

# VOnDA

## A Framework for Implementing Reactive Dialogue Agents

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January 7, 2020

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# Chapter 1

## Purpose and Goal

VOnDA is a framework to implement the dialogue management functionality in dialogue systems. Although domain-independent, VOnDA is tailored towards dialogue systems with a focus on social communication, which implies the need of a long-term memory and high user adaptivity. VOnDA's specification and memory layer relies upon (extended) RDF/OWL, which provides a universal and uniform representation, and facilitates interoperability with external data sources. The starting point for designing VOnDA was the Information State-Update approach to dialogue systems, which has a strong resemblance to the Belief-Desire-Intention approach to Artificial Agents. Thus, it is not surprising that VOnDA can also serve as a base formalism for agent functionality.

VOnDA consists of three parts: A programming language tailored towards the specification of reactive rules and transparent RDF data store usage, a compiler that turns source code in this language into Java code, and a run-time core which supports implementing dialogue management modules using the compiled rules.

The framework is domain-independent. It was originally designed for multi-modal human-robot interaction, but there is currently no specific functionality in the core to either support the multi-modality nor the human-robot interaction. The architecture (see figure 1.1) of the framework is open and powerful enough to add these things easily.

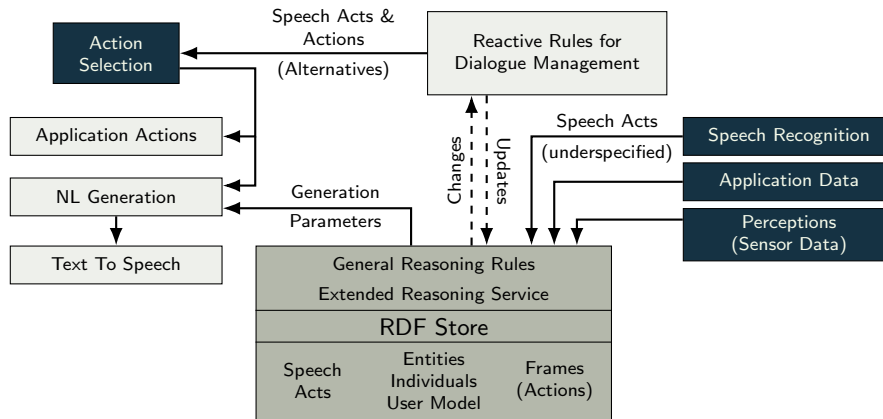


Figure 1.1: Schematic VOnDA agent

At the base is an RDF store which implements the belief state and takes incoming sensor and interaction data and stores it as RDF data. The data format is backed by a data specification in the form of an ontology developed as part of the dialogue manager, making the data (via the specification) available to all other components.

The RDF store and reasoner of choice used in VOnDA is HFC [Krieger, 2013]. For further details about the general functionalities of HFC see chapter 3.4. Section 2.1 contains an example

how HFC is used as database in a VOnDA project.

The dialogue manager gets several inputs from various sources, the ones already used are: input from automatic speech recognition (ASR) or typed natural language input, user parameters, like name, age, hobbies, etc. but also more dynamic ones like mood or health data, and also triggers from high-level planning.

The second major component is the rule processor for the dialogue management rules. When new data is added, a set of declaratively specified reactive rules will propose dialogue moves or other actions and send these proposals to the action selection mechanism. This mechanism selects the “best” of the proposed actions and sends it back. If the proposed action results in dialogue acts, these are turned into verbal output and gestures with the help of a multimodal generation component, which retrieves parameters from the RDF database to adapt the generation to the user’s likings, and can also take into account sensor data such as her or his estimated mood. The rules themselves can use all available data, the incoming new data, but also the interaction history and other data stored in the RDF database to make decisions.

The last major component contains the language interpretation module (not explicitly shown in the picture), which turns spoken or written utterances into dialogue acts, possibly with an intermediate step that involves a more elaborate semantic format, and a multimodal generation component, which converts outgoing dialogue acts into natural language utterances and gestures.

## Chapter 2

# A Hands-On Example

This chapter will walk you through the creation of a simple interaction manager, which you can either create yourself, or just follow by looking at the playground system named ChatCat, which is placed in the `examples` folder. More complex examples are planned to be added soon.

The simplest version of an interaction manager analyses natural language coming from the user, and generates natural language and gestures for the robot resp. its virtual replacement, an avatar. Generation is based on incoming stimuli, like speech or text input, or high-level action requests coming from some strategic planning component, or any other sensor input, if available.

In this tutorial, we will create a very simple example system that has a database representation of itself and the user it will interact with. It can greet the user, ask for his/her name and say goodbye.

### 2.1 Setting up the Basic Data Structures

A dialogue system aiming for social interaction does need some kind of memory representation. Therefore, the first step of building your dialogue manager with VOnDA will be to set up your basic data structures in the form of an OWL ontology. The RDF database serves two purposes: it contains 1) the data structure definitions of the data that is used in the dialogue system, like a User class and the properties that are associated with it, and 2) the (dynamic) data objects, which are created or extended on-the-fly when the dialogue system is running. The advantage of using and RDF store for the data structure specifications lies in its flexibility. Extending or changing them is easy, which is important since your system will be evolving and becoming more and more elaborate.

For the specification of dialogue acts, we recommend that you use the dialogue act hierarchy provided in `examples/chatcat/src/main/resources/ontology/dialogue.nt`, which is based on the ISO standard DIT++ hierarchy, as well as two default files which are necessary for basic OWL functionality in HFC.

#### 2.1.1 Creating N-Triples Files

HFC currently loads data only from files in the N-Triples format. The majority of RDF software packages works with the more common RDF/XML format, which can be automatically translated with a simple shell script that is provided with the example (`examples/chatcat/ntcreate.sh`). This script uses Raptor [Beckett, 2017], which is provided for example in the `raptor2-utils` .deb package. This tutorial uses screenshots from Protégé [Stanford Research, 2017], which we used for the creation of the basic ontology, but you can just use your favourite RDF/OWL IDE.

First, create a new file that includes an RDF class `Agent`, and two subclasses of this class, `Robot` and `Human`. After that, create a (functional) data type predicate name for the class `Agent` with the range `xsd:string`.



As we do not know the user a priori, we will have the system create an instance for him/her at run-time. However, we know our robot in advance, so we create an instance of the class Robot and name it *Robert*, and then convert the new ontology using Raptor to N-Triples (i.e., with the `ntcreate.sh` script). Now, a HFC configuration file (currently in `.ini` format) must be created, as described in the next section.

**Important:** If you are using Protégé, you should save the file in RDF/XML Syntax; the script will not work properly otherwise.

## 2.1.2 Creating a HFC Configuration File

The ontology files loaded into a HFC instance, and which reasoning rules are applied, are specified in a configuration file in `.ini` format. It also contains various settings for HFC parameters. Figure 2.1 shows the config file used for the chatcat example. In the following, we will explain the sections of the config file in detail.

```
[Settings]
#minNoArgs=3
#maxNoArgs=4
#noAtoms=100000
#noTuples=500000
# This file store tuples created or changed during run-time
PersistencyFile=tuples.nt
Encoding=UTF-8

[Namespaces]
# namespaces for XSD, RDF, RDFS, and OWL are already defined
dial = http://www.dfki.de/lt/onto/common/dialogue.owl#
cat = http://www.semanticweb.org/anna/ontologies/2018/3/chatcat#

# instead, you can also load one or more namespace files
#default.ns

[Tuples]
# the axiomatic triples for OWL-Horst w/ EQ reduction
default.eqred.nt

[Tuples]
dialogue.nt
# the name for the base ontology
chatcat.nt

[Rules]
# we need special rules for transaction time (mixture of triples/quadruples)
default.eqred.quads.rdl
```

Figure 2.1: An exemplary HFC config.ini file

**[Settings]** For most applications concerning dialogue management, it is important to specify a *PersistencyFile* to save the data between two runs of the system. This file can be put in any location, it will be created automatically in the specified place. If your application relies on inter-session memory, you probably don't want it to reside in some temporary directory. All new information that your dialogue system enters into the database will be collected here. The persistency file can also be used to find out which tuples have been created, i.e., for on-line and post-mortem debugging. If you want to wipe the memory of your system, simply delete this file.

