fizz

Jean-Louis Villecroze

jlv@f1zz.org @CocoaGeek

May 19, 2018 (*Version 0.3.0-X*)

Abstract

fizz is an experimental language and runtime environment for the exploration of *cognitive architectures* and combined *Machine Learning* (ML) and *Machine Reasoning* (MR) solutions. It is based primarily on *symbolic programming* and *fuzzy formal logic*, and it features a distributed, concurrent, asynchronous and responsive *inference engine*.

Contents

1 About this document

This document is a user manual for *fizz* and assumes some basic familiarity with *logic programming*. It is divided into the following parts:

Concepts & Syntax	introduces the concepts and the syntax used to describe and manipulate *knowledge*
Console	introduces the usage of the builtin *console*
Terms	introduces the various types that can be manipulated
Primitives	lists and describes all the *primitives* functions
Elementals	lists and describes all the supported *Classes* of *Elementals*
Advanced topics	describes more advanced topics including the *Services*
Release notes	contains pertinent information for each subsequent releases

All code elements are presented in a distinct font like `print("hello, world!")`. Note that any tabulation shown in a listing is only present to enhance the readability of the code. Tabulations are not part of the language syntax. *Primitives* syntax is often a combination of code element and italic font. The part in italic is always the input to the primitive. *Primitives* inputs use special symbols :

symbol?	indicates that the input is optional
symbol|*number*	indicates that the input can be either a *symbol* or a *number*
symbol+	indicates that the *primitive* can take on several *symbols* as input, but at least one is required
*symbol**	indicates that the *primitive* can take on several *symbols* as input, but one is optional

Many thanks to Joshua Nozzi (@JoshuaNozzi) and Keith Kolmos (@KeithMKolmos) for reviewing this document and providing many insightful corrections and suggestions.

2 Concepts & Syntax

If you are familiar with *PROLOG*, you will find that *fizz* takes some of its fundamental elements and syntax from it. There are five main concepts in *fizz* , which we will be discussing in this section:

Knowledge	is a collection of related *statements* and/or *prototypes*.
Statement	is a collection of *terms* with an assigned *truth value* (think *fact*).
Predicate	is a labeled collection of *terms* with an assigned *truth value* range (or *variable*).
Prototype	is a chained collection of *predicates* that can be evaluated (think *rule*).
Elemental	is a runtime object which hold *knowledge* and can answer to query.
Service	is a runtime object which provide a unique service within the *runtime*.

One of the main differences between *PROLOG* and *fizz* is how *inference* is done not by a single entity having access to all *facts* and *rules*, but by the cooperation of a collection of objects each having access only to what they must know (*knowledges*). *Elemental* objects in *fizz* are very much independent *actors*, which must exchange messages (mostly by a queries and replies mechanism) in order to execute any inferences. While this is far from being the most efficient method (and performance in some aspect is much worse for some types of inferences) it allows for instance a *statement* that is broadcasted to trigger the execution of any *prototype* that references it (via a *predicate*). It also supports inferences to be distributed among many cores and/or many hosts[1].

2.1 Knowledge

A *Knowledge* groups a series of related *Statements* and *Prototypes* under the same logical concept (often refered in this document as "label"). For example, if we wanted to create a list of the three basic colors we would define it as follows:

[1] not yet fully implemented

```
color {

    (red,1.0,0.0,0.0);
    (green,0.0,1.0,0.0);
    (blue,0.0,0.0,1.0);

}
```

Knowledge definition always starts with a label that identifies the concept, followed by a *frame* (optional) and a series of *Statements* and/or *Prototypes* within curly brackets. The *frame* (see Section 3.3 on page 10 for details on that *term*) specified after the *symbol* is known as the *properties* of the *knowledge*.

When a *knowledge* is used to define only *statements*, it is said to be *factual knowledge*. If it contains only *prototypes*, it is called a *procedural knowledge*.

2.2 Statement

A *Statement*, as we have seen in the example above, is a comma-separated list of *terms* within parantheses and terminated by a semicolon. We will look into all the supported *terms* in more details in Section 3 on page 7, but so far we have used *symbols* and *numbers*. Each time a *statement* is defined, it can be assigned a *truth value* (indicating the relation of the *statement* to truth). Let's look at an example where each *statement* is assigned a value to represent the likelihood of a given weather occurence in a particular city:

```
weather {

    (paris,rain)        := 0.8;
    (seattle,sunny)     := 0.2;
    (london,fog)        := 0.9;
    (mawsynram,rain)    := 1;
    (honolulu,snow)     := 0;
    (honolulu,rain)     := 0.1;
    (honolulu,sunny)    := 0.6;
    (honolulu,cloudy)   := 0.3;

}
```

It's so unlikely that you will see snow in Honolulu, that we here state that such statement is false.

A *truth value* is always a number between 0 (false) and 1 (true). When no *truth value* is assigned, the default value for a *statement* is 1. It is always defined last, prefixed with a `:=`. As part of a *statement* definition, we could also join a collection of *properties* that apply to the *statement* in the form of a *frame* object which is inserted right after the closing parenthesis. Here's a version of the above knowledge where each statement have been timestamped (see section 5.2 on page 32 for how):

```
weather {

    (paris,rain)        {stamp = 1507093154.766867} := 0.8;
    (seattle,sunny)     {stamp = 1507093158.846844} := 0.2;
    (london,fog)        {stamp = 1507093174.863446} := 0.9;
    (mawsynram,rain)    {stamp = 1507093176.743262} := 1  ;
    (honolulu,snow)     {stamp = 1507093177.671228} := 0  ;
    (honolulu,rain)     {stamp = 1507093178.743266} := 0.1;
    (honolulu,sunny)    {stamp = 1507093179.807307} := 0.6;
```

```
10      (honolulu,cloudy)   {stamp = 1507093180.879415} := 0.3;
11
12  }
```

Without getting ahead of ourselves (next section), a *statement*'s properties can be queried the same way as its *terms*:

```
?- #weather(:x,:y) {stamp = :s?[gte(1507093176)]}
-> ( mawsynram , rain , 1507093176.743262 ) := 1.00 (0.001) 1
-> ( honolulu , rain , 1507093178.743266 ) := 0.10 (0.002) 2
-> ( honolulu , sunny , 1507093179.807307 ) := 0.60 (0.002) 3
-> ( honolulu , cloudy , 1507093180.879415 ) := 0.30 (0.002) 4
```

2.3 Predicate

A *Predicate*, while being syntactically similar to a *Statement*, represents not a *fact* but a *question* to be figured out. In the following example we will write a *predicate* which formulates the query: *"tell me where it is very likely to rain"*:

```
1  @weather(:x,rain) <0.7|1.0>
```

The `<0.7|1.0>` at the end of the *predicate* is a *truth value range*. In this case, it indicates that we will only accept the *statements* where *truth values* are between `0.7` and `1.0`. Beside a *range*, a *predicate* will also accept a *number* or an unbound *variable*. The latter will allow the *truth value* of each *statements* received for the *predicate* to be used in the following *predicates*.

Because a `predicate` is querying a particular *knowledge*, its *label* must be indicated. Here, we're using the `weather` *knowledge* we defined earlier. The `@` prefix indicates to the runtime that the predicate is referencing a *knowledge* and not a *primitive*. *Primitives* are built-in functions, such as `lst.length`, which can be used to get the number of elements in a list *term*. See Section 5 on page 29 for all the supported *primitives*. If we wanted to use a *primitive* we would have omitted the `@` like in this example:

```
1  lst.length([1,2,3,4,5],:length)
```

There is however a situation when a prefix (other than `!`) can be used with a *primitive*. Using `&` will cause the *primitive* to be executed on the *runtime environement* threads pool and not within the *elemental*. We will often reference this as "offloading".

A secondary meaning of the `@` prefix is to indicate that the *predicate* should be considered a *trigger*. As stated in section 2 on page 2), when a *statement* is broadcasted in the *runtime environment*, the *predicate* will set up the *prototype* to which it belongs for evaluation. For performance reasons, it is often best to indicate when a given *predicate* is not a *trigger*. For these situations, the `@` prefix can be replaced by `#`. If we look back at our earlier example, any new `weather` *statement* will activate the *prototype* in which we used that *predicate*, we can change it as follow:

```
1  #weather(:x,rain) <0.7|1.0>
```

Lastly, if a caret (`^`) is added right after the *terms* of the *predicate*, it will indicate that once the *predicate* as succeded, the solver should not consider any other alternative based on any of the *predicates* that came

before (this is similar to the `cut` operator in *PROLOG*). When the *predicate* is part of series of *prototypes*, the other *prototypes* may still be considered depending on what type of *predicates* came before the *cut*. To illustrate a *cut* let's consider the following example which defines `str.default` as a *knowledge* which given a *term* will either "return" that *term* when it is a valid *string* or a second *term* if it is not:

```
1 str.default {
2
3     (:a,:b,:b) :- console.puts("1>"), !is.string(:a)^;
4     (:a,:b,:b) :- console.puts("2>"), is.string(:a) , str.length(:a,0)^;
5     (:a,:b,:a) :- console.puts("3>"), is.string(:a) , str.length(:a,_?[gt(0)]);
6
7 }
```

If we now query this *knowledge* with a *symbol* as first *term*, we would expect the second *term* to be unified with the third *term*:

```
?- #str.default(a,"b",:b)
1>
-> ( "b" ) := 1.00 (0.001) 1
```

As we have started each *prototypes* with a call to the `console.puts` *primitive*, we can observe how the second and third *prototypes* were indeed not called. Have we had omitted the *cut* from the two first *prototypes*, we would have seen this:

```
?- #str.default(a,"b",:b)
1>
2>
-> ( "b" ) := 1.00 (0.001) 1
3>
```

Because each of the *prototypes* is composed of *primitives* only, they will be considered sequentially by the solver. In fact, the solver will always considere *prototypes* sequentially but if a *predicate* is not a *primitive*, the following *prototype* will be considered while the solver waits for answers to the *query* it put out for the *predicate*.

As we would expect, if the *cutting predicate* is not reached by the solver the *cut* will have no effect as we see in the following example:

```
?- #str.default("a","b",:b)
1>
2>
3>
-> ( "a" ) := 1.00 (0.001) 1
```

As you probably noticed in the past examples, we have used as one of the *terms* `:x` and `:length`. These are *variables* and they can stand for any other type of *terms* (except *variables* themselves) during the *inference* process. See Section 3.6 on page 11 for more details on *variables*.

2.4 Prototype

A *Prototype* defines the relationship between a collection of *statements*, which may produce a new *statement* if the logical inference reaches a conclusion. For example, we could create a new logical concept that would contain a *prototype* based on the `weather` example we wrote earlier. We will call it `surely_raining`:

```
surely_raining {

    (:x) :- @weather(:x,rain) <0.7|1.0>;

}
```

A *prototype* is composed of an *entrypoint*: a comma-separated list of *terms* within parentheses followed by a `:-` and a comma-separated collection of *predicates* terminated by a semi-colon. The *entrypoint* specifies what a *predicate* referencing this *knowledge* would be like and it is also used during *inference* to check if the *prototype* should be used. In this case, it would have a single *term* that will be unified with the local variable `:x`. If we wanted to check if it is surely raining in Paris, we would write:

```
@surely_raining(paris)
```

If a caret (`^`) is insterted between the *entrypoint* and the `:-`, it will indicates that during inferences when the *prototype*'s *entrypoint* unifies with a *statement* or a query, no other *prototypes* should be considered, even if, in the end, the inference fails. This allows for cases where a single *prototype* among many must be used.

In some instances, it's often desired to take the negation of a *predicate*. This can be done by prefixing the *predicate* with a `!` like this:

```
!is.string(3.14)
```

Since `3.14` is a number, the call to the *primitive* `is.string` will return a *truth value* of `0` since that *primitive* checks if its argument is a *string*. Negating this will result in the *predicate* returning `1` as its *truth value*. When a *prototype* contains more than a single *predicate*, the *truth value* of the statements matching each *predicate* will be used to compute the *truth value* of the *predicate* as a *fuzzy logical and*. For example, to answer the question *"Where are we the most likely to see a rainbow?"* we would write a new *knowledge* as follows:

```
maybe_rainbow {

    (:x) :- @weather(:x,rain), @weather(:x,sunny);

}
```

With the `weather` *knowledge* we have, we would get the answer `honolulu` with a *truth value* of `0.1`.

Before moving on to the next concept, lets backtrack to the following example:

```
surely_raining {

    (:x) :- @weather(:x,rain) <0.7|1.0>;

}
```

The *prototype* could have been written using a constrained *wildcard variable*:

```
surely_raining {

    (:x) :- @weather(:x,rain) _?[lte(1.0),gt(0.7)];

}
```

Using a *variable* would have allow us to take in the actual *truth value* of all the *statements* satisfying the *predicate* and use them in whichever way necessary.

2.5 Elemental

Elementals in *fizz* are the main components of the *runtime environment* (also called *substrate*). In most cases, when a *knowledge* is loaded a new *elemental* object is created to handle it, however a single *elemental* can manage multiple *knowledges*. There are several types of *elementals* in *fizz* . See Section 6 on page 66 for more details. Each *elemental* presents on the *substrate* is assigned an unique identifier (GUID), unless one is provided.

Elementals objects can have *properties* associated with them. In most cases, such data allow for customization or optimization of the objects. This is done with a *frame* (which is a supported *term*, see Section 3.3 on page 10) in between the *knowledge*'s body and its label, as seen in the following example:

```
rand {class = MRKCRandomizer, min = 1550, max = 1650} {

}
```

In the example we request a specific class of *elemental* object to be instantiated using the `class` label and specify a `min` and `max` value. While these two *properties* are specific to `MRKCRandomizer`, `class` is a reserved label. There's a few other reserved labels:

`alias`	a *symbol* by which the *elemental* will also be known locally
`class`	a *symbol* indicating the *class* of the *elemental* object
`guid`	a *string* containing the GUID to be used by the *elemental* object
`spawn`	assigned to the *symbol* `no` will not cause the *knowledge* to instantiate a new *elemental*

If there is no existing matching *elemental* for a *knowledge* (that is, no *elemental* objects with the same name and capable of accepting the *knowledge*), a new one will be instantiated even if `spawn` is set to `no`.

