output for nodes identification.

Note

> Taken from #101.

How is using a model processor is different from simply calling a function taking a model after the parsing is complete ?

No difference. Model processor is only a convenience that ensures that calling a processor is not forgotten.

Note

> Taken from #124.

Are object processors also called after the parsing is complete ?

Object processors are called after parsing and reference resolution. Thus, an object processor always have all references resolved.

Note

> Taken from #124.

If an object processor returns a value of another object type, does a processor for that type is called ?

If you return a value in an object processor, the current object is replaced. The replaced object is not further processed.

Note

> Taken from #124.

Is there an existing DSL for JSON schema ?

We are not aware of any project using textX for JSON Schema implementation.

It however shouldn't be hard to define grammar for JSON Schema in textX. You can start with the JSON example. Actually, JSON schema is JSON file so it can be parsed with any JSON parser (the official python one, or even textX JSON example) and validated and analysed afterwards. You could then extract schema validation rules and apply them to subsequent JSON files. JSON schema is meta-language, thus it could be applied to itself.

However, there are standard JSON Schema implementations in Python that do that well and probably will parse much faster than textX.

TextX targets situation where you want to parse something that doesn't have readily available parser, like some custom textual formats or DSLs. For example, to combine JSON Schema with other formalisms.

Note

> Taken from #51.

What's new in textX 1.5

It's been quite a while since the last release of textX so this release brings a lot of new features and fixes.

Operator precedence change

Probably the most important/visible change is the change in the operator precendence. In the previous version, sequence had lower precedence than ordered choice which is counter-intuitive to the users that had previous experience with other tools where this is not the case.

Ordered choice is now of lowest precedence which brings some backward compatibility that should be addressed for migration to the new version.

For example, previously you would write:

```
Rule:
    ('a'  'b') | ('c' 'd')
;
```

To match either `a b` or `c d`.

Now you can drop parentheses as the precedence of sequence is higher:

```
Rule:
    'a'  'b' | 'c' 'd'
;
```

For the previous case there would be no problem in upgrade to 1.5 even if the grammar is not changed. But consider this:

```
Rule:
    'a' 'b' | 'c' 'd'
;
```

In the previous version this would match `a`, than `b` or `c`, and then `d` as the `|` operator was of higher precedence than sequence.

For your grammar to match the same language you must now write:

```
Rule:
  'a' ('b' | 'c') 'd'
;
```

Unordered groups

There is often a need to specify several matches that should occur in an arbitrary order.

Read more here

Match filters

Match rules always return Python strings. Built-in rules return proper Python types. In order to change what is returned by match rules you can now register python callables that can additionally process returned strings.

Read more here

Multiple assignments to the same attribute

textX had support for multiple assignments but it wasn't complete. When multiple assignment is detected, in the previous version, textX will decide that the multiplicity of the attribute is *many* but this lead to the problem if there is no way for parser to collect more than one value even if there is multiple assignments. For example, if all assignments belong to a different ordered choice alternative (see issue #33).

In this version textX will correctly identify such cases.

Read more here

Model API

There is now a set of handful functions for model querying.

Read more here.

Additional special model attributes

In addition to `_tx_position` there is now `_tx_position_end` attribute on each model object which has the value of the end of the match in the input stream.

In addition there is now `_tx_metamodel` attribute on the model which enables easy access to the language meta-model.

Read more about it here.

textX Emacs mode

textX now has a support for Emacs. This package is also available in MELPA.

Bibliography

▸ [Dejanovic2017] - Dejanovi\'{c}, I. and Vaderna, R. and Milosavljevi\'{c}, G. and Vukovi\'{c}, \v{Z}. - *{TextX: A Python tool for Domain-Specific Languages implementation}*. - 2017. - Copy citation_key