**[Namespaces]** This section contains abbreviations for ontology namespaces. The abbreviation `dial` in figure 2.1, allows to refer to `<http://www.dfki.de/lt/onto/common/dialogue.owl#Accept>` using `<dial:Accept>` instead, for example in queries to the database. As you can see, we included a shortcut for our chatcat ontology here.

**[Tuples]** Here all ontology files have to be listed that should be loaded into the knowledge base on start-up. The persistency file, if you have specified one, will be loaded automatically. You should also include the file `dialogue.nt` which, as previously mentioned, contains the specifications of the dialogue acts usually used by the VOnDA framework.

**[Rules]** This specifies the set of rules that HFC uses for OWL reasoning. Currently, the file `default.eqred.quads.rdl` is required for proper operation of VOnDA, since it relies on the so-called *transaction time* representation, which allows to keep a (possibly) infinite memory, while still preserving a monotonic RDF store, i.e., only adding and never deleting tuples. This representation uses quadruples, where the forth element is the timestamp when the tuple was added to the store. For tuples with infinite resp. universal validity, the timestamp should be set to zero. For further information, please refer to the documentation of HFC.

## 2.2 Setting up the Basic Java Classes

First, the project's abstract (Java) "agent" class has to be implemented, which must be a subclass of `de.dfki.mlt.rudimant.agent.Agent`, a class in the run-time library of VOnDA. Furthermore, you will need an implementation of `de.dfki.mlt.rudimant.agent.CommunicationHub`. To see an example of what these could contain, take a look in the source folder of ChatCat.

The two most important things here are that there is an active connection to a database (as an instance of `RdfProxy`) and that you have an instance of the beforementioned VOnDA Agent wrapper implementation in your client. Of course this code can not compile until you build your first rule file, i.e., your VOnDA Agent. Then, a `main` has to create an instance of your client and is started using the `startListening()` method.

We recommend to have a look at the classes of the ChatCat system as a base for your own system and extend it. It comes you with a very simple GUI to enter text or dialogue acts which you can use to test your first dialogue steps.

## 2.3 Connecting NLU and Generation Components

Basically, you can connect any NLU and NLG components to your project that are able to create or, respectively, process dialogue acts of the format that VOnDA provides (cf. 3.1.2).

For the sake of simplicity, this example uses SRGS to build a primitive NLU and `cplan`<sup>1</sup> to create natural language out of the dialogue acts the agent outputs.

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<sup>1</sup><https://github.com/bkiefner/cplan>

## 2.4 First Interaction Rules

Now that the basics have been arranged, we are set up for writing our first dialogue management rules. First we want to react to the user greeting the system, what we expect to be happening on startup. In the SRGS file (`src/main/resources/grammars/srgs/chatcat.xml`), we defined that an utterance of the user like "Hello" will be parsed as the dialogue act `InitialGreeting`, with the proposition `Greet`. We now can define a rule reacting to this utterance:

```
greet_back:
  if (lastDA() <= #InitialGreeting(Greet)) {
    user = new Human;
    if (! saidInSession(#Greeting()) {
      propose("greet_back") {
        emitDA(#ReturnGreeting(Greet));
      }
    }
    lastDAprocessed();
  }
```

This will create a new instance of the RDF class `Human` we defined when setting up the ontology, storing it in a global variable `user` that in our case has been defined in the `ChatAgent` and will be present during the whole conversation. The check `! saidInSession(#Greeting)` currently doesn't seem to make sense, why this is necessary will be obvious when we have completed the example. This test already shows an important property of the system: `Greeting` is the superclass of `InitialGreeting` and `ReturnGreeting` in the DIT++ ontology, and the function will return `true`, no matter what type of greeting we gave, since it tests for subsumption, like the comparison operators `<=` and `<` that work on dialogue act arguments that we use in the next rule example. More details about how to exploit this functionality will be given in section ??

After greeting, we want to find out the user's name. We thus define a rule as follows:

```
ask_for_name:
  if (!user.name && !(myLastDA() <= #WHQuestion(Name))) {
    propose("ask_name") {
      emitDA(#WHQuestion(Name));
    }
    lastDAprocessed();
  }
```

And once we got the answer from the user, we can store this knowledge in the database:

```
remember_name:
  if (lastDA() <= #Inform(Name)) {
    user.name = lastDA().what;
    lastDAprocessed();
  }
```

We currently don't have a person detector, so we assume that someone's here when the system is started. To make sure the conversation starts even if the user doesn't start with a greeting, we use a *timeout* to implement a system greeting after some time.

```
timeout("robot_starts", 4000) {
  start_conversation:
    if (! (receivedInSession(#Greeting(top)) || saidInSession(#Greeting(top)))) {
      propose("robot_greets") {
        tod = Date.timeOfDay();
        emitDA(#InitialGreeting(Greet, when={tod}));
      }
    }
}
```

Explain the `timeOfDay` code, and that a Java import and an entry in `ChatAgent` is necessary to obtain compilable code

These are enough rules to start a conversation, so let's compile and try out the new dialogue system.



## 2.5 Specifying how to Compile and Run your Project

Now that we have implemented our first rules, we need to compile them. In the `bin` directory of your VOnDA installation is a script `vondac` that will use your compilation config file to compile your project. The most convenient way to use it is either to establish a softlink in a directory that is already in your `PATH` or to add VOnDA's `bin` directory to it.

The `compile.yml` should contain the following parameters:

<code>inputFile</code>	Relative to the current location, where is the top-level rule file?
<code>outputDirectory</code>	Relative to the current location, where should the compiled classes go?
<code>wrapperClass</code>	The name of your abstract Java Agent, including package prefix
<code>ontologyFile</code>	The path to your ontology <code>.ini</code> , relative to the current location
<code>rootPackage</code>	The topmost package to put the compiled Java classes in
<code>failOnError</code>	If true to exits compilation on any encountered type errors <sup>2</sup> , otherwise continues

Since the compile and the runtime phase of VOnDA need different information, e.g., the run-time phase needs NLU and NLG components, there is a second `yml` file for the run-time phase containing the following specifications (This is the example from ChatCat):

```
ontologyFile:      src/main/resources/ontology/chatcat.ini
NLG:
eng:
mapperProject:     src/main/resources/grammars/cplanner/allrules-mapper
generationProject: src/main/resources/grammars/cplanner/allrules
NLU:
eng:
class:             de.dfki.chatcat.SrgsParser
grammar:           src/main/resources/grammars/srgs/chatcat.xml
```

This configuration can be used to start your compiled system by passing it to the `init` method of `Agent`, allowing for easier configuration of these modules, also in multi-language settings. You can as well put all information into one `yml` file, using it for run time and compile time, since the irrelevant configuration keys will be ignored.

### 2.5.1 Resolving Name Ambiguities

As you might have noticed whilst looking at `chatcat.yml`, there is another parameter used in the compile configuration of our example project:

```
nameToURI:
Agent: "<cat:Agent>"

nameToClass:
Date: de.dfki.chatcat.util.Date
```

When trying to compile without the first two lines, you will find that VOnDA produces the warning "base name `Agent` can be one of `<http://www.semanticweb.org/anna/ontologies/2018/3/chatcat#Agent>`, `<dial:Agent>`, please resolve manually."

This is the compiler telling us that when defining the RDF class `Agent` in the database step, we actually redefined an existing class. VOnDA warns us about this and urges us to resolve this ambiguity. Thus, we could either rename our class, or explicitly state which namespace should be accessed whenever the class `Agent` is used. `nameToURI` can be used to do the latter. You can also use this functionality to remap RDF class names: VOnDA will always map the name on the left to the class URI provided on the right.