2.6 Service

Services are a special case of *elemental* objects which exist on the *substrate* as a singleton. Each of these objects provides *services* to all other *elementals*. The *services* are provided via the classic query/reply pattern shared by all *elementals*. See Section 7 on page 74 for more details.

3 Terms

There are eight categories of *terms* in *fizz* . In this section we will introduce each one of them and see how they are each different from the other. They all have one thing in common, however: their immutability. While this may be common with *atoms*, it is less common with more complex data such as *lists* (at least in non-functional languages).

3.1 Atoms

There are four different kinds of *atoms* in *fizz* :

- Number
- String
- Symbol
- Binary

They are the most basic data that can be handled.

3.1.1 Number

A *number* in *fizz* represents a 64-bit numerical value. It can be an integer (signed or unsigned) or a floating point value, depending on how it is written and eventually postfixed. For example, if we consider the following statement:

```
1 yearly_stats {
2
3     (2001,0.4,45u,3f);
4
5 }
```

The first *term* will be understood as a signed integer, the second term will be floating point, while the third *term* will be unsigned. The last *term*, by the addition of the postfix `f`, will be promoted from signed integer to floating point. Numbers expressed in *scientific notation*, such as `3e-2` will also be understood as floating point values. For two numbers to be successfully unified, their difference must be smaller than the *epsilon* value specified in the *runtime environment* configuration (see Section 4.2 on page 14).

3.1.2 String

Strings in *fizz* are no different from other languages: a series of characters between double quotes. For example:

```
1 quotes {
2
3     (DrSeuss,"Don't cry because it's over, smile because it happened.");
4     (OscarWilde,"Be yourself; everyone else is already taken.");
5     (Gandhi,"Be the change that you wish to see in the world.");
6
7 }
```

The common escape sequence using a backslash (for example `"\n"`) is supported with the following characters:

a	alert (bell) character
b	backspace
f	formfeed
n	newline
r	carriage return
t	horizontal tab
v	vertical tab

Two strings will only unify if their content and length perfectly match. Note that at this time, Unicode isn't supported.

3.1.3 Symbol

Symbols in *fizz* are fundamental. Just like *strings*, they can contain characters as well as numbers but they are not started and terminated by double quotes. As such, they cannot contain spaces, nor start with a number. They are often used as identifiers. Here are a few example of valid *symbols*:

```
identifiers {

    (jill);
    (jack74);
    (bob.phone);
    (bob.age);

}
```

Two *symbols* will only unify if they perfectly match.

3.1.4 Binary

Binary terms are a way for *fizz* to handle *elementals* specific binary data. Such a *term* uses `base64` to encode binary contents into text in between single quote such as in the following example:

```
blobs {

    ('dGhlIGJyb3duIGZveCBqdW1wcyBvdmVyIHRoZSBsYXp5IGRvZw==');

}
```

Two *binaries* will only unify if there's a perfect match of the decoded binary data. When a *knowledge* containing such *term* is parsed, the parsing will fail if the binary data fails to be decoded.

3.2 List

Lists are common and widely used. They allow the grouping a collection of *terms* into a single *object*. The syntax for a *list* is a comma-separated collection of *terms* (including *lists*) in between square brackets. For example, we could have written the *color* example from earlier where each colors RGB values are expressed as *lists*:

```
color {

    (red,[1.0,0.0,0.0]);
    (green,[0.0,1.0,0.0]);
    (blue,[0.0,0.0,1.0]);

}
```

There's a special kind of *list* that can be used to *split* the content of the *list* (head and rest). Used with recursion, it makes it possible to iterate over all the *terms* in a *list* possible. Consider the following *knowledge*:

```
lst.print {

    ([]);
    ([:h|:r]) :- console.puts(:h), @lst.print(:r);

}
```

The above example sets up `lst.print` with a *prototype*, which will print the *head* of the *list* and then recursively call itself with the *rest* of the *list*. The *knowledge* also constains a *statement* for when the *list* is empty. While it is not mandatory, it will cause a call to `lst.print` to always succeed.

3.3 Frame

In *fizz* , a *frame* is the equivalent of a *dictionary* in other languages. It stores key/value pairs. This is done by having a comma-separated collection of key/value pairs within curly braces. Here is an example:

```
gameboy.color {

    ({r = 0.509803, g = 0.784313, b = 0.294117});
    ({r = 0.325490, g = 0.670588, b = 0.392156});
    ({r = 0.164705, g = 0.549019, b = 0.349019});
    ({r = 0.000000, g = 0.294117, b = 0.282352});

}
```

While the value associated with a key can be any valid *term* (including a *Frame*), the key (also called *label*) can only be a valid *symbol*. Unlike with *lists*, *unification* of two *frames* will only be done over the *labels* that both *terms* have in common.

3.4 Functor

A *Functor* in *fizz* is akin to a *structure*, although it really is more of a *named list* (since a C-like structure will have fields). Here's an example where the likelihood of a given weather is given as a functor:

```
weather2 {

    (paris,rain(0.5),wind(0.1),sun(0.4),snow(0.1),fog(0.1));
    (london,rain(0.6),wind(0.1),sun(0.3),snow(0.0),fog(0.7));

}
```

When it comes to unifying *functors*. The *label* of each *functor* will be unified as well as each of the *terms*, therefore *arity* (the number of *terms*) of each *functors* also need to be the same.

3.5 Range

Range terms are a way to express a *range* of numerical values between *minimum* and *maximum* values. The syntax of a *range* is something that we have already encountered in Section 2.3 on page 4 when expressing the acceptable *truth value* range for a *predicate*. Here's an example where we look at the manufacturer-reported range of some electrical cars:

```
car.range {

    (ford(focus),76);
    (tesla(model_s),<210|315>);
    (tesla(model_x),<237|289>);
    (chevy(bolt),238);
    (nissan(leaf),107);

}
```

A *range* will unify with a fellow *range* but also with a *number* as long as it is within the *range*. If we were to query the above *knowledge* for a car with a range of at least 300 miles, we would do so like this: `@car.range(:x,300)` and get the variable `:x` bound to the value `tesla(model_s)`.

3.6 Variable

Variables in *fizz* , like in any *logic programming language*, are placeholders for any *terms*. As we have seen in several examples, the syntax for defining a *variable* is a *symbol* prefixed with a colon. Often when unification is happening, it is handy to indicate that we do not care about a given *term*. For such situations, we use the *wildcard variable*, which is a single underscore. If we take the `car.range` *knowledge* we defined above, we may want to list all the `tesla` cars, but without caring about the range of each model. We would express this in a predicate as follows: `@car.range(tesla(:m),_)`, and the `:m` *variable* will be bound to the values `model_s` and `model_x`.

Because inferences in *fizz* are distributed (within a single *substrate* or accross multiple networked *substrates*), the number of replies to a query need to be minimized whenever possible. As such, *variables* support *constraints* specifications. Let's look at an example where we are querying the `gameboy.color` knowledge we defined earlier:

```
?- @gameboy.color({r = :r, g = :g, b = :b })
-> ( 0.509803 , 0.784313 , 0.294117 ) := 1.00 (0.001) 1
-> ( 0.325490 , 0.670588 , 0.392156 ) := 1.00 (0.001) 2
-> ( 0.164705 , 0.549019 , 0.349019 ) := 1.00 (0.001) 3
-> ( 0 , 0.294117 , 0.282352 ) := 1.00 (0.001) 4
```

If we were only interested in the colors where the red component is within `0.1` and `0.4`, we could modify our query to use *primitives* to put constraints on the value bound to the `:r` *variables*:

```
?- @gameboy.color({r = :r, g = :g, b = :b }), gt(:r,0.1), lt(:r,0.4)
-> ( 0.325490 , 0.670588 , 0.392156 ) := 1.00 (0.001) 1
-> ( 0.164705 , 0.549019 , 0.349019 ) := 1.00 (0.001) 2
```

We now have two matching colors instead of four. However, we did that by filtering the answers we got to our query on the `gameboy.color` *knowledge*. By specifying *constraints* directly on the *variable* within the *predicate*, we could have only received the two matching *statements*:

```
?- @gameboy.color({r = :r?[gt(0.1),lt(0.4)], g = :g, b = :b})
-> ( 0.325490 , 0.670588 , 0.392156 ) := 1.00 (0.001) 1
-> ( 0.164705 , 0.549019 , 0.349019 ) := 1.00 (0.001) 2
```

Constraints are specified after a *variable* with a `question mark` followed by *list* or a *variable* which will be bound at runtime to a *list*. Each of the element in the *list* (which can be a *functor*, *range* or *symbol*) is a

constraint that any value bound to the *variable* must satisfy. In the above example, we indicated that the value for `:r` must be greater than `0.1` and less than `0.4`.

Constraints support multiple *functors* as listed in this table:

`gt`	greater than
`gte`	greater than or equal
`lt`	lesser than
`lte`	lesser than or equal
`neq`	not equal
`aeq`	almost equal
`lst.member`	value is present in a *list*
`lst.except`	value is not present in a *list*
`is.atom`	value is an *atom term*
`is.binary`	value is a *binary term*
`is.string`	value is a *string term*
`is.symbol`	value is a *symbol term*
`is.number`	value is a *number term*
`is.list`	value is a *list term*
`is.range`	value is a *range term*
`is.frame`	value is a *frame term*
`is.func`	value is a *functor term*
`is.unbound`	no value is bound yet
`str.find`	value is a *string* which contains a specified substring

Most *functors* requiere a single *term* except the `is.*` ones which can be given as a *symbol*, and `aeq` which expects two. *Constraints* can be use on any *variables*, including in a *prototype*'s entrypoint as shown here:

```
1 lst.zip {
2
3     ([],[])^                          :- true;
4     ([:e],[:e])^                      :- true;
5     ([:e,:e|:r],:l)                   :- #lst.zip([:e|:r],:l);
6     ([:e,:f?[neq(:e)]|:r],[:e|:l])    :- #lst.zip([:f|:r],:l);
7
8 }
```

3.7 Constant

Constants in *fizz* are a special kind of *variable* whose content is static. Aside from the *constants* defined by the *runtime environment*, new ones can be defined via command line arguments. *Constants* do not support *constraints*, and are prefixed with a dollar sign. The following table lists all the *constants* provided by the *runtime environment*:

`$true`	the boolean value for *true*
`$false`	the boolean value for *false*
`$cores`	the number of CPU cores enabled for *fizz*

3.8 Volatile

Volatiles in *fizz* are a special kind of *constant* whose content is most likely to change in between *unifications*. They can be used to add, for example, a time stamp to a *statement* being asserted (added to a *knowledge*) like in this example:

```
?- assert(car(blue,%now))
-> (  ) := 1.00 (0.001) 1
?- @car(:color,:stamp)
-> ( blue , 1503602300.742353 )
```

The syntax for *volatiles* is similar to *constants*, but with a percent instead of the dollar sign. The following table lists all the *volatiles* currently supported:

`%now`	current time (UTC) in seconds since (Unix) Epoch
`%today`	date and time as a *string*
`%rnd`	a randomly generated *number* between 0 and 1
`%sym`	a randomly generated *symbol*
`%gui`	a randomly generated GUID as a *string*

Because of their values are always changing, *volatiles* will always unify with anything. They should really not be used in a *statement*.

4 Console

4.1 Usage

Because of its *asynchronous* and *concurrent* nature, *fizz* provides a *console* with a slightly unusual mode of operation. The default state of the *console* is to display any outputs coming from the *runtime* or from the queries entered by the user. Here's the *console* when the program is started:

```
$ ./fizz.x64
Fizz 0.1.0-P (20171116.1221) [x64|3]
```

To switch to input, for example to enter a query or any of the supported *console*'s command, press the `ESC` key or one of the `arrow` keys. When the *console* is waiting for user input, it will display a `?-`. If `Ctrl-C` is pressed, the *console* will exit the input state. The `up` and `down` arrow keys also serve to cycle thru the history. While, the *console* is in such mode, any output coming from the *runtime* will be buffered until the mode is exited. Press the `enter` key to exit the *input* mode. If a query or command was entered, it will be executed (in most case asynchronously) and any result will be printed:

```
Fizz 0.1.0-P (20171116.1221) [x64|3]

load : loading manual.fizz ...
load : loaded  manual.fizz in 0.013s

?- @gameboy.color(:color)
-> ( {r = 0.509803, g = 0.784313, b = 0.294117} ) := 1.00 (0.001) 1
-> ( {r = 0.325490, g = 0.670588, b = 0.392156} ) := 1.00 (0.001) 2
-> ( {r = 0.164705, g = 0.549019, b = 0.349019} ) := 1.00 (0.001) 3
-> ( {r = 0, g = 0.294117, b = 0.282352} ) := 1.00 (0.001) 4
```

Each solution to a query will be presented as a *statement* where each *variable* becomes one of the *statement*'s terms (in the order they appears in the predicates). The *truth value* will be printed after, followed by the elapsed time (in seconds) since the query was sent. The last number is a sequential number for the *reply*. It is worth noting that in *fizz* a query will not be stopped at the first answer.