The second specification serves to resolve type checks in favour of Java instead of RDF classes. The fully specified name is currently not used, but might be used in later versions to generate Java `import` statements.

## Structured Overview

The compiler turns the VOnDA source code into Java source code using the information in the ontology. Every source file becomes a Java class. The generated code will not serve as an example of good programming practice, but a lot of care has been taken in making it still readable and debuggable. The compile process is separated into three stages: parsing and abstract syntax tree building, type checking and inference, and code generation.

### 3.1.1 VOnDA's Architecture

The diagram illustrates the VONDA architecture, showing the interaction between the VONDA Compiler, VONDA Debugger, and the VONDA Runtime.

**VONDA Runtime:**

- Rule Module Class N** and **Rule Module Class 1** (light gray boxes) are at the top, with an ellipsis between them.
- Top Level Rule Class** (light gray box) is below them. Arrows labeled "imports" and "calls" connect Rule Module Class 1 to the Top Level Rule Class.
- Concrete Agent API Implementation** (light green box) is below the Top Level Rule Class, with an arrow labeled "extends" pointing to it.
- Common Agent API Interface Description** (dark blue box) is below the Concrete Agent API Implementation, with an arrow labeled "extends" pointing to it.
- Common Agent API Implementation** (medium blue box) is below the Common Agent API Interface Description. It is divided into two columns: "Main event processing loop" and "RDF Object Access".
- Dialogue Act Creation / Comparison** (medium blue box) is below the Common Agent API Implementation. It is divided into two columns: "NLG" and "NLU".
- Client Interface** (dark blue box) is at the bottom, with an arrow pointing to the NLG column of the Dialogue Act Creation / Comparison box.

**VONDA Compiler:**

- A vertical blue box labeled "VONDA Compiler" is on the right.
- Arrows point from the compiler to **RuleModuleN.java**, **RuleModule1.java**, **MyAgent.java**, **MyAgentBase.java**, **Agent.rudi**, and **Agent.java** (all in light gray boxes).
- An arrow labeled "Class & Predicate Definitions" points from the compiler to the **RDF Database**.

**VONDA Debugger:**

- A blue box labeled "VONDA Debugger" is at the bottom right.
- An arrow points from the debugger to the **RDF Database**.
- An arrow points from the debugger to the **Client Interface**.

**RDF Database:**

- A gray cylinder labeled "RDF Database" is in the center.
- An arrow labeled "Belief State Data" points from the database to the **Dialogue Act Creation / Comparison** box.

A VONDA project consists of an ontology, a custom extension of the abstract `Agent` class (the so-called *wrapper class*), a client interface to connect the communication channels of the application to the agent, and a set of rule files that are arranged in a tree, using `import` statements. The blue core in Figure 3.1 is the runtime system that is part of VONDA, while all light grey elements are the application specific parts of the agent. A `Yaml` project file contains all necessary information for compilation: the ontology, the wrapper class, the top-level rule file and other parameters, like custom compile commands for VONDA’s debugger.

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accesses are actually accesses to the database, etc (see section 3.1.2). Every rule file can define variables and functions in VOnDA syntax which are then available to all imported files.

The current structure assumes that most of the Java functionality that is used inside the rule files will be provided by the `Agent` superclass. There are, however, alternative ways to use other Java classes directly (see section 3.1.2 for further info). The methods and fields from the custom wrapper class can be made available to all rule files by declaring them in the interface connecting the `.rudi` code to the Java framework. This interface must have the same name as the wrapper class but end with `.rudi` (in the example of figure 3.1, this would be `MyAgent.rudi`).

### 3.1.2 The VOnDA Rule Language

VOnDA's rule language looks very similar to Java/C++. There are a number of specific features which make it much more convenient for the specification of dialogue strategies. One of the most important features is the way objects in the RDF store can be used throughout the code: RDF objects and classes can be treated similarly to those of object oriented programming languages, including the type inference and inheritance that comes with type hierarchies.

#### The Structure of a VOnDA File

VOnDA does not require to group statements in some kind of high-level structure like e.g. a class. It is, in fact, not possible to define classes in `.rudi` files at all, rules and method declarations have to be put directly into the rule file. The same holds for every kind of valid (Java-) statement, like assignments, `for` loops etc. From this, the compiler will create a Java class where the methods and rules that are transformed are represented as methods of this specific (generated) class. All other statements as well as auto-generated calls to the methods representing the rules will be put into the `process()` method that VOnDA creates to build a rule evaluation cycle. In doing so, the execution order of all statements, including the rules, is preserved.

This functionality offers possibilities to e.g. define and process high-level variables that you might want to have access to in subsequent rules or to insert termination conditions that prevent some rule executions.

**Warning:** It is important to know that variables declared globally in a file will be transformed to fields of the Java class. We found that in very rare occasions, this can lead to unexpected behaviour when using them in a `propose` or `timeout` block as well as changing them in a global statement. As `propose`s and `timeout`s will not immediately be executed, they need every variable used inside them to be effectively final. VOnDA leaves the evaluation of validity of variables for such blocks to Java. We found that Java might mistakenly accept variables that are not effectively final, what might lead to completely unexpected behaviour when `propose`s and `timeout`s with changed variable values are executed.

The only important exception, where globally defined variables persist throughout the whole runtime of the system are variables defined in the top-level rule file. This is on purpose, and can be used to define persistent variables also usable in lower-level rule files.

#### RDF accesses and functional vs. relational properties



Figure 3.2: Ontology and VOnDA code

Figure 3.2 shows an example of VOnDA code, and how it relates to RDF type and property specifications, schematically presented on the right. The domain and range definitions of properties are picked up by the compiler and then used in various places, e.g., to infer types, do automatic code or data conversions, or create “intelligent” boolean tests, like in line 4, which will expand into two tests, one testing for the existence of the property for the object, and in case that succeeds, a test if the value is smaller or equal than zero. If there is a chain of more than one field/property access, every part is tested for existence in the target code, keeping

the source code as concise as possible. Also for reasons of brevity, the type of a new variable needs not be given if it can be inferred from the value assigned to it.

New RDF objects can be created with `new`, similar to Java objects; they are immediately reflected in the database, as are all changes to already existing objects.

```
c = new Child;
String name = c.name;
c.name = "new name";
Set middle = c.middleNames;
c.middleNames += "John";
c.middleNames -= "James";
c.name = null;
```



```
String name = (String)c.getValue("<upper:name>");
c.setValue("<upper:name>", "new name");
Set middle = (Set<Object>)c.getValue("<upper:middleNames>");
c.add("<upper:middleNames", "John");
c.remove("<upper:middleNames", "James");
c.clearValue("<dom:name>");
```

Table 3.1: Examples for an RDF property access

missing creation of child in lower part, plus "Set middle" is no proper code, line numbers used in text, but not present in figure

The connection of VOnDA to the ontology loaded into HFC during compile time enables the compiler to recognize the correct RDF class to create a new instance when encountering `new`, and to resolve field/property accesses to all RDF instances. Field accesses as shown in line 2 and 3 of table 3.1 will be analyzed and transformed into database accesses. VOnDA will also draw type information from the database. If the name property of the RDF class `Child` is of type `String`, exchanging line 2 by the line `int name = c.name` will result in a warning of the compiler. During this process, the compiler will automatically also use the correspondence of XSD and Java types shown in table 3.2.

<code>&lt;xsd:int&gt;</code>	Integer	<code>&lt;xsd:integer&gt;</code>	Long
<code>&lt;xsd:string&gt;</code>	String	<code>&lt;xsd:byte&gt;</code>	Byte
<code>&lt;xsd:boolean&gt;</code>	Boolean	<code>&lt;xsd:short&gt;</code>	Short
<code>&lt;xsd:double&gt;</code>	Double	<code>&lt;xsd:dateTime&gt;</code>	Date
<code>&lt;xsd:float&gt;</code>	Float	<code>&lt;xsd:date&gt;</code>	XsdDate
<code>&lt;xsd:long&gt;</code>	Long	<code>&lt;xsd:dateTimeStamp&gt;</code>	Long

Table 3.2: Standard RDF types and the Java types as which they will be recognized

Moreover, VOnDA determines whether an access is made using functional or relational predicates and will handle it accordingly, assuming a collection type if necessary. In the rule language, the operators `+=` and `-=` are overloaded. They can be used with sets and lists as shortcuts for adding and deleting objects. `a += b` will be compiled to `a.add(b)` and `a -= b` results in `a.remove(b)`, as shown in table 3.1.

## Rules and rule labels

The core of VOnDA dialogue management are the dialogue rules, which will be evaluated at run-time system on every trigger generated from the environment or the internal processing. A rule (optionally) starts with a name that is given as a Java-like label: an identifier followed by a colon. Following this label is an `if`-statement, with optional `else` case. The clause of the `if`-statement expresses the condition under which the rule, or rather the `if` block, is to be executed; in the `else` block you can define what should happen if the condition is `false`, like stopping the evaluation of (a sub-tree of) the rules if necessary information is missing.

```

introduction:
  if (introduction) {
    if (user.unknown) {
      ask_for_name:
        if (talkative) askForName();
    } else
      greetUser();
  }

```

Figure 3.3: A simple rule

Rules can be nested to arbitrary depth, so if-statements inside a rule body can also be labelled. The labels are a valuable tool for debugging the system at run-time, as they can be logged live with the debugger GUI (cf. chapter 3.3). The debugger can show you which rules were executed when and what the individual results of each base clause of the conditions were.

### The propose and timeout constructs

There are two statements with a special syntax and semantics: `propose` and `timeout`. `propose` is VONDA's current way of implementing probabilistic selection. All (unique) `propose` blocks that are in active rule actions are collected, frozen in the execution state in which they were encountered, like closures known from functional programming languages. When all possible proposals have been selected, a statistical component decides on the "best", whose closure is then executed.

```

if (!saidInSession(#Greeting(Meeting))) {
  // Wait 7 secs before taking initiative
  timeout("wait_for_greeting", 7000) {
    if (!receivedInSession(#Greeting(Meeting)))
      propose("greet") {
        da = #InitialGreeting(Meeting);
        if (user.name) da.name = user.name;
        emitDA(da);
      }
  }

  if (receivedInSession(#Greeting(Meeting)))
    propose("greet_back") { // We assume we know the name by now
      emitDA(#ReturnGreeting(Meeting, name={user.name}));
    }
}

```

Figure 3.4: `propose` and `timeout` code example

`timeouts` generate the same kind of closures, but with a different purpose. They can for example be used to trigger proactive behaviour, or to check the state of the system after some time period, or in regular intervals. A `timeout` will only be created if there is no active `timeout` with the same name.

There are two variants of `timeout`: *labeled timeouts*, like the one in the previous example, run out after the specified time (unless they are cancelled before that using the `cancelTimeout(label)` function) and then execute their body, and *behaviour timeouts*, where the first

AW: Just a mention that to my knowledge we never used behaviour timeouts in PAL, has it been tested? BK: Yes, but it must be described in more detail.

argument is a dialogue act (see next section) instead of a label. These are executed either when the specified time is up or the behaviour that was triggered by the dialogue act is finished, whatever comes first.

## Interrupting the rule evaluation cycle

There are multiple ways to stop rule evaluation locally (i.e. skipping the evaluation of the current subtree) or globally (i.e. stopping the whole evaluation cycle). You can skip the evaluation of a specific rule you are currently in with the statement `break label_name;`. This will only stop the rule with the respective label (no matter how deep the break statement is nested in it), such that the next following rule is evaluated next.

If the evaluation is cancelled with the keyword `cancel`, all of the following rules in the current file will be skipped (including any imported rules). If the keyword `cancel_all` is used, none of the following rules, neither local nor higher in the rule tree, will be evaluated. This is the VOnDA way of deciding to not further evaluate whatever triggered the current evaluation cycle and will mostly be used as an 'emergency exit', as the dialogue rules should be rejecting any non-matching trigger by themselves.

To leave `propose` and `timeout` blocks, you need to use an empty `return`, as they are only reduced representations of normal function bodies.

There should be a complete description of the rule evaluation cycle, with details such as the initialization of rule class objects, etc.

## Dialogue Acts

A central functionality of a dialogue system is receiving and emitting dialogue acts that result from a user utterance resp. can be transformed to natural language by a generation component to communicate with the user. In VOnDA, the function for sending dialogue acts is called `emitDA`.

The dialogue act representation is an internal feature of VOnDA. We are currently using the DIT++ dialogue act hierarchy [Bunt et al., 2012] and shallow frame semantics along the lines of FrameNet [Ruppenhofer et al., 2016] to represent dialogue acts. The natural language understanding and generation units connected to VOnDA should therefore be able to generate or, respectively, process this representation.

```
emitDA(#Inform(Answer, what={solution}));
```

Figure 3.5: Dialogue Act Example

Figure 3.5 shows the dialogue act representation in VOnDA, as passed to, e.g., the `emitDA` function. `Inform(...)` will be recognized by VOnDA as dialogue act because it has been marked with `#`. It will then create a new instance of the class `DialogueAct` that contains the respective modifications. As a default, arguments of a `DialogueAct` creation (i.e., character strings on the left and right of the equal sign) are seen as and transformed to constant (string) literals, because most of the time that is what is needed. Surrounding a character sequence with curly brackets (`{}`) marks it as an expression that should be evaluated. In fact, arbitrary expressions are allowed inside the curly brackets.

What about automatic conversion to string?

While this kind of shallow semantics is enough for many applications, we already experience its shortcomings when trying to handle, for example, social talk. One of the next improvements will be the extension of Dialogue Acts to allow for embedded structures.

## Type inference and overloaded operators

VOnDA allows static type assignments and casting, but in many cases these can be avoided. If, for example, the type of the expression on the right-hand side of a declaration assignment is known or inferable, it is not necessary to explicitly state it.

You can also declare variables final.

A time-saving (and code-readability-improving) feature of VOnDA is the automatic completion of boolean expressions in the clauses of `if`, `while` and `for` statements. As it is obvious in these cases that the result of the expression must be of type `boolean`, VOnDA automatically fills in a test for existence if it is not. When encountering field accesses, it makes sure that every partial access is tested for existence (i.e., not `null`) to avoid a `NullPointerException` in the runtime execution of the generated code.

Be aware that the expansion in the figure only occurs if the multiple field access is used as boolean test. In the example of 3.4, if the first clause in the boolean expression is omitted, a `NullPointerException` could still occur because the second clause does not trigger an automatic test for existence of activity.

```

if (! c.user.personality.nonchalance){ ... }

      ↓↓

if (!(((c != null) && (c.user != null))
      && (c.user.personality != null))
      && (c.user.personality.nonchalance != null))) {
    ...
}

```

Table 3.3: Transformation of complex boolean expressions

```

if (activity.status && activity.status == 'foo'){ ... }

```

Table 3.4: Transformation of complex boolean expressions

Many operators are overloaded, especially boolean operators such as `<=`, which compares numeric values, but can also be used to test if an object is of a specific class, for subclass tests between two classes, and for subsumption of dialogue acts.

<pre> if (sa &lt;= #Question){     ... } </pre>	<pre> if (sa.isSubsumedBy(new DialogueAct("Question")) {     ... } </pre>
---	---

Table 3.5: Overloaded comparison operators

## External methods and fields

As mentioned before, you can use every method or field you declare in your custom Agent implementation in your VOnDA code. Their declaration in the Java-rudi interface should look like a normal Java field or method definition (cf. figure 3.6). It is possible to use generics in these definitions, although they are, for complexity reasons, restricted to be one single uppercase letter.