When invoking the *executable*, the arguments of the command line can be any numbers of strings specifying the path and name of files to be loaded by the *runtime*, as seen in the above example. If the path leads to a folder, it will be assumed that it is a previously frozen *runtime* enviroment to kindle. The command line option `-l` can be used to switch the console logging on. This option will expect as argument the path and name of the log file to be created. For example:

```
$ ./fizz.x64 -l test.log manual.fizz
```

The command line option `-q` can be used to specify a query to be executed right after the executable enter its Read–Eval–Print Loop (REPL). Be aware, thought that loading files in *fizz* is done asynchronously. Therefore a query using any yet-to-be loaded *knowledges* will fail. For example:

```
./fizz.x64 -q "/load(\"manual.fizz\")"
Fizz 0.1.0-P (20171116.1221) [x64|3]

?- /load("manual.fizz")
load : loading manual.fizz ...
load : loaded  manual.fizz in 0.013s
```

Any key pressed while outside of the console input state will cause a `console.keypress` *statement* to be broadcasted in the *substrate*. Any *elemental* can make use of it (via an activable *predicate*) and execute inferences based on the key that was pressed. The sole *term* of that *statement* is the ASCII code of the key. As an example, here's a *knowledge* which display an hint to the user each time it press a key:

```
1 help {
2
3     () :- @console.keypress(_), hush, console.puts("press ESC to enter input mode");
4
5 }
```

Lastly, pressing `Ctrl-C` outside of the input state, will cause the *executable* to terminate.

4.2 Adjusting the *runtime*

Severals parameters of the *runtime environment* can be adjusted by creating (or modifying) a `JSON` file. In order for the executable to use that file when it starts, the file must have the same name as the executable and have the exension `.json`. Here's an example of a file that adjusts all the possible parameters:

```
1 {
2     "runtime" : {
3         "scheduler" : {
4             "threads"  : 4,
5             "affinity" : true,
6             "spinning" : 500
7         },
8         "offloader" : {
9             "minpool"  : 1,
```

```
            "maxpool"  : 4,
            "timeout"  : 750,
            "affinity" : false
        },
        "httpclient" : {
            "dnstimeout" : 3.5,
            "maxconnect" : 8,
            "maxrequest" : 4,
            "maxresolve" : 4,
            "maxcontent" : 2048
        },
        "livereload" : {
            "enabled"   : true,
            "interval"  : 250
        }
    },
    "substrate" : {
        "ttl" : {
            "type" : "real",
            "data" : 55.0
        },
        "grace" : {
            "type" : "real",
            "data" : 0.5
        },
        "sspr" : {
            "type" : "uint",
            "data" : 8
        },
        "pulse" : {
            "type" : "uint",
            "data" : 250
        },
        "epsilon" : {
            "type" : "real",
            "data" : 0.000001
        },
        "lettered" : {
            "type"  : "string",
            "data"  : "MRKCBFSolver"
        },
        "bundle.len" : {
            "type" : "uint",
            "data" : 1024
        },
        "bundle.tmo" : {
            "type" : "real",
            "data" : 0.5
        }
    }
}
```

It contains two sections: the `runtime` and the `substrate`. The former adjusts the threading and multi-cores models of the *runtime* while the later adjusts the common behavior of all *elemental* objects will use.

Let's look at the key/value pairs in the `scheduler` section:

`threads`	represents the number of threads to be used. This number will not change at any point in time
`affinity`	if set to `true`, each thread will be assigned to a given core of the host
`spinning`	the amount of time (in ms) that each thread will spin for when waiting to something to do before going to sleep. Increasing that value may lower the latency at the cost of a higher CPU load

The `offloader` section is responsible for tuning the part of the runtime that handles *offloaded* processing using a dynamically resizable thread pool. The execution of any *primitives* flagged as *offloaded* will be executed on the pool instead of being executed within the *elemental* object calling it. The key/value pairs meanings is as follows:

`minpool`	the minimum number of threads in the pool at any given time.
`maxpool`	the maximum number of threads in the pool at any given time.
`timeout`	the maximum amount of time a non-busy thread will wait before it exits the pool.
`affinity`	if set to `true`, each thread will be assigned to a given core of the host.

The `httpclient` section is responsible for tuning the built-in HTTP client used by the *elemental* class `FZZCHttpPuller`. If this section is not present in the configuration file, the HTTP client will not be available. The key/value pairs meanings is as follows:

`dnstimeout`	timeout (in seconds) when performing a DNS lookup.
`maxconnect`	maximum number of concurrent connection to any host.
`maxrequest`	maximum number of concurrent request for the same host (0 for no limit).
`maxresolve`	maximum number of concurrent Domain-name resolution (0 for default).
`maxcontent`	maximum size of the content to store in RAM, before storing it into a temporary file.

The `livereload` section deals with the automatic *live code reload* built in *fizz* . If this section is not present in the configuration file, this functionality will not be available. The command line option `-n` can be used to force this functionality to be disabled even if it is enabled in the configuration `JSON` file. The key/value pairs meanings is as follows:

`enabled`	`true` to enable functionality, `false` to disable.
`interval`	interval of time (in ms) in between checks of the loaded scripts file's timestamp.

Because the `substrate` section of the JSON file deals with the configuration of each *elemental*, the format that is expected is a little different. The meaning of each value is:

`ttl`	this is the *time to live* for anything posted on the *substrate* (in seconds).
`grace`	this is the *grace period* for any *query* (in seconds).
`sspr`	the maximum number of *statements* to be included in a single *query* reply. If there are more *statements* to be sent, more replies will be sent.
`pulse`	the frequency (in miliseconds) at which each *elementals* gets to perform cleanups and other cyclic tasks. The lower the value, the more CPU will be used.
`epsilon`	the upper bound on the relative error due to rounding in floating point arithmetic to be used when comparing *numbers*.
`lettered`	default *elemental* class to be used when creating *elemental* to handle asserted *statements*.
`bundle.len`	the maximum number of *statement* that can be bundled into a single *knowledge* before it is *asserted* in the *substrate*.
`bundle.tmo`	the timeout value (seconds) before bundled *statements* are to be asserted if no other *statements* is added to the bundle.

Lastly, there are two command line options of interest: `-s` and `-c`. The formost can be used to specify an alternate settings `JSON` file as show here:

```
./fizz.x64 -s laptop.json manual.fizz
Fizz 0.1.0-P (20171116.1221) [x64|3]

load : loading manual.fizz ...
load : loaded  manual.fizz in 0.013s
```

The latter allows *constants* to be defined as shown in this example:

```
./fizz.x64 -c user=$USER
Fizz 0.1.0-P (20171116.1221) [x64|3]

?- console.puts($user)
jlv
-> (  ) := 1.00 (0.000) 1
```

The expected syntax for each defined constants is `label=value`. The value can be any *term* while the label is expected to be a *symbol*. Multiple `-c` options can be given.

4.3 Commands

Commands differs from *queries* by starting with a slash. Otherwise, their syntax is similar to a *predicate* (minus the *truth value* range). For example:

```
?- /load("./samples/manual.fizz")
load : loading ./samples/manual.fizz ...
load : loaded  ./samples/manual.fizz in 0.011s
```

Will load the contents of the `manual.fizz` file into the *runtime*.

bye

`/bye`

Close the console and terminate the executable.

create

`/create(`*symbol*`,`*symbol*`,`*frame*`,`*number?*`)`

Creates one (or more if a fourth *terms* is provided) *elemental* object which *label* will be the first *term*. The second *term* is the name of the /em class on which the *elemental* should be based. The third *term* contains the *properties* of the object. For example, to create ten *elementals* labeled `product` each with a *statements* limit of `1000`, we would type:

```
?- /create(product,MRKCLettered,{s.limit = 1000},10)
create : okay.
```

cpus

`/cpus`

Print to the *console* the number of cores the host computer has. This can be handy when you do not know that answer and want to adjust the configuration of the *runtime*.

```
?- /cpus
host has 4 CPUs
```

delete

/delete(*symbol|string,symbol|string**)

The `delete` command allows for *elementals* to be removed from the *substrate*. The command will accept any numbers of *symbols* or *string* as its *terms*. The only supported *strings* are GUID while the *symbols* can be either an *alias* or a *knowledge*'s label. When the later is used, all *elementals* objects with this label will be removed:

```
?- /delete(number,fill.it,"3716b075-7d64-2440-eda0-96b1b3e9ae20")
delete : completed in 0.000s
```

If any of the *terms* doesn't resolve into an actual *elemental*, the command will still complete successfully.

export.csv

/export.csv(*string*,*functor*,*string*,*list*,*frame?*)

This command exports *statements* into a file storing tabular data (*numbers* and *strings*) in a plain text format, using the character from the third *term* as delimiter for the generated lines. The first *term* indicates the path and filename of the file to be created, while the second *term* is the *predicate* to be queried for. The *list* provided as fourth *term* contains the index of each columns (starting from 0) to be included in each lines. If provided, the fifth *term* is a *frame* which can specify a timeout value (in seconds) after which the command shall complete (with the label `tmo`); and if the *truth value* of each *statements* is to be added as a column (with the label `truth`). When no timeout is provided, the default is half a second.

As an example, let's consider the following two *knowledges*:

```
1  product {
2
3      (model_e,tesla,2012);
4      (iphone_x,apple,2018);
5      (vive,htc,2015);
6      (coconut_water,zico,2000);
7
8  }
9
10 product {
11
12     (iphone,apple,2007);
13     (iphone_3GS,apple,2009);
14     (7710,nokia,2005) := 0.9;
15
16 }
```

To export all *statements* with a third term greater than 2005, we would use the command as follow:

```
?- /export.csv("products.csv",product(_,_,_?[gt(2005)]),",",[0,2],{truth = yes})
export.csv : wrote 5 lines in 0.021s.
```

Which will generate a `products.csv` file containing:

```
iphone,2007,1.0
iphone_3GS,2009,1.0
model_e,2012,1.0
iphone_x,2018,1.0
vive,2015,1.0
```

By using an intermediate *knowledge* instead of directly querying the *knowledge* that interests us, we could have further filter and/or modify the *statements* generated. Here's a simple example which add a GUID to each of the lines that will be stored in the CSV file:

```
product.g {

    (:l,:m,:y,%gui) :- #product(:l,:m,:y?[gt(2005)]);

}
```

The `export.csv` command will then be:

```
?- /export.csv("products.csv",product.g(_,_,_,_),",",[])
export.csv : wrote 5 lines in 0.016s.
```

And it the CSV file contents will be:

```
model_e,tesla,2012,3c5b83d9-278e-654a-3c88-07d99d2c1fd0
iphone_x,apple,2018,5036ef91-7a5f-904b-fa89-771e852f492e
vive,htc,2015,9369d034-941b-de47-66b8-877da629fae5
iphone,apple,2007,6fa0953c-f6b4-bd45-8bb7-6e21ab9df9e8
iphone_3GS,apple,2009,33118137-4253-0241-82ba-951a3ed16de9
```

export.json

`/export.json(`*string*`,`*functor*`,`*frame?*`)`

This command exports *statements* into a JSON file. The first *term* indicates the path and filename of the file to be created, while the second *term* is the *predicate* to be queried for. If provided, the third *term* is a *frame* which can specify a timeout value (in seconds) after which the command shall complete (with the label `tmo`). When no timeout is provided, the default is half a second. Note that only *string*, *number*, *list* and *frame* can be exported to JSON.

As an example, let's consider the following `gameboy.color` *knowledge*:

```
gameboy.color {

    ({r = 0.509803, g = 0.784313, b = 0.294117});
    ({r = 0.325490, g = 0.670588, b = 0.392156});
    ({r = 0.164705, g = 0.549019, b = 0.349019});
    ({r = 0.000000, g = 0.294117, b = 0.282352});

}
```

If we wanted to export the colors for which the *red value* if in between `0.1` and `0.4`, we would do:

```
?- /export.json("color.json",gameboy.color({r = \_?[gt(0.1),lt(0.4)]}))
export.json : wrote file color.json
```

And the generated JSON file will contain:

```
{
    "gameboy.color" : [ {
        "r" : 0.325490,
        "g" : 0.670588,
        "b" : 0.392156
    } , {
        "r" : 0.164705,
        "g" : 0.549019,
        "b" : 0.349019
    } ]
}
```

Since there was more than one matching *statement*, the generated JSON object will contain an array with all the *frames* that were in the *statements*. The key for that array will be the label of the *functor* used to query the *substrate*. If the array only contains a single *frame*, the *frame* only will be exported as we can see in the generated file:

```
{
    "r" : 0.325490,
    "g" : 0.670588,
    "b" : 0.392156
}
```

When the *statements* to be exported do not contains a single *term*, all the exportable *terms* will be exported within a JSON array. For example, if we consider the following *knowledge*:

```
product {

    (model_e,tesla,2012);
    (iphone_x,apple,2018);
    (vive,htc,2015);
    (coconut_water,zico,2000);

}

product {

    (iphone,apple,2007);
    (iphone_3GS,apple,2009);
    (7710,nokia,2005) := 0.9;

}
```

and export it as follow:

```
?- /export.json("products.json",product(_,_,_?[gt(2005)]))
export.json : wrote file products.json
```

The JSON file will then contains:

```
{
    "product" : [ [ "iphone" , "apple" , 2007 ]  ,
                  [ "iphone_3GS" , "apple" , 2009 ]  ,
                  [ "model_e" , "tesla" , 2012 ]  ,
                  [ "iphone_x" , "apple" , 2018 ]  ,
                  [ "vive" , "htc" , 2015 ]
                ]
}
```

freeze

`/freeze(`*string*`)`

This command *freezes* the *runtime* enviroment to a binary format that can be kindled at a later point. The only accepted *term* is the path of the folder in which the saving to be done. Please note that any on-going *query* is not preserved.

history.cls

`/history.cls`

Clear the *console*'s history.

history.len

`/history.len(`*number*`)`

Change the length of the *console*'s history. The default is `100`.

import.csv

`/import.csv(`*string*`,`*symbol*`,`*string*`,`*list*`,`*number?*`,`*number?*`)`

Imports data from a file storing tabular data (*numbers* and *strings*) in a plain text format (using any characters from the third *term* as delimiter and generates *statements* from each line. The first *term* indicates the path and filename of the file to be imported, while the second *term* is the label to be used for the *statements* that will be generated. The *list* provided as fourth *term* contains the number of each columns (starting from 0) to be extracted from each line of the file and put in the *statement*. If provided, the fifth *term* is the number of lines from the file to skip and if there is a fifth *term* it will be the number of lines to be processed.