There is a variety of standard Java methods called on Java classes that VOnDA automatically recognizes, like e.g. the `substring` method for Strings. If you find that you need VOnDA to know the return type of a new method that can or should only be called upon instances of a specific class, you can provide VOnDA with knowledge about them by adding their definition to the interface as follows:

Fields of Java classes that you want to access over the instances of such a class can be defined analogously:

```

[type]. myType someVar

```

Of course you can also use generics in these definitions. For example, the `get` method on lists is defined as follows in the VOnDA framework:

It is important to realize that all declarations in the interface are only compile information for VOnDA and will not be transferred to the compiled code, whereas such declarations in the rule code itself will also appear in the compiled code.

## Functional constructs

VOnDA allows for using lambda constructions. At the moment, their usage is limited to the implementation of Predicate or Comparator in the functions listed in table 3.8 that are pre-defined in the Agent framework.

For example, if you want to filter a set of RDF objects by a subtype relation, you can write:

```

des = filter(agent.desires, (d) -> ((Desire)d) <= UrgentDesire);

```

AW: it's just a general function now, so is it not limited anymore?

<code>myType someVariable;</code>	there is a variable of type <code>myType</code>
<code>myType someFunction(typeA a, typeB b);</code>	the method <code>someFunction</code> takes arguments of types <code>typeA</code> and <code>typeB</code> and returns an object of type <code>myType</code> (void = void)

Table 3.6: Definitions of existing Java fields and methods for VOnDA

<code>[type]. myType Function(typeA a);</code>	declaration of a function that has to be called on an instance of class <code>type</code> .
--	---

Table 3.7: Definition of a non-static method of Java objects

`import`

`import` is a keyword in the VOnDA language. A global line like "`import File;`", to be placed at an arbitrary position between the rules, results in the inclusion of the file `File.rudi` at exactly this position.

This inclusion has two important effects. On the one hand, it triggers the compilation of the included file at exactly this point, such that any fields and methods known at this time will be available in the important file and it does not need to be compiled separately. On the other hand, it has the effect that all the rules contained in the imported file will be inserted in the rule cycle at the specific position of the `import`, where in the resulting code the `process()` method of the imported file will be executed.

So the `import` functionality makes it possible to distribute the rules of a project into multiple files, respectively modules, and pin them together in such a way that they are handled as one unit when compiling or executing the compiled code. This is not only useful for clarity and structuring of a project, but also supports modularity, as different subtrees of the `import` hierarchy can easily be added, moved, taken away or re-used in different projects.

### Java-Code verbatim in rule files

To maintain simplicity, VOnDA intentionally only provides limited Java functionalities. Whatever is not feasible in `.rudi` code should be done in methods in the wrapper class.

In cases where this is not enough and you urgently need a functionality that VOnDA cannot parse or represent correctly, you can use the verbatim function. Everything between `/*` and `*/` will be treated like a multi-line Java comment, meaning the content is not parsed or evaluated further. It will be transferred to the compiled code at exactly this position between statements, but without the comment symbols.

In particular, this functionality can be used to import Java classes (i.e., with Java `import` statements) at the beginning of a rule file. You should however be aware that VOnDA will not know these classes nor their methods and fields. It will however accept creations of instances of unknown classes, as well as your casting of results of unknown methods. If, be it for commodity or for other reasons, you want VOnDA to have type information about methods called on instances on one of these classes, you can put this information into the type interface of the wrapper class (cfg. chapter 3.1.2).

## 3.2 The Run-Time System

The run-time library contains the basic functionality for handling the rule processing, including the proposals and timeouts, and for the on-line inspection of the rule evaluation. There is, however, no blueprint for the main event loop, since that depends heavily on the host application. The run-time library also contains methods for the creation and modification of shallow semantic structures, and especially for searching the interaction history for specific utterances. Most of this functionality is available through the abstract `Agent` class, which has to be extended to a concrete class for each application.

There is functionality to talk directly to the HFC database using queries (compare section 3.4.1), in case the object view is not sufficient or too awkward.

```
[List<T>]. T get(int a);
```

AW: This is just a different language than the rest of the documentation... reformulate?



```

boolean some(Collection<T> coll, Function<Boolean, T> pred);
boolean all(Collection<T> coll, Function<Boolean, T> pred);
List<T> filter(Collection<T> coll, Function<Boolean, T> pred);
List<T> sort(Collection<T> coll, Function<Integer, T, T> comp);
Collection<T> map(Collection<S> coll, Function<T, S> f);
int count(Collection<T> coll, Function<Boolean, T> pred);
T first(Collection<T> coll, Function<Boolean, T> pred);

```

Table 3.8: Functions that take lambda expressions as an argument

The set of your reactive VOnDA rules is executed whenever there is a change in the information state (IS). These changes are caused by incoming sensor or application data, intents from the speech recognition, or expired timers. A rule can have direct effects, like changes in the IS, or system calls. Furthermore, it can generate so-called *proposals*, which are (labeled) blocks of code in a frozen state that will not be immediately executed, similar to closures.

All rules are repeatedly applied until a fix point is reached: No new proposals are generated and there is no IS change in the last iteration. Then, the set of proposals is evaluated by a statistical component, which will select the best alternative. This component can be exchanged to make it as simple or elaborate as necessary, taking into account arbitrary features from the data storage.

### 3.2.1 Functionalities (methods) Provided by the Run-Time System

The following methods are declared in `src/main/resources/Agent.rudi`; their implementation is provided by Java itself or the VOnDA framework.

- Pre-added Java methods

```

[Object]. boolean equals(Object e);
[String]. boolean startsWith(String s);
[String]. boolean endsWith(String s);
[String]. String substring(int i);
[String]. String substring(int begin, int end);
[String]. boolean isEmpty();
[String]. int length();

[List<T>]. T get(int a);
[Collection<T>]. void add(Object a);
[Collection<T>]. boolean contains(Object a);
[Collection<T>]. int size();
[Collection<T>]. boolean isEmpty();
[Map<S, T>]. boolean containsKey(S a);
[Map<S, T>]. T get(S a);
[Array<T>]. int length;

int random(int limit);
float random();

```

- Short-hand conversion methods from Agent

```

int toInt(String s);
float toFloat(String s);
double toDouble(String s);
boolean toBool(String s);
String toStr(type i); // type in (int, short, byte, float, double, boolean)

```

- Other Agent methods

```

// Telling the Agent that something changed
void newData();

```

```
String getLanguage();

// Math methods
int random(int limit);
float random();

// logging methods
Logger logger;

// discarding actions and shutdown
void clearBehavioursAndProposals();
void shutdown();
```

- Timeouts

```
void newTimeout(String name, int millis);
boolean isTimedOut(String name);
void removeTimeout(String name);
boolean hasActiveTimeout(String name);
// cancel and remove an active timeout, will not be executed
void cancelTimeout(String name);
```

- Methods handling with dialogue acts

```
// sending of dialogue acts
DialogueAct createEmitDA(DialogueAct da);
DialogueAct emitDA(int delay, DialogueAct da);
DialogueAct emitDA(DialogueAct da);

// Access to dialogue acts of the current session
// my last outgoing resp. the last incoming dialogue act
DialogueAct myLastDA();
DialogueAct lastDA();

// Did I say something like ta in this session (subsumption)? If so, how many
// utterances back was it? (otherwise, -1 is returned)
int saidInSession(DialogueAct da);
// like saidInSession, only for incoming dialogue acts
int receivedInSession(DialogueAct da);

boolean waitingForResponse();
void lastDAprocessed();
DialogueAct addLastDA(DialogueAct newDA);
[DialogueAct]. void setProposition(String prop);
```

- Methods using lambda expressions

```
boolean some(Collection<T> coll, Function<Boolean, T> pred);
boolean all(Collection<T> coll, Function<Boolean, T> pred);
List<T> filter(Collection<T> coll, Function<Boolean, T> pred);
List<T> sort(Collection<T> coll, Function<Integer, T, T> c);
Collection<T> map(Collection<S> coll, Function<T, S> f);
int count(Collection<T> coll, Function<Boolean, T> pred);
T first(Collection<T> coll, Function<Boolean, T> pred);
T random(Collection<T> coll);
```

- Methods callable on Rdf objects

```
Rdf toRdf(String uri);
[Rdf]. String getURI();
```

```
[Rdf]. boolean has(String predicate);  
[Rdf]. long getLastChange(boolean asSubject, boolean asObject);
```

### 3.3 Debugger/GUI

VOnDA comes with a GUI [Biwer, 2017] that helps navigating, compiling and editing the source files belonging to a project. It can also be attached to your VOnDA project at runtime to support debugging by logging the evaluation of rule conditions.

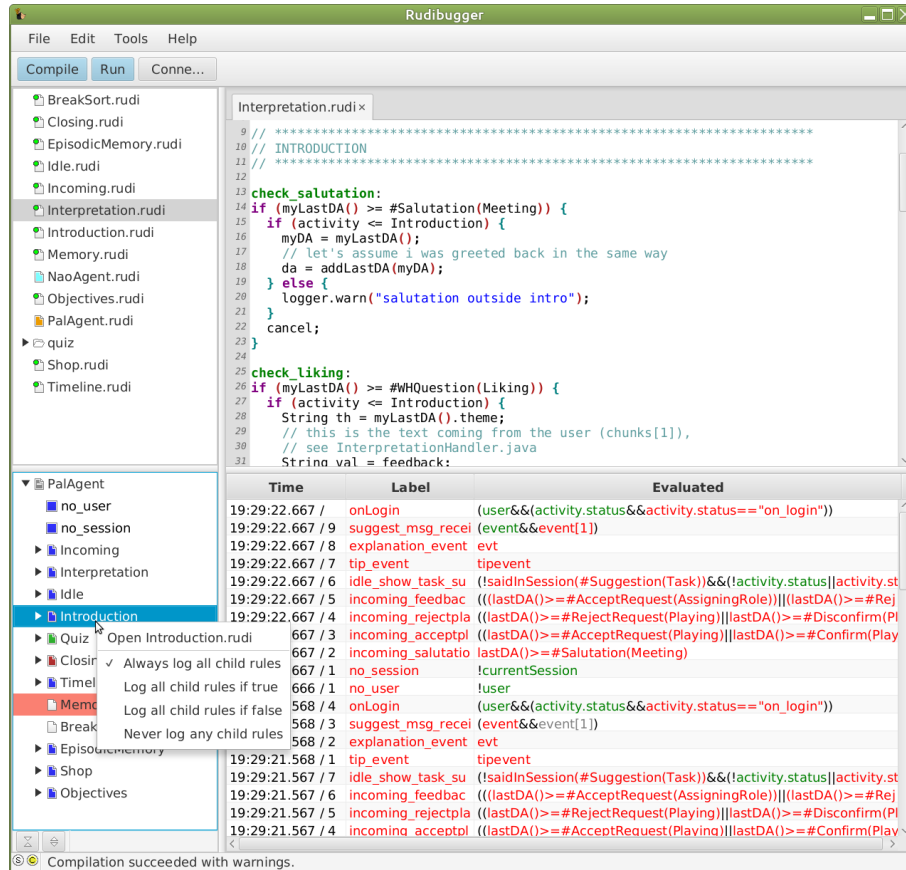


Figure 3.6: The VOnDA GUI window

For further details, please take a look into rudibugger's own documentation. The project can be found on <https://github.com/yoshegg/rudibugger>.

### 3.4 The RDF Database HFC

VOnDA follows the information state/update paradigm. The information state is realized by an RDF store and reasoner with special capabilities (HFC Krieger [2013]), namely the possibility to directly use  $n$ -tuples instead of triples. This allows to attach temporal information to every data chunk Krieger [2012, 2014]. In this way, the RDF store can represent *dynamic objects*, using either *transaction time* or *valid time* attachments, and as a side effect obtain a complete history of all changes. HFC is very efficient in terms of processing speed and memory footprint, and has recently been extended with stream reasoning facilities. VOnDA can use HFC either directly as a library or as a remote server, also allowing for more than one instance if needed (for this feature see section 4.2.1).

The following is the syntax of HFC queries (EBNF):

```

<query>      ::= <select> <where> [<filter>] [<aggregate>] | ASK <groundtuple>
<select>     ::= {"SELECT" | "SELECTALL"} ["DISTINCT"] {"*" | <var>^+}
<var>        ::= "?"{a-zA-Z0-9}^+ | "?_"
<nwchar>     ::= any NON-whitespace character
<where>      ::= "WHERE" <tuple> {"&" <tuple>}^*
<tuple>      ::= <literal>^+
<gtuple>     ::= <constant>^+
<literal>    ::= <var> | <constant>
<constant>   ::= <uri> | <atom>
<uri>        ::= "<" <nwchar>^+ ">"
<atom>       ::= "\" <char>^* "\" [ "@" <langtag> | "^" <xsdtype> ]
<char>       ::= any character, incl. whitespaces, numbers, even '\ '
<langtag>    ::= "de" | "en" | ...
<xsdtype>    ::= "<xsd:int>" | "<xsd:long>" | "<xsd:float>" | "<xsd:double>" |
               "<xsd:dateTime>" | "<xsd:string>" | "<xsd:boolean>" | "<xsd:date>" |
               "<xsd:gYear>" | "<xsd:gMonthDay>" | "<xsd:gDay>" | "<xsd:gMonth>" |
               "<xsd:gYearMonth>" | "<xsd:duration>" | "<xsd:anyURI>" | ...
<filter>     ::= "FILTER" <constr> {"&" <constr>}^*
<constr>     ::= <ineq> | <predcall>
<ineq>       ::= <var> "!=" <literal>
<predcall>   ::= <predicate> <literal>^*
<predicate>  ::= <nwchar>^+
<aggregate> ::= "AGGREGATE" <funcall> {"&" <funcall>}^*
<funcall>    ::= <var>^+ "=" <function> <literal>^*
<function>   ::= <nwchar>^+

```

AW: Just asking: How long can we still talk of "recently extended"?

Table 3.9: BNF of the database query language

The reserved symbols ASK, SELECT, SELECTALL, DISTINCT, WHERE, FILTER and AGGREGATE do *not* need to be written in uppercase, but neither filter predicates nor aggregate functions should be named like reserved symbols.

*don't-care* variables should be marked *explicitly* by using `?_`, particularly if SELECT is used with `*` as in:

```

SELECT DISTINCT * WHERE ?s <rdf:type> ?_
SELECT * WHERE ?s <rdf:type> ?o ?_

```

To change the object position without projecting it you can use *don't-care* variables:

```

SELECT ?s WHERE ?s <rdf:type> ?o ?_ FILTER ?o != <foo-class>

```

Aggregates in HFC take whole tables or parts of them and calculate a result based on their entities. As the type of aggregates and filter functions cannot be overloaded, there are multiple similar functions for different types, e.g. F for float, L for long, D for double, I for int, and S for String.

Apart from `==` and `!=`, functional operators can be used in filter expressions as well. As for aggregates, there are multiple versions of the same function for different data types.

AW: I do have an idea of how to write hfc queries of the simplicity that is sufficient for most DM stuff, and I have no understanding of what this means... Explain?