If we wanted to import a `CSV` file such as this:

```
5.1,3.5,1.4,0.2,Iris-setosa
4.9,3.0,1.4,0.2,Iris-setosa
7.0,3.2,4.7,1.4,Iris-versicolor
6.4,3.2,4.5,1.5,Iris-versicolor
6.3,3.3,6.0,2.5,Iris-virginica
5.8,2.7,5.1,1.9,Iris-virginica
```

We would do as follows:

```
?- /spy(append,iris)
spy : observing iris
?- /import.csv("iris.data",iris,",",[])
import.csv : 6 lines read in 0.001s.
spy : S iris(5.100000, 3.500000, 1.400000, 0.200000, "Iris-setosa") := 1.00
spy : S iris(4.900000, 3, 1.400000, 0.200000, "Iris-setosa") := 1.00
spy : S iris(7, 3.200000, 4.700000, 1.400000, "Iris-versicolor") := 1.00
spy : S iris(6.400000, 3.200000, 4.500000, 1.500000, "Iris-versicolor") := 1.00
spy : S iris(6.300000, 3.300000, 6, 2.500000, "Iris-virginica") := 1.00
spy : S iris(5.800000, 2.700000, 5.100000, 1.900000, "Iris-virginica") := 1.00
```

Since we wanted all the columns to be used, we simply provide an empty *list* as the fourth *term*. Also, if a column is detected as holding a numerical value, it will be automatically converted as a *number*. If we had wanted to convert the last column into a *symbol* (instead of the *string* we are getting), we would have had to use an intermediary *elemental* object which would have made the conversion. Something such as this:

```
convert {

    ()  :-  @input(:e1,:e2,:e3,:e4,:l),
            str.tolower(:l,:l1),str.tosym(:l1,:l2),
            assert(iris(:e1,:e2,:e3,:e4,:l2),1.0f);

}
```

It simply states that each time an `input` *statement* is broadcasted in the *substrate* (which is what `import` does), the last *term* will be converted to a *symbol* after having its case changed to lowercase. Finally, a new `iris` *statement* is asserted. Running it we now get:

```
?- /spy(append,iris)
spy : observing iris
?- /import.csv("iris.data",input,",",[])
import.csv : 6 lines read in 0.001s.
spy : S iris(5.100000, 3.500000, 1.400000, 0.200000, iris-setosa) := 1.00
spy : S iris(4.900000, 3, 1.400000, 0.200000, iris-setosa) := 1.00
spy : S iris(7, 3.200000, 4.700000, 1.400000, iris-versicolor) := 1.00
spy : S iris(6.400000, 3.200000, 4.500000, 1.500000, iris-versicolor) := 1.00
spy : S iris(6.300000, 3.300000, 6, 2.500000, iris-virginica) := 1.00
spy : S iris(5.800000, 2.700000, 5.100000, 1.900000, iris-virginica) := 1.00
```

import.json

`/import.json(`*string*`,`*symbol*`,`*list?*`)`

Imports data from a JSON file. The first *term* indicates the path and filename of the file to be imported, while the second *term* is the label to be used for the *statement* that will be generated. If provided, the third *term* is a list of options to be used for the processing of the JSON objects contained in the file: `stringify` will keep all strings as *string terms*, `symbolize` will force all strings to be converted as *symbols*. The default behavior is to convert the strings that can be considered *symbol* as such.

As example, let's look at importing the *foreign exchange rates* from such a site as fixer.io[2]. For the sake of simplicity, the JSON file below was abbreviated:

[2] `http://api.fixer.io/latest?base=USD`

```
{
    "base":"USD",
    "date":"2017-12-08",
    "rates":{
            "AUD":1.3303,
            "BGN":1.6656,
            "BRL":3.2733,
            "CAD":1.2836,
            "CHF":0.99676,
            "CNY":6.6197,
            "CZK":21.764,
            "DKK":6.3377,
            "GBP":0.7454
    }
}
```

When we import the file, it will generate a *statement* containing a single *frame*. To further process the *frame* to fit your need, you will need to use some supporting *knowledge*, so that the right *statements* can be generated. In the sample `etc/samples/fixer.fizz` you will find such support code that will process the JSON data from above:

```
?- /spy(append,conversion)
spy : observing conversion
?- /import.json("./etc/usd-mini.json",input)
import.json : ./etc/usd-mini.json read in 0.001s.
spy : S conversion(USD, AUD, 1.330300) := 1.00 (700.000000)
spy : S conversion(USD, BGN, 1.665600) := 1.00 (700.000000)
spy : S conversion(USD, BRL, 3.273300) := 1.00 (700.000000)
spy : S conversion(USD, CAD, 1.283600) := 1.00 (700.000000)
spy : S conversion(USD, CHF, 0.996760) := 1.00 (700.000000)
spy : S conversion(USD, CNY, 6.619700) := 1.00 (700.000000)
spy : S conversion(USD, CZK, 21.764000) := 1.00 (700.000000)
spy : S conversion(USD, DKK, 6.337700) := 1.00 (700.000000)
spy : S conversion(USD, GBP, 0.745400) := 1.00 (700.000000)
```

The code in `fixer.fizz` splits the work over two *elementals*: `process` and `process.rates`:

```
process {

    () :-   @input(:f),
            frm.fetch(:f,base,:base),
            frm.fetch(:f,rates,:r),
            #process.rates(:base,:r);

}
```

The first one, activated when an `input` *statement* is published on the *substrate*, fetchs from the *frame* it contains the value for the `base` and `rates` labels and pass them to the second *elemental*:

```
process.rates {

    (:base,:f) :-   frm.fetch(:f,:l?[is.symbol],:v?[is.number]),
                    assert(conversion(:base,:l,:v),1.0f);
```

```
5
6 }
```

Since the `rates` are contained in a single *frame*, the *elemental*, concurrently fetchs all the label/value pairs from it, checking that they both match the expected type, then a new `conversion` statement is asserted.

import.txt

`/import.txt(`*string*`,`*symbol*`,`*number?*`,`*number?*`)`

Imports data from a file storing data in plain text and generates a single *statements* from each line. The first *term* indicates the path and filename of the file to be imported, while the second *term* is the label to be used for the *statements* that will be generated. If provided, the third *term* is the number of lines from the file to skip and if there is a fourth *term* it will be the number of lines to be processed. Each of the *statement* will have two *terms*: the first being a sequential number (starting at 0) and the second a *string* containing the whole line:

```
?- /spy(append,dna)
spy : observing dna
?- /import.txt("./etc/data/U00096.3.txt",dna,1,10)
spy : S dna(0, "AGCTTTTCATTCTGACTGCAACGGGCAATA...AAAAAAGAGTGTCTGATAGCAGCTTCTG") := 1.00
    (700.000000)
spy : S dna(1, "AACTGGTTACCTGCCGTGAGTAAATTAAAA...ACTAAATACTTTAACCAATATAGGCATA") := 1.00
    (700.000000)
spy : S dna(2, "GCGCACAGACAGATAAAAATTACAGAGTAC...CATTAGCACCACCATTACCACCACCATC") := 1.00
    (700.000000)
spy : S dna(3, "ACCATTACCACAGGTAACGGTGCGGGCTGA...GAAAAAAGCCCGCACCTGACAGTGCGGG") := 1.00
    (700.000000)
spy : S dna(4, "CTTTTTTTTTCGACCAAAGGTAACGAGGTA...GAAGTTCGGCGGTACATCAGTGGCAAAT") := 1.00
    (700.000000)
spy : S dna(5, "GCAGAACGTTTTCTGCGTGTTGCCGATATT...GCAGGGGCAGGTGGCCACCGTCCTCTCT") := 1.00
    (700.000000)
spy : S dna(6, "GCCCCCGCCAAAATCACCAACCACCTGGTG...CATTAGCGGCCAGGATGCTTTACCCAAT") := 1.00
    (700.000000)
spy : S dna(7, "ATCAGCGATGCCGAACGTATTTTTGCCGAA...CGCCGCCCAGCCGGGGTTCCCGCTGGCG") := 1.00
    (700.000000)
spy : S dna(8, "CAATTGAAAACTTTCGTCGATCAGGAATTT...CCTGCATGGCATTAGTTTGTTGGGGCAG") := 1.00
    (700.000000)
spy : S dna(9, "TGCCCGGATAGCATCAACGCTGCGCTGATT...GTCGATCGCCATTATGGCCGGCGTATTA") := 1.00
    (700.000000)
import.txt : 10 lines read in 0.001s.
```

kindle

`/kindle(`*string*`)`

This command loads a *runtime* enviroment from a previously saved binary format. The only accepted *term* is the path of the folder in which the saving was done. Using `kindle` and `freeze` are more efficient than `load` and `save` since it use a direct binary format instead of an intermediary text format that would need to be parsed. However, it is not possible to edit the *knowledge* with a text editor.

knows

`/knows(`*symbol*`|`*string*`)`

Check if an *elemental* object is present on the *runtime* using its alias (when the argument is a *symbol*) or its GUID (when the argument is a *string*). In the following example, we modify the `car.range` *knowledge* to specify an alias for the *elemental* object that will get created:

```
car.range {

    alias = crange

} {

    (ford(focus),76);
    (tesla(model_s),<210|315>);
    (tesla(model_x),<237|289>);
    (chevy(bolt),238);
    (nissan(leaf),107);

}
```

We can then use that alias with the `/knows` command:

```
?- /knows(c.range)
no
?- /knows(crange)
yes
```

list

`/list`

This command generates a list of all the *elemental* objects presents on the *substrate*. Each of the output lines, will contains, in order, the GUID, the class, label and, if available, the alias of each *elementals*:

```
?- /list
list : 288a77db-bab2-1748-38af-892fcf18d112 MRKCLettered        blobs
list : bf006e31-4bd4-c348-a1a7-0449fb0a167f MRKCLettered        car.range       (crange)
list : 1bb328bb-4938-8a43-9db0-2a1685acc19b MRKCLettered        color
list : 3cfc2da3-8728-0d49-22a0-761d19af28bb MRKCLettered        gameboy.color
list : c9928201-4dbd-5e4d-bab7-ee9e13c771dc MRKCLettered        identifiers
list : 47d3366d-5794-0949-d7a4-f7e462dfaa24 MRKCBFSolver        lst.print
list : 966b0df2-7010-6542-5f83-5cedb64afadb MRKCBFSolver        maybe_rainbow
list : 4048e8be-8adc-0b4a-b880-4968dbaff277 MRKCBFSolver        multiplier
list : 9a5d0527-34d8-ee44-3f9d-7a8522d51cc0 MRKCLettered        product
list : 46d90c88-339d-fa40-da96-3cf068763eca MRKCLettered        product
list : 87240913-e8a1-9e43-3a9c-4b9f47e15b27 MRKCBFSolver        product.g
list : aa7f7a44-d894-c54d-db96-c537d7fb117c MRKCLettered        quotes
list : cfff6ad5-17ce-db43-3d8b-9855d8001539 MRKCRandomizer      rand
list : dd875f1a-9596-a649-7fbb-09420e20396f MRKCBFSolver        surely_raining
list : 6d4e5104-22a2-ee43-3eb3-073f45b08a1e MRKCLettered        weather
list : cb6a0d33-0000-0644-f89a-c7e678060aff MRKCLettered        weather2
list : 45f63bd5-b824-594f-e990-1487247ef64d MRKCLettered        yearly_stats
list : 17 elementals listed in 0.000s
```

load

/load(*string+*)

The `load` command allows *knowledge* to be loaded from (properly formatted) text files. All terms in the `predicate` are expected to be *strings*.

```
?- /load("./samples/manual.fizz")
load : loading ./samples/manual.fizz ...
load : loaded  ./samples/manual.fizz in 0.011s
?- @gameboy.color(:color)
-> ( {r = 0.509803, g = 0.784313, b = 0.294117} ) := 1.00 (0.001) 1
-> ( {r = 0.325490, g = 0.670588, b = 0.392156} ) := 1.00 (0.001) 2
-> ( {r = 0.164705, g = 0.549019, b = 0.349019} ) := 1.00 (0.001) 3
-> ( {r = 0, g = 0.294117, b = 0.282352} ) := 1.00 (0.001) 4
```

If any of the files to be loaded have already been loaded, they will each be unloaded before being re-loaded. See the command `unload` (Section 4.3 on page 28) to manually unload the *knowledge* from a given set of files.

reload

/reload(*string+*)

The `reload` command allows *knowledge* to be re-loaded from (properly formatted) text files. All terms in the `predicate` are expected to be *strings*.

```
?- /load("./etc/samples/manual.fizz")
load : loading ./etc/samples/manual.fizz ...
load : loaded  ./etc/samples/manual.fizz in 0.018s
?- /reload("./etc/samples/manual.fizz")
reload : unloading ./etc/samples/manual.fizz ...
reload : unloaded ./etc/samples/manual.fizz in 0.003s
reload : loading ./etc/samples/manual.fizz ...
reload : loaded  ./etc/samples/manual.fizz in 0.018s
```

poke

/poke(*symbol*|*string*,*symbol*,*term*)

The `poke` command allows the *properties* of an *elemental* object to be written. For example, in the case of the `rand` *elemental* as defined in Section 2.5 on page 7, we can change the value of its `min` *properties* as follows:

```
?- /poke(rand,min,1545)
?- /peek(rand,min)
peek : min = 1545
```

In this example, as in the one for the `/peek` command, we have used the label of the *elemental* to identify it. If there are more than one *elemental* responding to the same label, they will all receive and process the `poke`. In such situation, we should have use the GUID of the *elemental* to only target a single one.