CountDistinct	FSum	LMax
Count	FMean	LMean
DMean	LGetFirst2	LMin
DSum	LGetLatest2	LSum
DTMax	LGetLatest	LGetLatestValues
DTMin	LGetTimestamped2	Identity

Table 3.10: Available aggregates

CardinalityNotEqual	FNotEqual	IntStringToBoolean	LMin
Concatenate	FProduct	IProduct	LNotEqual
DTIntersectionNotEmpty	FQuotient	IQuotient	LProduct
DTLessEqual	FSum	IsAtom	LQuotient
DTLess	GetDateTime	IsBlankNode	LSum
DTMax2	GetLongTime	IsNotSubtypeOf	LValidInBetween
DTMin2	HasLanguageTag	ISum	MakeBlankNode
EquivalentClassAction	IDecrement	IsUri	MakeUri
EquivalentClassTest	IDifference	LDecrement	NoSubClassOf
EquivalentPropertyAction	IEqual	LDifference	NoValue
EquivalentPropertyTest	IGreaterEqual	LEqual	PrintContent
FDecrement	IGreater	LGreaterEqual	PrintFalse
FDifference	IIncrement	LGreater	PrintSize
FEqual	IIntersectionNotEmpty	LIncrement	PrintTrue
FGreaterEqual	ILessEqual	LIntersectionNotEmpty	SameAsAction
FGreater	ILess	LIsValid	SameAsTest
FIncrement	IMax2	LLessEqual	SContains.java
FLessEqual	IMax	LLess	UDTLess
FLess	IMin2	LMax2	
FMax	IMin	LMax	
FMin	INotEqual	LMin2	

Table 3.11: Available filter functions

### 3.4.1 Usage of HFC in VOnDA

The RDF store contains the dynamic and the terminological knowledge: specifications for the data objects and their properties, as well as a hierarchy of dialogue acts, semantic frames and their arguments. These specifications are also used by the compiler to infer the types for property values (see sections 3.1.2 and 3.1.2), and form a declarative API to connect new components, e.g., for sensor or application data.

The ontology contains the definitions of dialogue acts, semantic frames, class and property specifications for the data objects of the application, and other assertional knowledge, such as specifications for “forgetting”, which could be modeled in an orthogonal class hierarchy, and supported by custom deletion rules in the reasoner.

For queries which are too complex to be handled the VOnDA way, or if you want to do reasoning which for efficiency reasons should be handled by HFC rather than Java (e.g., if you are filtering for specific property values in a pool of many instances of the same class), there also is a direct communication port to HFC.

```
List<String> uris = new ArrayList<>();  
// the ancestor is that hyponym which has the shortest path to syn  
String ancestors = "select ?s where ?s <wn20schema:hyponym> {} ?_ ";  
QueryResult qr = proxy.selectQuery(ancestors, syn);  
uris = RdfProxy.getValues(qr);
```

The above code, for example, retrieves all hyponyms of a given synset *syn*.

Currently, it is recommended to place such code in Java methods that you can then use in your VOnDA code to indirectly perform the queries. In the future, functionality will be added to support facilitated query construction directly in VOnDA code.

## Chapter 4

# Building VOnDA Agents

### 4.1 Implementation Patterns and Caveats

#### 4.1.1 Proper Usage of `lastDAprocessed` and `emitDA`

`lastDAprocessed()` is a built-in method that helps you clean up after a dialogue act has been dealt with. You usually want to call it in your `propose` block, because when the block is executed that means that the dialogue act has been processed. The method's effect is to set an internal timestamp at the moment it has been called, which affects the return value of `lastDA()`: `lastDA()` will only return a dialogue act if it has been sent after the point in time specified by the `lastDAprocessed` timestamp.

Be aware this also means that if the statement you execute in your `propose` block is `lastDAprocessed();`, all following calls to `lastDA()` will evaluate to an empty dialogue act. Thus, using expressions like `theme=lastDA().theme` in an `emitDA` are strongly discouraged, because they will fail if the `emitDA` is used after calling the cleanup method. There is, however, good reason to not move the `lastDAprocessed()` to the very end of your proposal, as proposals are executed in a separate thread and your VOnDA rules are (re-)evaluated in parallel. This might, in rare cases where your proposal code takes more time to process (for one possible reason, see 4.1.2), lead to your system generating and executing new proposals based on the "old" dialogue act, thus responding more than once to one input.

#### 4.1.2 A Few Words About `emitDA` and `createBehaviour`

There is a feature to the `emitDA` method which has not been mentioned in section 3.1.2, but might become important in your specific application.

`emitDA` actually only is a wrapper method which uses the given dialogue act to create a behaviour, which is the actual thing being sent to the communication hub. `createBehaviour` wants to be passed a delay parameter, which specifies the amount of time the ???communication thread??? should be paused after emitting the given behaviour. This might be important to your application if you use for example TTS and want to delay the next utterance until playing the current one has been finished. Normal `emitDA` sets the delay to `Behaviour.DEFAULT_DELAY`, which by default is zero, but you can also call `emitDA(delay, dialogueAct)` to directly specify a delay, or even override `createBehaviour` to perform a more complex computation of the delay time, e.g. to adopt to text length \* speed of your TTS voice.

Attention! Once you are doing this, make sure that you use `lastDAprocessed()` early in your `propose` block as suggested in 4.1.1. If you don't and the thread the proposal is executed in is delayed long enough, new proposals will be generated based on the old dialogue act and your agent might end up saying things twice.

AW: Is it the communication thread, or how can we call it?

#### 4.1.3 Waiting for a User's Answer in a Conversation

It's not very polite to be talking all the time without letting the interlocutor say something themselves. Particularly, you'll want to make sure that once the system asked a question, it will at least wait for some time before going on, to give the user a chance to answer. To this end, you can use the pre-built `waitingForResponse` method, which returns true if the system was the last one to speak and the dialogue act it uttered was a question or a request.



## 4.1.4 Volatile variables in rule files and how to keep information between evaluation cycles

AW: Might want to reformulate this a bit

An interesting property of VOnDA's architecture that is important to be informed about is that when starting a new rule evaluation cycle, new class instances for all imported rule files will be created. This means that whenever the VOnDA rules are executed in a new cycle, they are executed in a "clean state" where all variables you previously set in the rule file itself have been reset. The only exception from this are variables which are either located in the abstract (Java) Agent class or in your top-level rule file.

Thus: Always keep in mind that only variables defined in the Java Agent instance or in the top-level rule file or imported via it are persistent, everything else is volatile!

## 4.2 Advanced Features

### 4.2.1 Connecting to a second HFC Server

In the standard setup, your VOnDA project uses one HFC server that on starting your system loads all the information from your ontology and that receives your new database entries and modifications.

However, there might be cases where this approach is not what you want. If your project uses a big database with static information, that you use but do not need to write to, you might prefer to not start the server anew each time you start your system, as this might consume time.

In this case, there is another solution: you can start your HFC server remotely and then connect to it in your VOnDA agent.

On a linux machine, you can run a server by executing the following lines:

To connect your VOnDA agent to a local server you just need to add the following code, where port is the port you started it on and myProxy is the RdfProxy instance you can post your queries to.

```
myClient = RPCFactory.createSyncClient(HfcDbService.Client.class,
    "localhost", port);
_myProxy = new RdfProxy(new ClientAdapter(myClient));
```

TODO: add  
hfc server start  
script

This additional server does of course not have the same status as the innate HFC proxy, as you only connect to it at run-, not at compile-time. You can query it for information as described in 3.4.1, but classes from this database will not be recognized in the rudi code and you cannot write to it.

or can you?  
Try?!

## 4.3 Troubleshooting: Typical Problems

- **The execution of my propose or timeout block does not have the effect I expected**  
Are you using any variables inside that block whose contents are changed by other parts of your code after the block has been issued?
- **The fields of the dialogue act sent by emitDA in my Proposal do not contain the values they should according to my conditions**  
Check whether you have "buffered" those values in final variables before issuing the Proposal and are referring to those. Using lastDA directly in the propose block is dangerous because it might already contain the next dialogue act (or none at all).
- **I get a NullPointerException in my Proposal**  
Please check whether all the variables you're using in the propose block are final and can't be changed by someone else between the time the Proposal is registered and the time it is executed. Also make sure you're not trying to read the fields of lastDA() after you called lastDAprocessed.
- **My system seems to execute the same Proposal multiple times**  
Make sure that in your propose block, you are calling lastDAprocessed as described in 4.1.1 and also "resetting" everything else that triggers the rule to be executed.
- **The variable that I use in my rules for storing information does not have the contents it is supposed to**  
Be aware that variables not defined in the top-level rule file are not persistent between rule evaluation cycles, thus you should not store information there which you want to keep (see section 4.1.4).

- **When compiling, I get the warning ''base name x can be one of y, z, please resolve manually''**  
It seems your ontology is redefining an existing class. Refer to section 2.5.1 to see how to resolve the problem.

## Chapter 5

# VOnDA Syntax Overview

```
//
/*@
// A "Java" comment, everything in this comment will be transferred literally
// to the compiled file, without the comment brackets.
public static int MAX_INT = 100;
@*/

// *****
// Tests and Comparisons
// *****

Child child;

// test for value under path, intermediate tests are generated
if (child.father.surname) logger.info("foo");

// subsumption of dialogue acts, (equality is also possible)
if (lastDA() <= #AcceptOffer(Bringing)) logger.info("foo");

// Test if two RDF objects are the same object.
// Mark the difference to the next example! Here, the objects are compared,
// as in the case of !=, but all other comparison operators compare the classes
Child c1;
Agent c2;
if (c1 == c2) logger.info("foo");

// Is the class of c1 a subclass, resp. a strict subclass of the class of c2 ?
if (c1 <= c2) logger.info("foo");
if (c1 < c2) logger.info("foo");

// Is the class of c1 a subclass of the class 'Child'?
if (c1 <= Child) logger.info("foo");

// Is s not null and not empty?
String s = "bar";
if (s) logger.info("foo");

// Is s.compareTo(t) < 0
s = "bar"; t = "baz";
if (s < t) logger.info("foo");

// Is i not null and not zero? (Same for all other Number containers)
```

```

Integer i = -1;
if (i) logger.info("foo");

// Is o not null?
Object o = new Object();
if (o) logger.info("foo");

// *****
// Forward declaration of methods
// *****

String foo(String a, String b);

if (foo("a", "b")) {
    logger.info("yes!");
}

String foo (String a, String b) { return a + b; }

// *****
// Breaking out of rules
// *****

// break can be used to exit the rule specified, rules following this
// rule will still be executed
test_rule:
    if (true) {
        second_rule:
            if (false) {
                break test_rule;
            }
    }

// return from a file (not looking at subsequent rules) with cancel
test_rule2:
    if (true) {
        second_rule:
            if (false) {
                cancel;
            }
    }

// Stop all rule execution (even at higher levels) with cancel_all
test_rule3:
    if (true) {
        second_rule:
            if (false) {
                cancel_all;
            }
    }

// *****
// Near-to-Java features
// *****

// you can declare a variable final if you need to use it in a propose or
// timeout block
test_rule4:

```

```

    if(true) {
        final c = "hi";
        final boolean b = false;
        propose("test") {
            if(c.equals("bye"))
                logger.info("bye");
        }
    }

// *****
// Coverage - To be revised and sorted properly
// *****

// there can always be an 'else' case
if (true && !false) { /* do something */ } else { /* do something else */ }

// TODO: sum1 and sum2 should, but do not become a proper declaration here
// An unknown function is used. The system tries to infer the type of
// operator arguments as best as possible
somevar = getSomething();
sum1 = 3 + somevar;
sum2 = somevar + 3;
anothervar = getSomething();
someint = 1 < 3 ? anothervar : 3;

// You can use casts and conditional expressions just like in Java
Integer anotherint = (Integer) i;
anotherint = anotherint < 3 ? anotherint : 3;

// There are also while and for loops and switch-case blocks available
while (true) { continue; }
for (abc = 1; abc < 10; abc++) { ++abc; }

ArrayList<String> iterlist;
// The following two lines are equivalent, the type of a is inferred
for (String a : iterlist) {}
for (a : iterlist) {}

String str;
switch (str) {
    case "a": break;
    case "b":
    default:
}

// It is possible to perform implicit casts on iterable elements in a for
// loop; there is, however, no type safety promise!
ArrayList<Object> iterlist2;
for (Integer a : iterlist2) {}

// These are some examples for lambda expressions
List<String> newlist = {"a", "cd", "ab", "b"};
allas = filter(newlist, (element) -> ((String)element).contains("a"));
dosort = sort(newlist, (a, b) -> (int)((((String)a).length() - ((String)b).length()));

// Creation of dialogue acts. Elements that are Variables need to be
// enclosed in {}, all others will be converted to Strings (symbols are default)
robotname = "Robert";

```

```

dia = #Inform(Liking, agent=username, patient={robotname});

void callToSomeMethod() {
    // a stub for an external function
}

// You can set labelled timeouts that will execute the code given to them
// once the time (given in milliseconds) is over
timeout("do_something", 15000) {
    callToSomeMethod();
}

// You can also condition a timeout on the finishing of a behaviour. The code
// block will be executed when either the specified time runs out or the
// behaviour finishes
timeout_behaviour(15000, #Inform(Call, when=soon)) {
    callToSomeMethod();
}

// Automatic conversion to string of POD types
s = "number" + 10;
s = 10.0 + "number";
// and of RDF (returns URI)
s = "nameOf_" + child;
// Also in assignments
String number = 10;
// And dialogue acts
DialogueAct da1 = #Confirm(Correct, number={10});

// you can call any function on the top level
t = "10";
toInt(t);

// *****
// Access to Dialogue Acts
// *****
DialogueAct da = #Inform(Posessing);
if (! da.theme) {
    da.theme = "Ball";
}
System.out.println(da.theme);
da.setDialogueActType("Confirm");
da.setProposition("Acquiring");
//System.out.println(da);
//

```

# Bibliography

- Dave Beckett. Raptor RDF Syntax Library. <http://librdf.org/raptor/>, März 2017. URL <http://librdf.org/raptor/>. Zuletzt überprüft: 11.10.2017.
- Christophe Biwer. rudibugger - Graphisches Debugging der Dialogmanagementtechnologie VOnDA. Bachelor's Thesis, Saarland University, 2017.
- Harry Bunt, Jan Alexandersson, Jae-Woong Choe, Alex Chengyu Fang, Koiti Hasida, Volha Petukhova, Andrei Popescu-Belis, and David R Traum. ISO 24617-2: A semantically-based standard for dialogue annotation. In *LREC*, pages 430–437. Citeseer, 2012.
- Hans-Ulrich Krieger. A temporal extension of the Hayes/ter Horst entailment rules and an alternative to W3C's n-ary relations. In *Proceedings of the 7th International Conference on Formal Ontology in Information Systems (FOIS)*, pages 323–336, 2012.
- Hans-Ulrich Krieger. An efficient implementation of equivalence relations in OWL via rule and query rewriting. In *Semantic Computing (ICSC), 2013 IEEE Seventh International Conference on*, pages 260–263. IEEE, 2013.
- Hans-Ulrich Krieger. A detailed comparison of seven approaches for the annotation of time-dependent factual knowledge in rdf and owl. In *Proceedings 10th Joint ISO-ACL SIGSEM Workshop on Interoperable Semantic Annotation*, 2014.
- Josef Ruppenhofer, Michael Ellsworth, Miriam RL Petruck, Christopher R Johnson, and Jan Scheffczyk. *FrameNet II: Extended theory and practice*. Institut für Deutsche Sprache, Bibliothek, 2016.
- Stanford Research. Protege.stanford.eu. <http://protege.stanford.edu>, 2017. Zuletzt überprüft: 11.10.2017.