save

`/save(`*string*`,`*symbol**`)`

The `save` command allows *knowledge* to be saved to a (properly formatted) text file, allowing it to be reloaded at a later time. The command supports saving all *knowledges* or a selection based on their *labels*. To save all existing *knowledges* currently in the *runtime* environment, you only need to provide the name of the text file to be created:

```
?- /save("all.fizz")
save: completed in 0.141s.
```

If we wanted to save only the `weather` *knowledges*, we would do:

```
?- /save("weather.fizz",weather)
save: completed in 0.04s.
```

All terms except the first one are expected to be *symbols*.

scan

`/scan`

The `scan` command will keep printing statistics on the *runtime environment* until none of the statistics changes in the *substrate*:

```
scan : e:11 k:7 s:2 p:7 u:3.49 t:11 q:3945 r:4384 z:0
scan : e:11 k:7 s:2 p:7 u:3.73 t:1 q:4471 r:5069 z:0 (qps:2191.7 rps:2854.2)
scan : e:11 k:7 s:2 p:7 u:3.98 t:4 q:4995 r:5793 z:0 (qps:2071.1 rps:2861.7)
scan : e:11 k:7 s:2 p:7 u:4.23 t:1 q:5503 r:6498 z:0 (qps:2056.7 rps:2854.3)
scan : e:11 k:7 s:2 p:7 u:4.48 t:2 q:6138 r:7401 z:0 (qps:2529.9 rps:3597.6)
scan : e:11 k:7 s:2 p:7 u:5.00 t:3 q:6843 r:8541 z:0 (qps:0.0 rps:3666.7)
scan : e:11 k:7 s:2 p:7 u:5.25 t:1 q:7789 r:9452 z:0 (qps:3814.5 rps:3673.4)
scan : e:11 k:7 s:2 p:7 u:5.50 t:4 q:8790 r:10426 z:0 (qps:3956.5 rps:3849.8)
```

The breakdown of the statistic is identical to the `stats` command with the addition of `qps` and `rps` which are respectively *queries per seconds* and *replies per seconds*.

spy

`/spy(append,`*symbol+*`)`
`/spy(remove,`*symbol+*`)`

Instructs the *runtime* to start or stop printing any events (queries, replies, ...) related to any of the *knowledge* labels provided as arguments. *Spying* is a handy way to see what is happening within the *runtime* and can be extremly useful to debug. In the following example, we *spy* on the `gameboy.color` *knowledge* then submit a query:

```
?- /spy(append,gameboy.color)
spy : observing gameboy.color
?- @gameboy.color({r = :r?[gt(0.1),lt(0.4)], g = :g, b = :b})
spy : Q @gameboy.color({r = :r ? [gt(0.100000), lt(0.400000)], g = :g, b = :b}) (14.999830)
spy : R gameboy.color({r = 0.325490, g = 0.670588, b = 0.392156}) := 1.00 (14.999510)
-> ( 0.325490 , 0.670588 , 0.392156 ) := 1.00 (0.001) 1
spy : R gameboy.color({r = 0.164705, g = 0.549019, b = 0.349019}) := 1.00 (14.999510)
-> ( 0.164705 , 0.549019 , 0.349019 ) := 1.00 (0.001) 2
```

Output from *spying* will always be prefixed with `spy`. The first letter after the colon indicates the type of the observed event:

`Q`	a query.
`R`	a reply.
`S`	a statement.
`T`	a query is being scrapped.

stats

`/stats`

Print to the *console* some basic statistic about what is happening in the runtime:

```
?- /stats
stats : e:2 k:1 s:0 p:0 u:1.29 t:1 q:0 r:0 z:0
```

The breakdown of the statistic is the following:

`e`	current number of *elemental* objects in the *substrate*.
`k`	total number of *knowledges* on the *substrate*.
`s`	total number of *statements* on the *substrate*.
`p`	total number of *prototypes* on the *substrate*.
`u`	up time (in seconds) of the *runtime*.
`t`	elapsed time (in miliseconds) it took for the statistics to be collected.
`q`	total number of *queries* posted on the *substrate*.
`r`	total number of *replies* (in *statements*) posted on the *substrate*.
`z`	total number of *statement* posted (without *query*) on the *substrate*.

tells

`/tells(`*symbol*|*string*, *functor*|*symbol*`)`

Sends a *message* (in the form of a *functor* or a *symbol*) to an *elemental* object identified by its alias or GUID, the first argument. Not all *elemental* object can handle *message*.

```
?- /tells(some.obj,do(this,45))
```

unload

`/unload(`*string+*`)`

The `unload` command allows *knowledge* loaded from a file to be unloaded. All terms in the `predicate` are expected to be *strings*.

```
?- /load("./samples/manual.fizz")
load : loading ./samples/manual.fizz ...
load : loaded  ./samples/manual.fizz in 0.011s
?- @gameboy.color(:color)
-> ( {r = 0.509803, g = 0.784313, b = 0.294117} ) := 1.00 (0.001) 1
-> ( {r = 0.325490, g = 0.670588, b = 0.392156} ) := 1.00 (0.001) 2
-> ( {r = 0.164705, g = 0.549019, b = 0.349019} ) := 1.00 (0.001) 3
-> ( {r = 0, g = 0.294117, b = 0.282352} ) := 1.00 (0.001) 4
?- /unload("./samples/manual.fizz")
unload : unloading ./samples/manual.fizz ...
unload : unloaded ./samples/manual.fizz in 0.000s
```

wipe

`/wipe`

The `wipe` command will cause the *runtime* enviroment to be cleared of all existing *elementals* objects. The state of the *runtime* will be similar to the state at of the *runtime* when the executable is started.

peek

`/peek(`*symbol*|*string*,*symbol*`)`

The `peek` command allows the *properties* of an *elemental* object to be read. For example, if we have a `rand` *elemental* as defined in Section 2.5 on page 7, we can read the value of its `min` *properties* as follows:

```
?- /peek(rand,min)
peek : min = 1550
```

5 Primitives

This Section details the *primitives* provided by the *runtime*. For each one, expected (and optional) arguments are described and for most a use case examples is given. All *primitives* are grouped under related categories.

5.1 Arithmetic

This section contains all the *primitives* that deal with basic *arithmetic*.

add

`add(`*number*|*variable*`,`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the sum of its two first *terms* with the third. For example:

```
?- add(4,3,:x)
-> ( 7 ) := 1.00 (0.001) 1
```

If the third *term* is a *number* or a *variable* bound to a *number*, one of the first *terms* can be an unbound *variable*. In that case the *primitive* will find the right value to make the addition valid as seen in the example below:

```
?- add(4,:x,7)
-> ( 3 ) := 1.00 (0.000) 1
```

div

`div(`*number*|*variable*`,`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the division of the first *term* by the second with the third. For example:

```
?- div(10,3,:x)
-> ( 3.333333 ) := 1.00 (0.000) 1
```

If the third *term* is a *number* or a *variable* bound to a *number*, one of the first *terms* can be an unbound *variable*. In that case the *primitive* will find the right value to make the division valid as seen in the following example:

```
?- div(:x,3,3.3333333)
-> ( 10.000000 ) := 1.00 (0.000) 1
```

div.int

`div.int(`*number*|*variable*`,`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the integer division of the first *term* by the second with the third. For example:

```
?- div.int(37,6,:x)
-> ( 6 ) := 1.00 (0.001) 1
```

If the third *term* is a *number* or a *variable* bound to a *number*, one of the first *terms* can be an unbound *variable*. In that case the *primitive* will find any values that will make the division valid as seen in the following example:

```
?- div.int(:v,6,5)
-> ( 30 ) := 1.00 (0.001) 1
-> ( 31 ) := 1.00 (0.001) 2
-> ( 32 ) := 1.00 (0.001) 3
-> ( 33 ) := 1.00 (0.001) 4
-> ( 34 ) := 1.00 (0.002) 5
-> ( 35 ) := 1.00 (0.002) 6
```

inv

`inv(`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the inverse value of the first *term* with the second. For example:

```
?- inv(4,:x)
-> ( -4 ) := 1.00 (0.000) 1
?- inv(:x,4)
-> ( -4 ) := 1.00 (0.000) 1
```

mod

`mod(`*number*`,`*number*`,`*number*|*variable*`)`

This *primitive* will unify or bind results from performing an integer division between the first two *terms* with the third. For example:

```
?- mod(9,2,:v)
-> ( 1 ) := 1.00 (0.000) 1
?- mod(8,2,:v)
-> ( 0 ) := 1.00 (0.000) 1
```

The *primitive* doesn't support the first or second term as unbound variables.

mul

`mul`(*number*|*variable*,*number*|*variable*,*number*|*variable*)

This *primitive* will unify or bind the multiplication of the first two *terms* with the third. For example:

```
?- mul(10,3,:x)
-> ( 30 ) := 1.00 (0.000) 1
```

If the third *term* is a *number* or a *variable* bound to a *number*, one of the first *terms* can be an unbound *variable*. In that case the *primitive* will find the right value to make the multiplication valid as seen in the following example:

```
?- mul(10,:x,4)
-> ( 0.400000 ) := 1.00 (0.000) 1
```

sub

`sub`(*number*|*variable*,*number*|*variable*,*number*|*variable*)

This *primitive* will unify or bind the second *term* subtracted from the first one with the third. For example:

```
?- sub(10,4,:x)
-> ( 6 ) := 1.00 (0.000) 1
```

If the third *term* is a *number* or a *variable* bound to a *number*, one of the first *terms* can be an unbound *variable*. In that case the *primitive* will find the right value to make the subtraction valid as seen in the following example:

```
?- sub(10,:x,4)
-> ( 6 ) := 1.00 (0.000) 1
```

sum

`sum`(*number+*,*number*|*variable*)

This *primitive* will unify or bind the sum of all *terms* with the last *term*. For example:

```
?- sum(3,3,6,7,:sum)
-> ( 19 ) := 1.00 (0.000) 1
?- sum(3,3,6,7,19)
-> (  ) := 1.00 (0.000) 1
```

Countrary to the *primitive* `add`, this *primitive* does not support having any *term* unbound but the last one.

5.2 Basic

Under this grouping are all the *primitives* that provide very basic - and in most cases essentials - capabilities to the *runtime*.

assert

`assert(`*functor*`,`*number*`,`*frame?*`)`
`assert(`*symbol*`,`*list*`,`*number*`,`*frame?*`)`

The `assert` *primitive* allows for a *statement* to be added to an existing *knowledge*. If no *elemental* object capable of handling it exists, the *runtime* will instantiate one. The following example shows how a new *statement* is added at *runtime* to the `weather` *knowledge*:

```
?- @weather(seattle,:s)
-> ( sunny ) := 0.20 (0.001) 1
?- assert(weather(seattle,rain),0.6)
-> (  ) := 1.00 (0.001) 1
?- @weather(seattle,:s)
-> ( sunny ) := 0.20 (0.001) 1
-> ( rain ) := 0.60 (0.001) 2
```

The optional third *term* to the *primitive* is a *frame* which (as we have seen in section 2.2 on page 3) provides the properties of the *statement*. Here's how we could timestamp each *statement* when asserting them:

```
?- assert(weather(paris,rain),0.8,{stamp = %now})
-> (  ) := 1.00 (0.000) 1
?- assert(weather(seattle,sunny),0.2,{stamp = %now})
-> (  ) := 1.00 (0.000) 1
?- assert(weather(london,fog),0.9,{stamp = %now})
-> (  ) := 1.00 (0.000) 1
?- assert(weather(mawsynram,rain),1,{stamp = %now})
-> (  ) := 1.00 (0.000) 1
?- assert(weather(honolulu,snow),0,{stamp = %now})
-> (  ) := 1.00 (0.000) 1
```

When a statement is *asserted*, it will be broadcasted in the *substrate*. See *primitive* `repeal` for the inverse function.

break

`break(`*boolean*`)`

The *primitive* `break` will prematurely end an ongoing inference when its *term* unify to the boolean value *true*. The call will always evaluate to a *truth value* of `1.0`.

```
?- console.puts(a), break(1), console.puts(b)
a
-> (  ) := 1.00 (0.000) 1
?- console.puts(a), break(0), console.puts(b)
a
b
-> (  ) := 1.00 (0.000) 1
```

See the sample `leibniz.fizz` for an example of its use.

break.not

`break.not(`*boolean*`)`

The *primitive* `break` will prematurely end an ongoing inference when its *term* unify to the boolean value *false*. The call will always evaluate to a *truth value* of `1.0`.

```
?- console.puts(a), break.not(0), console.puts(b)
a
-> (  ) := 1.00 (0.000) 1
?- console.puts(a), break.not(1), console.puts(b)
a
b
-> (  ) := 1.00 (0.000) 1
```

bundle

`bundle(`*functor*`,`*number*`,`*frame*`,`*number?*`)`
`bundle(`*symbol*`,`*list*`,`*number*`,`*frame*`,`*number?*`)`

Like the `assert` *primitive*, `bundle` allows for a *statement* to be added to an existing *knowledge*. It however provides a way for the *statements* provided during consecutive (or concurrent) calls to be grouped into a single *knowledge*. Once a specified number of *statements* have been reached, or if the time elapsed since the last addition of a *statement* reaches a timeout value, the *knowledge* will be asserted into the *substrate*. In the following example, we define a *procedural knowledge* which when triggered (by any `line.f` *statement*) will assert a `frag` *statement* bundled within *knowledges* of 1024 *statements* in size:

```
1 import.frag {
2
3     () :- @line.f(:i,:s), bundle(frag(:i,:s),1,{},1024), hush;
4
5 }
```

If the last *term* isn't given, the default value specified in the *runtime* settings (`bundle.len`) will be used.

change

`change(`[*functor*`,`*number?*`,`*frame?*`]`,`[`*functor*`,`*number?*`,`*frame?*`])`
`change(`[*symbol*`,`*list*`,`*number?*`,`*frame?*`]`,`[`*symbol*`,`*list*`,`*number?*`,`*frame?*`])`

The `change` *primitive* combines a `repeal` followed by an `assert`. In the following example, we use it to replace an earlier version of the *statement* with one with the current time:

```
?- change([city.weather.latest(:id,_)],[city.weather.latest(:id,%now)])
```

Both terms are expected to be *lists*, describing the *statement* to be repealed and the *statement* to be asserted (as per the primitives `repeal` and `assert`).

console.exec

`console.exec(`*atom*`|`*functor*`)`

This *primitive* will trigger the background execution of a console's *command*. It can be used, for instance by an elemental to trigger the frequent saving of all (or selected) knowledge during the execution. Here's an example:

```
?- console.exec(bye)
-> (  ) := 1.00 (0.000) 1
bye!
```

console.gets

`console.gets(`*variable*`)`

This *primitive* will read a line from the console. Since the user will be prompted to enter a string as a synchronous operation, calling this *primitive* will only work when offloaded. For example:

```
?- &console.gets(:x)
>- hello world!
-> ( "hello world!" ) := 1.00 (5.105) 1
```

console.puts

`console.puts(`*term+*`)`

This *primitive* will output the concatenation of the terms in the console. For example:

```
?- console.puts(Hello,"", world","!")
Hello, world!
```

declare

`declare(`*list+*`)`
`declare(`*functor*`,`*number?*`,`*frame?*`)`
`declare(`*symbol*`,`*list*`,`*number?*`,`*frame?*`)`

This *primitive* will broadcast statements into the *runtime environment* built from its *terms*. A *functor* (or a *symbol* plus a *list*) followed by an optional *truth value* and an optional *frame* is requiered for the *primitive* to create a *statement*. Multiple statements can be broadcasted if they are enclosed in lists. For example:

```
?- /spy(append,blah)
spy : observing blah
?- declare(blah(23,hello))
spy : S blah(23, hello) := 1.00
-> (  ) := 1.00 (0.001) 1
?- declare([blah(23,hello)],[blah(25,bye)])
spy : S blah(23, hello) := 1.00
spy : S blah(25, bye) := 1.00
-> (  ) := 1.00 (0.002) 1
?- declare([blah(23,hello),0.8],[blah(25,bye),0.5])
spy : S blah(23, hello) := 0.80
spy : S blah(25, bye) := 0.50
-> (  ) := 1.00 (0.002) 1
?- declare([blah(23,hello),0.8],[blah(25,bye),0.5,{stamp = %now}])
spy : S blah(23, hello) := 0.80
spy : S blah(25, bye) := 0.50 {stamp = 1507446180.615446}
-> (  ) := 1.00 (0.002) 1
?- declare([[blah(23,hello),0.8],[blah(25,bye),0.5,{stamp = %now}]])
spy : S blah(23, hello) := 0.80
spy : S blah(25, bye) := 0.50 {stamp = 1507446211.905603}
-> (  ) := 1.00 (0.000) 1
```

If multiple *statements* have the same label, they will be grouped according to the *runtime environment*'s *sspr* value and broadcasted together.

define

`define(`*symbol*`,`*list*`,`*list*`,`*list*`)`

The `define` *primitive* allows for a *prototype* to be added to the *knowledge* contained on the *substrate*. If no *elemental* object capable of handling it exists, the *runtime* will instantiate one. The following example defines two *prototypes* which together print the content of a list given as input:

```
?- define(lst.print,[[]],[cut],[[[primitive],true()]])
-> (  ) := 1.00 (0.000) 1
?- define(lst.print,[[:h|:t]],[],[[[primitive],console.puts(:h)],[[],[lst.print,[:t]]]])
-> ( :h , :t ) := 1.00 (0.000) 1
?- #lst.print([a,b,c])
a
b
c
-> (  ) := 1.00 (0.002) 1
```

This would have had the same result as defining the `lst.print` *knowledge* as:

```
1 lst.print {
2
3     ([]) ^ :- true;
4     ([:h| :t]) :- console.puts(:h), #lst.print(:t);
5
6 }
```

The first *term* is the label of the *prototype*, followed by a *list* containing the *entrypoint*. The third *term* is a list of options (for example the *symbol cut* to turns the *prototype* into *a cut* one). The last *term* is a list containing the definitons of all the *predicates* that makes up the *prototype*. Each of the *predicate* is it-self defined within a list. As shown in the above example, this *list* is expected to have two *elements*. The first one is a list of options (symbols such as `negate, primitive, cut, offload, trigger`. The list can also contain a *range term* and a *frame term*. The second *term* can either be a *functor* or a *list* containing the label of the *predicate* and a list of the *predicate*'s *terms*.

See the *primitive* `revoke` for the inverse effect in Section 5.2 on page 38.

false

`false`
`false(`*boolean*`|`*variable*`)`

Calling this *primitive* with no *term* will cause the on-going *inference* to fail by resolving to a *truth value* of `0`. When used with a single *term* it will either test of a value is *false* or bind a *variable* to the value `false`.

forget

`forget(`*symbol+*`)`

The `forget` *primitive* will cause all *elemental* objects with the label given in its *terms* to be removed from the *substrate*.

```
?- forget(product,product.g)
-> (  ) := 1.00 (0.000) 1
```

fuzz

`fuzz(`*number*`)`

The `fuzz` *primitive* will resolve with a *truth value* during *inference* the value passed as term:

```
?- fuzz(0.2)
-> (  ) := 0.20 (0.000) 1
```

hush

`hush`

The *primitive* `hush` will husher the ongoing inference. No *statement* will be published and no query will be answered. This is useful mainly in situations where a *prototype* is activated by a *trigger* predicate and the goal of it is to

now

`now(`*number*`|`*variable*`)`

This *primitive* will unify and/or substitute its sole *term* with the current host time (UTC, expressed in seconds since Unix epoch).

peek

`peek(`*symbol*`,`*variable*`|`*term*`)`

The `peek` *primitive* allows for a *property* of the calling *elemental* object to be read and unified and/or substitued with the second *term*. If the label provided as the first *term* is not a known *property*, the call will evaluate to a *truth value* of `0.0`. For example, the following *knowledge* will multiply a value by a factor read from its *properties*:

```
1 multiplier { factor = 2 } {
2
3     (:v,:v2) :- peek(factor,:f), mul(:v,:f,:v2);
4
5 }
```

Using the *console command* `/poke` we can modify the value of the *knowledge* property on the fly as shown here:

```
?- #multiplier(3,:v)
-> ( 6 ) := 1.00 (0.002) 1
?- /poke(multiplier,factor,3)
?- #multiplier(3,:v)
-> ( 9 ) := 1.00 (0.002) 1
```

Accessing *properties* during inferences can allow for an easier reuse of *knowledge*. Please note that this *primitive* will not work when offloaded.

poke

`poke`(*symbol*, *term*)

The `poke` *primitive* allows for a *property* of the calling *elemental* object to be written with the second *term* as value. If the label provided as the first *term* is not a known *property* or if it is a reserved label (like `class guid label alias`), the call will evaluate to a *truth value* of `0.0`. Changing the value of a *property* during inference supports allow for the *elemental* to save states. The following example uses two *properties* to cycle through a list of words to only return a different word at each inference:

```
wword {

    index = 0,
    words = [when, why, where, how]

} {

    // the prototype will reset the index to 0 if its value is the size of the words list
    (:w) :- peek(index,:i),
            peek(words,:l),
            lst.length(:l,:s),
            eq(:i,:s),
            poke(index,0),
            false;

    // the main prototype
    (:w) :- peek(index,:i),
            peek(words,:l),
            lst.item(:l,:i,:w),
            add(:i,1,:i2),
            poke(index,:i2);

}
```

Just like with the `peek` *primitive*, offloading the execution of the *primitive* will not work.

repeal

`repeal`(*functor*, *number*)
`repeal`(*symbol*, *list*, *number*)

The `repeal` *primitive* allows for a *statement* to be removed from any existing *knowledge*. If the *functor* or the *terms list* contains unbound variables, any matching *statements* will be removed.

```
?- @weather(seattle,:s)
-> ( sunny ) := 0.20 (0.005) 1
-> ( rain ) := 0.60 (0.008) 2
?- repeal(weather,[seattle,rain],0.6)
-> (  ) := 1.00 (0.000) 1
?- @weather(seattle,:s)
-> ( sunny ) := 0.20 (0.005) 1
```

Note that the *elemental* object that was storing the *statement* will not be detached from the *substrate* even if it doesn't hold any more *knowledge*.

revoke

`revoke`(*symbol*,*list*,*list*,*list*)

The `revoke` *primitive* allows for a *prototype* to be removed from the *knowledge* contained on the *substrate*. It is the reverse action of the *primitive* `define` (see Section 5.2 on page 35). Using the example from that *primitive* we can remove both *prototypes* as follow:

```
?- revoke(lst.print,[[]],[cut],[[[primitive],true()]])
-> (  ) := 1.00 (0.000) 1
?- revoke(lst.print,[[:h|:t]],[],[[[primitive],console.puts(:h)],[[],[lst.print,[:t]]]])
-> ( :h , :t ) := 1.00 (0.000) 1
?- #lst.print([a,b,c])
```

Note that the *elemental* object that was storing the *prototype* will not be detached from the *substrate* even if it doesn't hold any more *knowledge*.

set

`set`(*term*,*term*)

The `set` *primitive* primary use is to assign a value to a *variable*, but it can also be used to unify *terms* or *variables*. When used in the former case, the order in the *terms* doesn't matter as shown in the example below:

```
?- set(:x,4)
-> ( 4 ) := 1.00 (0.000) 1
?- set(4,:x)
-> ( 4 ) := 1.00 (0.000) 1
```

set.if

`set.if`(*term*,*term*,*boolean*)

The `set.if` *primitive* functions as the *primitive* `set` but only if its third *term* is a *number* which boolean value is *true*. If it's *false*, it will evaluate to a *truth value* of `1.0` and the *variable* will not be bound. For example:

```
?- set.if(5,:v,1)
-> ( 5 ) := 1.00 (0.000) 1
?- set.if(5,:v,0)
-> ( :v ) := 1.00 (0.000) 1
?- set.if(5,:v,0), set(6,:v)
-> ( 6 ) := 1.00 (0.000) 1
```

set.if.not

`set.if.not`(*term*,*term*,*boolean*)

The `set.if` *primitive* functions as the *primitive* `set` but only if its third *term* is a *number* which boolean value is *false*. If it's *true*, it will evaluate to a *truth value* of `1.0` and the *variable* will not be bound. For example:

```
?- set.if.not(5,:v,0)
-> ( 5 ) := 1.00 (0.000) 1
?- set.if.not(5,:v,1)
-> ( :v ) := 1.00 (0.000) 1
```

then

`then`(*number*|*variable*,*number*|*variable*,*number*|*variable*,*number*|*variable+*)

This *primitive* will unify and/or substitute its last *term* with the date/time (UTC, expressed in seconds since Unix epoch) build from the other *terms*. The first time is expected to be the calendar *year*, followed by the *month* and the *day*. Following optional *terms* are, in order: *hours*, *minutes*, *seconds* and *miliseconds*. For example:

```
?- then(:y,:m,:d,%now)
-> ( 2017 , 12 , 14 ) := 1.00 (0.001) 1
?- then(:y,:m,:d,:h,:min,%now)
-> ( 2017 , 12 , 14 , 20 , 12 ) := 1.00 (0.001) 1
?- then(:y,:m,:d,:h,:min,:s,:ms,%now)
-> ( 2017 , 12 , 14 , 20 , 12 , 21 , 713 ) := 1.00 (0.001) 1
?- then(2018,1,1,:new_year)
-> ( 1514764800 ) := 1.00 (0.001) 1
```

tme.str

`tme.str`(*number*|*variable*,*string*|*variable*)

This *primitive* will unify and/or substitute its *terms* in between a date/time (UTC, expressed in seconds since Unix epoch) and a string representation of that date. The first *term* is expected to be either a *number* or a *variable* and the second either a *string* or a *variable*. For example:

```
?- tme.str(%now,:s)
-> ( "Thu, 22 Feb 2018 06:58:23 GMT" ) := 1.00 (0.000) 1
?- tme.str(:t,"Thu, 22 Feb 2018 06:58:23 GMT")
-> ( 1519282703 ) := 1.00 (0.000) 1
```

true

`true`
`true`(*boolean*|*variable*)

Calling this *primitive* will cause the *inference* to continue. This is sort of a *no-op* with limited use, except to turn a *statement* into a *prototype*. When it is used with a single *term* it will either test if a value is *true* or bind a *variable* to the value `true`.

whisper

`whisper`(*functor*,*number*,*frame?*)
`whisper`(*symbol*,*list*,*number*,*frame?*)

The `whisper` *primitive* allows for a *statement* to be added to an existing *knowledge*. If no *elemental* object capable of handling it exists, the *runtime* will instantiate one. The following example shows how a new *statement* is added at *runtime* to the `weather` *knowledge*:

```
?- @weather(seattle,:s)
-> ( sunny ) := 0.20 (0.001) 1
?- whisper(weather(seattle,rain),0.6)
-> (  ) := 1.00 (0.001) 1
?- @weather(seattle,:s)
-> ( sunny ) := 0.20 (0.001) 1
-> ( rain ) := 0.60 (0.001) 2
```

Unlike with `assert`, when a statement is *whispered*, it will not be broadcasted in the *substrate*. See *primitive* `repeal` for the inverse function.

5.3 Comparaisons

All *primitives* related to comparing two *terms* are grouped in this category.

aeq

`aeq(`*number*`,`*number*`,`*number*`)`

This *primitive* will evaluate to a *truth value* of `1.0` if its two first *terms* are almost equal *numbers*, and `0.0` if they do not. The third *term* is the maximum allowed difference between the two *numbers* to be estimated to be the same. For example:

```
?- aeq(4.5,4.51,0.01)
-> (  ) := 1.00 (0.001) 1
?- aeq(4.5,4.52,0.01)
-> (  ) := 0.00 (0.000) 1
```

are.different

`are.different(`*term*`,`*term*`)`

This *primitive* will evaluate to a *truth value* of `1.0` if its two *terms* do not unify, and `0.0` if they do.

are.same

`are.same(`*term*`,`*term*`)`

This *primitive* will evaluate to a *truth value* of `1.0` if its two *terms* do unify, and `0.0` if they don't.

cmp

`cmp(`*term*`,`*term*`,`*variable*`|`*term*`)`

This *primitive* will unify or bind the comparison (lesser, greater or equal) between the first two *terms* with the third. For example:

```
?- cmp(4,3,:c)
-> ( 1 ) := 1.00 (0.000) 1
?- cmp(2,3,:c)
-> ( -1 ) := 1.00 (0.000) 1
?- cmp(hello,hello,:c)
-> ( 0 ) := 1.00 (0.000) 1
```

eq

`eq`(*term*,*term*)
`eq`(*term*,*term*,*boolean*|*variable*)

This *primitive* will evaluate to a *truth value* of `1.0` if its two *terms* do unify, and `0.0` if they don't. It is a *short hand* to the `are.same` *primitive*. When used with three *terms*, the *primitive* will always evaluate to a *truth value* of `1.0` if its third *term* unify with the boolean value coming from the succes of the unification of the 2 first *terms*. For example:

```
?- eq(3,5,:e)
-> ( false ) := 1.00 (0.000) 1
?- eq(3,3,:e)
-> ( true ) := 1.00 (0.000) 1
```

gt

`gt`(*term*,*term*)

This *primitive* will evaluate to a *truth value* of `1.0` if the first *term* is a *number* and has a value greater than the second *term*, also a *number*. In all other cases, the *primitive* will evaluate to `0.0`.

gte

`gte`(*term*,*term*)

This *primitive* will evaluate to a *truth value* of `1.0` if the first *term* is a *number* and has a value greater or equal to the second *term*, also a *number*. In all other cases, the *primitive* will evaluate to `0.0`.

lt

`lt`(*term*,*term*)

This *primitive* will evaluate to a *truth value* of `1.0` if the first *term* is a *number* and has a value lesser than the second *term*, also a *number*. In all other cases, the *primitive* will evaluate to `0.0`.

lte

`lte`(*term*,*term*)

This *primitive* will evaluate to a *truth value* of `1.0` if the first *term* is a *number* and has a value lesser or equal to the second *term*, also a *number*. In all other cases, the *primitive* will evaluate to `0.0`.

neq

`neq`(*term*,*term*)
`neq`(*term*,*term*,*boolean*|*variable*)

This *primitive* will evaluate to a *truth value* of `1.0` if its two *terms* do not unify, and `0.0` if they do. It is a *short hand* to the `are.different` primitive. When used with three *terms*, the *primitive* will always evaluate to a *truth value* of `1.0` if its third *term* unify with the boolean value coming from the succes of the unification of the 2 first *terms*. For example:

```
?- neq(3,5,:e)
-> ( true ) := 1.00 (0.000) 1
?- neq(3,3,:e)
-> ( false ) := 1.00 (0.000) 1
```

5.4 Frame

All *primitives* related to handling *frames* are grouped in this category.

frm.fetch

`frm.fetch`(*frame*, *symbol*|*variable*, *term*|*variable*)
`frm.fetch`(*frame*, *symbol*|*variable*, *term*|*variable*, *term*)

The *primitive* `frm.fetch` main purpose is to get the value stored in a frame (the first *term*) for a given label (the second *term*) and unify it with the third *term*. If a fourth *term* is provided, it is considered to be the default value to be used to unify with the third in case the label isn't found in the *frame*. For example:

```
?- frm.fetch({a = 3, b = hello},b,:v)
-> ( hello ) := 1.00 (0.000) 1
```

If the second *term* is an unbound variable, the inference engine will list all label/value combinations:

```
?- frm.fetch({a = 3, b = hello},:l,:v)
-> ( a , 3 ) := 1.00 (0.000) 1
-> ( b , hello ) := 1.00 (0.001) 2
```

frm.length

`frm.length`(*frame*, *number*|*variable*)

This *primitive* will unify or substitue its second *term* with the length (that is the number of items) in the *frame* passed as first *term*.

```
?- frm.length({a = 3, b = hello},:l)
-> ( 2 ) := 1.00 (0.000) 1
```

frm.make

`frm.make`(*list+*, *frame*|*variable*)

This *primitive* will unify or substitue its last *term* with a *frame* created from a collection of label/value pairs. For example:

```
?- frm.make([a,4],[b,"hello"],:f)
-> ( {a = 4, b = "hello"} ) := 1.00 (0.000) 1
?- frm.make([[a,4],[b,"hello"]],:f)
-> ( {a = 4, b = "hello"} ) := 1.00 (0.000) 1
```

frm.store

`frm.store`(*frame*, *symbol*|*variable*, *term*, *frame*|*variable*)

This *primitive* unifies or substitues the last *term* with the first *term* after the required label/value pair (the second and third *terms*) have been updated or inserted in the *frame*. For example:

```
?- frm.store({a = 3, b = hello},c,"world!",:o)
-> ( {a = 3, b = hello, c = "world!"} ) := 1.00 (0.000) 1
```

frm.empty

`frm.empty(`*frame*`)`

The *primitive* `frm.empty` will resolve with a *truth value* of `1` if its sole *term* is an empty *frame*. For example:

```
?- frm.empty({})
-> (  ) := 1.00 (0.000) 1
?- frm.empty({a = 1})
-> (  ) := 0.00 (0.001) 1
```

frm.label

`frm.label(`*frame*`,`*symbol*`|`*variable*`)`

With this *primitive*, it is possible to check if a given *label* exists in the *frame*. It will resolve with a *truth value* of `1` if the *label* exists. `0`, otherwise:

```
?- frm.label({a=1,b=2,c=3},a)
-> (  ) := 1.00 (0.000) 1
?- frm.label({a=1,b=2,c=3},d)
-> (  ) := 0.00 (0.000) 1
```

If the second *term* is an unbound variable, the *inference* will generate as many solutions as there are pairs in the *frame*:

```
?- frm.label({a=1,b=2,c=3},:label)
-> ( a ) := 1.00 (0.000) 1
-> ( b ) := 1.00 (0.000) 2
-> ( c ) := 1.00 (0.000) 3
```

frm.labels

`frm.labels(`*frame*`,`*list*`|`*variable*`)`

This *primitive* will unify or substitue its second *term* with a list of all the labels of the label/value pairs in the *frame*.

```
?- frm.labels({a=1,b=2,c=3},:labels)
-> ( [a, b, c] ) := 1.00 (0.000) 1
```

When the second *term* is a *list* of *symbols*, the list ordering doesn't have to match the order in which the *frame* label/value pairs have been specified:

```
?- frm.labels({a=1,b=2,c=3},[a,b,c])
-> (  ) := 1.00 (0.000) 1
?- frm.labels({a=1,b=2,c=3},[b,a,c])
-> (  ) := 1.00 (0.001) 1
?- frm.labels({a=1,b=2,c=3},[b,d,a])
-> (  ) := 0.00 (0.000) 1
?- frm.labels({a=1,b=2,c=3},[b,c,a])
-> (  ) := 1.00 (0.000) 1
```

frm.values

`frm.values(`*frame*`,`*list*`|`*variable*`)`

This *primitive* will unify or substitue its second *term* with a *list* of all the values of the label/value pairs in the *frame*.

```
?- frm.values({a=1,b=2,c=3},:labels)
-> ( [1, 2, 3] ) := 1.00 (0.000) 1
```

Just like with the `frm.labels` *primitive*, the *list* ordering doesn't have to match:

```
?- frm.values({a=1,b=2,c=3},[1,2,3])
-> (  ) := 1.00 (0.000) 1
?- frm.values({a=1,b=2,c=3},[1,3,2])
-> (  ) := 1.00 (0.000) 1
?- frm.values({a=1,b=2,c=3},[1,3,4])
-> (  ) := 0.00 (0.000) 1
```

frm.pairs

`frm.pairs(`*frame*`,`*list*`|`*variable*`)`

The *primitive* `frm.pairs` will unify or substitue its second *term* with a *list* of all the label/value pairs in the *frame*. Each of the pairs will be stored in a *list* of two elements as seen in this example:

```
?- frm.pairs({a=1,b=2,c=3},:pairs)
-> ( [[a, 1], [b, 2], [c, 3]] ) := 1.00 (0.000) 1
```

When the second *term* is a *list* that contains *lists*, the *list* ordering doesn't have to match the order in which the *frame* label/value pairs have been specified.

frm.cat

`frm.cat(`*frame*`,`*frame*`,`*frame*`|`*variable*`)`

Thie *primitive* will merge two *frames* and unify/substitute it with the third *term*.

```
?- frm.cat({a=1,b=2,c=3},{d=4},:merged)
-> ( {a = 1, b = 2, c = 3, d = 4} ) := 1.00 (0.000) 1
```

When a label exists in both *frames*, both value will be put in a *list* and the *list* will be stored in the output *frame*:

```
?- frm.cat({a=1,b=2,c=3},{c=4},:merged)
-> ( {a = 1, b = 2, c = [3, 4]} ) := 1.00 (0.000) 1
```

frm.sub

`frm.sub(`*frame*`,`*list*`,`*frame*`|`*variable*`)`

This *primitive* will extract a collection of label/value pairs from the *frame* given as the first *term* and unify or substitue its third *term* with a *frame* containing them. The second *term* is a list of all the labels to be included. Here's an example:

```
?- frm.sub({a=1,b=2,c=3},[a,c],:sub)
-> ( {a = 1, c = 3} ) := 1.00 (0.000) 1
```

5.5 Functor

This section covers all the *primitives* that manipulate *functors*.

fun.length

`fun.length`(*functor*, *number*|*variable*)

This *primitive* will unify or substitue its second *term* with the length (that is, the *arity*) of the *functor* passed as first *term*.

```
?- fun.length(truck(red,1930,ford),:l)
-> ( 3 ) := 1.00 (0.000) 1
```

fun.make

`fun.make`(*symbol*, *list*, *functor*|*variable*)

The `fun.make` *primitive* unify or substitue its third *term* with a *functor* created from the first (the label) and second (the list of *terms*) *terms*. For example:

```
?- fun.make(product,[\:name,apple,_],:func)
-> ( product(:name, apple, _) ) := 1.00 (0.000) 1
```

fun.member

`fun.member`(*functor*, *term*)

This *primitive* will resolve to the *truth value* of `1` only if the second *term* unifies with any of the *terms* in the *functor*. For example:

```
?- fun.member(truck(red,1930,ford),ford)
-> (  ) := 1.00 (0.000) 1
?- fun.member(truck(red,1930,ford),red)
-> (  ) := 1.00 (0.000) 1
?- fun.member(truck(red,1930,ford),green)
-> (  ) := 0.00 (0.000) 1
```

If the second *term* is an unbound *variable*, the *primitive* will generate as many *statements* as there are *terms* in the *functor*:

```
?- fun.member(truck(red,1930,ford),:x)
-> ( red ) := 1.00 (0.000) 1
-> ( 1930 ) := 1.00 (0.000) 2
-> ( ford ) := 1.00 (0.000) 3
```

fun.label

`fun.label`(*functor*,*symbol*|*variable*)

This *primitive* will unify or substitue its second *term* with the label of the *functor* passed as first *term*.

fun.terms

`fun.terms`(*functor*,*list*|*variable*)

This *primitive* will unify or substitue its second *term* with a list of the *functor*'s terms. For example:

```
?- fun.terms(truck(red,1930,ford),:terms)
-> ( [red, 1930, ford] ) := 1.00 (0.002) 1
```

When the second *term* is a *list*, it will have to be ordered the same way to successfully unify.

5.6 List

All *primitives* related to handling *lists* are grouped in this category.

lst.except

`lst.except`(*term*,*list*)

The `lst.except` *primitive* will resolve to a *truth value* of `1.0` if its first *term* is not in the list provided as second *term*, like in the following example:

```
?- lst.except(3,[3,2])
-> (  ) := 0.00 (0.000) 1
?- lst.except(5,[3,2])
-> (  ) := 1.00 (0.000) 1
```

lst.length

`lst.length`(*list*,*number*|*variable*)

This *primitive* will unify or substitue its second *term* with the length (that is the number of items) in the *list* passed as first *term*.

```
?- lst.length([1,2,3,4,5],:l)
-> ( 5 ) := 1.00 (0.000) 1
```

If the first *term* is an unbound *variable* and the second *term* is a *number*, the *variable* will be bound to a list of that size filled with *wilcard variable*:

```
?- lst.length(:l,5)
-> ( [_, _, _, _, _] ) := 1.00 (0.000) 1
```

lst.member

`lst.member(`*term*`|`*variable*`,`*list*`|`*variable*`)`

The `lst.member` *primitive* will unify the first *term* with each element of the list provided as second *term*, like in the following example:

```
?- lst.member(:x,[3,2])
-> ( 3 ) := 1.00 (0.000) 1
-> ( 2 ) := 1.00 (0.000) 2
?- lst.member(3,[3,2])
-> (  ) := 1.00 (0.000) 1
?- lst.member(5,[3,2])
-> (  ) := 0.00 (0.000) 1
```

The *primitive* can be used to generate all possible combinations when used with a *list* having *wildcard variables* in it. Here's an example:

```
?- set(:l,[a,_,c,_,e]), lst.member(f,:l), lst.member(g,:l)
-> ( [a, f, c, g, e] ) := 1.00 (0.001) 1
-> ( [a, g, c, f, e] ) := 1.00 (0.001) 2
```

lst.head

`lst.head(`*list*`,`*term*`)`

This *primitive* will unify or substitue its second *term* with the head (the first element)) in the *list* passed as first *term*:

```
?- lst.head([a,b,c,d],:h)
-> ( a ) := 1.00 (0.000) 1
```

lst.tail

`lst.tail(`*list*`,`*list*`|`*variable*`)`

This *primitive* will unify or substitue its second *term* with the tail (the last element) in the *list* passed as first *term*:

```
?- lst.tail([a,b,c,d],:h)
-> ( d ) := 1.00 (0.000) 1
```

lst.remove

`lst.remove(`*term*`,`*list*`,`*list*`|`*variable*`)`

The `lst.remove` *primitive* will resolve to a *truth value* of `1.0` if its first *term* is in the list provided as second *term*, and will unify or substitue its third *term* with a copy of its second *term* where all instances of the first *term* as been removed. For example:

```
?- lst.remove(a,[a,b,c,a,d],:l)
-> ( [b, c, d] ) := 1.00 (0.000) 1
```

lst.rest

`lst.rest(`*list*`,`*list*`|`*variable*`)`

This *primitive* will unify or substitue its second *term* with the tail (a *list* containing all elements but the first) in the *list* passed as first *term*:

```
?- lst.rest([a,b,c,d],:h)
-> ( [b, c, d] ) := 1.00 (0.000) 1
```

lst.empty

`lst.empty(`*list*`)`

The *primitive* `lst.empty` will resolve with a *truth value* of `1` if its sole *term* is an empty *list*. For example:

```
?- lst.empty([a,b,c,d])
-> (  ) := 0.00 (0.000) 1
?- lst.empty([])
-> (  ) := 1.00 (0.000) 1
```

lst.item

`lst.item(`*list*`,`*number*`|`*variable*`,`*term*`|`*variable*`)`

This *primitive* can be used to get a given element from a *list* based on its index, or find the index of the first occurence of a *term* in the *list*:

```
?- lst.item([a,b,c,d],0,:e)
-> ( a ) := 1.00 (0.000) 1
?- lst.item([a,b,c,d],:i,b)
-> ( 1 ) := 1.00 (0.000) 1
```

When the last two *terms* of the *primitive* are unbound *variables*, it will generate all possible combinations of the two *terms*:

```
?- lst.item([a,b,c,d],:i,:v)
-> ( 0 , a ) := 1.00 (0.000) 1
-> ( 1 , b ) := 1.00 (0.001) 2
-> ( 2 , c ) := 1.00 (0.001) 3
-> ( 3 , d ) := 1.00 (0.001) 4
```

lst.cat

`lst.cat(`*term+*`,`*list*`|`*variable*`)`

The *primitive* unifies the last *term* with a concatenation of all the other *terms* into a *list*. For example:

```
?- lst.cat(1,2,3,4,:l)
-> ( [1, 2, 3, 4] ) := 1.00 (0.000) 1
?- lst.cat([1,2],3,[4],:l)
-> ( [1, 2, 3, 4] ) := 1.00 (0.000) 1
```

lst.diff

`lst.diff(`*list*`)`

The *primitive* `lst.diff` will resolve with a *truth value* of `1` if its sole *term* is a *list* whose elements are all unique. For example:

```
?- lst.diff([a,b,c,d])
-> (  ) := 1.00 (0.000) 1
?- lst.diff([a,b,a,d])
-> (  ) := 0.00 (0.000) 1
```

lst.flip

`lst.flip(`*list*|*variable*`,`*list*|*variable*`)`

The `lst.flip` *primitive* will unify both *terms* with a *list* whose content is the inverse of the content of whichever *term* is a *list*. For example:

```
?- lst.flip([a,b,c,d],:l)
-> ( [d, c, b, a] ) := 1.00 (0.000) 1
?- lst.flip(:l,[a,b,c,d])
-> ( [d, c, b, a] ) := 1.00 (0.000) 1
```

lst.make

`lst.make(`*term+*`,`*list*|*variable*`)`

This *primitive* unifies the last *term* with a *list* containing all the other *terms*. For example:

```
?- lst.make([a],b,c,d,:l)
-> ( [[a], b, c, d] ) := 1.00 (0.001) 1
?- lst.make(a,b,c,d,:l)
-> ( [a, b, c, d] ) := 1.00 (0.001) 1
```

lst.span

`lst.span(`*range*|*list*`,`*list*`)`

This *primitive* will unify a *range* (first term) over all the elements of a *list* without having the same element twice in the output *list* (the third *term*). For example:

```
?- lst.length(:l,4), lst.span(<1|4>,:l);
-> ( [1, 2, 3, 4] ) := 1.00 (0.001) 1
-> ( [1, 2, 4, 3] ) := 1.00 (0.001) 2
-> ( [1, 3, 2, 4] ) := 1.00 (0.001) 3
-> ( [1, 3, 4, 2] ) := 1.00 (0.001) 4
-> ( [1, 4, 3, 2] ) := 1.00 (0.001) 5
-> ( [1, 4, 2, 3] ) := 1.00 (0.001) 6
-> ( [2, 1, 3, 4] ) := 1.00 (0.001) 7
-> ( [2, 1, 4, 3] ) := 1.00 (0.001) 8
-> ( [2, 3, 1, 4] ) := 1.00 (0.001) 9
-> ( [2, 3, 4, 1] ) := 1.00 (0.001) 10
-> ( [2, 4, 3, 1] ) := 1.00 (0.001) 11
```

```
-> ( [2, 4, 1, 3] ) := 1.00 (0.001) 12
-> ( [3, 2, 1, 4] ) := 1.00 (0.001) 13
-> ( [3, 2, 4, 1] ) := 1.00 (0.002) 14
-> ( [3, 1, 2, 4] ) := 1.00 (0.002) 15
-> ( [3, 1, 4, 2] ) := 1.00 (0.002) 16
-> ( [3, 4, 1, 2] ) := 1.00 (0.002) 17
-> ( [3, 4, 2, 1] ) := 1.00 (0.002) 18
-> ( [4, 2, 3, 1] ) := 1.00 (0.002) 19
-> ( [4, 2, 1, 3] ) := 1.00 (0.002) 20
-> ( [4, 3, 2, 1] ) := 1.00 (0.002) 21
-> ( [4, 3, 1, 2] ) := 1.00 (0.002) 22
-> ( [4, 1, 3, 2] ) := 1.00 (0.002) 23
-> ( [4, 1, 2, 3] ) := 1.00 (0.002) 24
?- lst.length(:l,3), lst.span([a,b,c],:l);
-> ( [a, b, c] ) := 1.00 (0.000) 1
-> ( [a, c, b] ) := 1.00 (0.001) 2
-> ( [b, a, c] ) := 1.00 (0.001) 3
-> ( [b, c, a] ) := 1.00 (0.001) 4
-> ( [c, b, a] ) := 1.00 (0.001) 5
-> ( [c, a, b] ) := 1.00 (0.001) 6
```

lst.swap

`lst.swap`(*list*, *number*, *term*, *variable*|*list*)

This *primitive* will unify or bind its last *term* with a copy of its first *term* where the element at the position given as second *term* has been swapped for the third *term*. For example:

```
?- lst.swap([a,b,c,d,e],0,f,:l)
-> ( [f, b, c, d, e] ) := 1.00 (0.001) 1
?- lst.swap([a,b,c,d,e],3,f,:l)
-> ( [a, b, c, f, e] ) := 1.00 (0.001) 1
```

5.7 Boolean Logic

This section contains all the *primitives* that deal with *boolean logic* operations.

boo.and

`boo.and`(*boolean+*, *boolean*|*variable*)

This *primitive* will unify or bind its last *term* with the boolean `AND` of all other *terms*. For example:

```
?- boo.and(1,0,1,:v)
-> ( false ) := 1.00 (0.000) 1
?- boo.and(1,1,1,:v)
-> ( true ) := 1.00 (0.000) 1
```

boo.not

`boo.not`(*boolean*|*variable*, *boolean*|*variable*)

This *primitive* will unify or bind its *terms* with the boolean negation of the other *term*. For example:

```
?- boo.not(1,:v)
-> ( false ) := 1.00 (0.001) 1
?- boo.not(0,:v)
-> ( true ) := 1.00 (0.000) 1
?- boo.not(0,1)
-> (  ) := 1.00 (0.001) 1
?- boo.not(:v,1)
-> ( false ) := 1.00 (0.000) 1
```

boo.or

`boo.or(`*boolean+*`,`*boolean*`|`*variable*`)`

This *primitive* will unify or bind its last *term* with the boolean `OR` of all other *terms*. For example:

```
?- boo.or(1,0,1,:v)
-> ( true ) := 1.00 (0.000) 1
?- boo.or(1,1,1,:v)
-> ( true ) := 1.00 (0.000) 1
?- boo.or(0,0,:v)
-> ( false ) := 1.00 (0.000) 1
```

boo.xor

`boo.xor(`*boolean+*`,`*boolean*`|`*variable*`)`

This *primitive* will unify or bind its last *term* with the boolean *exclusive disjunction* of all other *terms*. For example:

```
?- boo.xor(1,1,:v)
-> ( false ) := 1.00 (0.001) 1
?- boo.xor(1,0,:v)
-> ( true ) := 1.00 (0.001) 1
?- boo.xor(1,0,1,:v)
-> ( false ) := 1.00 (0.001) 1
?- boo.xor(1,0,0,:v)
-> ( true ) := 1.00 (0.001) 1
```

5.8 Mathematics

This section contains all the *primitives* that deal with *mathematical* operations.

mao.abs

`mao.abs(`*number*`|`*variable*`,`*number*`|`*variable*`)`

This *primitive* will unify or bind the second *term* with the absolute value of the first *term*. If the second *term* is a *number* and the first one is an unbound *variable* the call will generates two *statements*. For example:

```
?- mao.abs(2,:v)
-> ( 2 ) := 1.00 (0.000) 1
?- mao.abs(-2,:v)
-> ( 2 ) := 1.00 (0.000) 1
?- mao.abs(:v,4)
-> ( -4 ) := 1.00 (0.000) 1
-> ( 4 ) := 1.00 (0.000) 2
```

mao.ceil

`mao.ceil(`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the second *term* with the smallest integer value greater than or equal to the first *term*. For example:

```
?- mao.ceil(2.1,:x)
-> ( 3 ) := 1.00 (0.000) 1
?- mao.ceil(2.5,:x)
-> ( 3 ) := 1.00 (0.000) 1
?- mao.ceil(2.99,:x)
-> ( 3 ) := 1.00 (0.000) 1
```

If the second *term* is a *number* and the first one is an unbound *variable*, the *primitive* will bind the *variable* with a *range* value:

```
?- mao.ceil(:r,3)
-> ( <2.000001|2.999999> ) := 1.00 (0.000) 1
```

mao.exp

`mao.exp(`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the second *term* with *e* raised to the power of the first *term*. For example:

```
?- mao.exp(2,:v)
-> ( 0.301030 ) := 1.00 (0.000) 1
```

If the second *term* is a *number* and the first one is an unbound *variable*, the *primitive* will bind the *variable* with the inverse operation:

```
?- mao.exp(:v,0.301030)
-> ( 2.000000 ) := 1.00 (0.000) 1
```

mao.floor

`mao.floor(`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the second *term* with the largest integer value less than or equal to the first *term*. For example:

```
?- mao.floor(2.145,:x)
-> ( 2 ) := 1.00 (0.000) 1
?- mao.floor(2.145,2)
-> (  ) := 1.00 (0.000) 1
?- mao.floor(6,:x)
-> ( 6 ) := 1.00 (0.000) 1
```

If the second *term* is a *number* and the first one is an unbound *variable*, the *primitive* will bind the *variable* with a *range* value:

```
?- mao.floor(:r,4)
-> ( <4|4.999999> ) := 1.00 (0.000) 1
```

mao.log

`mao.log(`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the second *term* with the natural logarithm (base-e logarithm) of the first *term*. For example:

```
?- mao.log(2.7,:x)
-> ( 0.993252 ) := 1.00 (0.000) 1
```

If the second *term* is a *number* and the first one is an unbound *variable*, the *primitive* will bind the *variable* with the inverse operation:

```
?- mao.log(:v,0.993252)
-> ( 2.700001 ) := 1.00 (0.000) 1
```

mao.log10

`mao.log10(`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the second *term* with the common logarithm (base-10 logarithm) of the first *term*. For example:

```
?- mao.log10(31.62,:v)
-> ( 1.499962 ) := 1.00 (0.000) 1
```

If the second *term* is a *number* and the first one is an unbound *variable*, the *primitive* will bind the *variable* with the inverse operation:

```
?- mao.log10(:v,1.5)
-> ( 31.622777 ) := 1.00 (0.000) 1
```

mao.modf

`mao.modf(`*number*|*variable*`,`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the second and third *terms* with the integer and fractional parts the first *term*. For example:

```
?- mao.modf(3.14,:i,:f)
-> ( 3 , 0.140000 ) := 1.00 (0.000) 1
?- mao.modf(3.14,:i,0.14)
-> ( 3 ) := 1.00 (0.000) 1
?- mao.modf(3.14,3,:f)
-> ( 0.140000 ) := 1.00 (0.000) 1
```

If the second and third *terms* is a *number* and the first one is an unbound *variable*, the *primitive* will bind the *variable* with a floating pont value created from the integer and fractional values:

```
?- mao.modf(:v,3,0.14)
-> ( 3.140000 ) := 1.00 (0.000) 1
```

mao.pow

`mao.pow(`*number*|*variable*`,`*number*|*variable*`,`*number*|*variable*`)`

The `mao.pow` *primitive* will unify or bind its third *terms* with the value of its first *term* raised to the power of its second *term*. For example:

```
?- mao.pow(8,3,:v)
-> ( 512 ) := 1.00 (0.001) 1
```

If the first or second *terms* are variables (but not at the same time), the *primitive* will bind them to the corresponding value which will make the operation work (invser power). For example:

```
?- mao.pow(8,:p,512)
-> ( 3 ) := 1.00 (0.000) 1
?- mao.pow(:v,3,512)
-> ( 8.000000 ) := 1.00 (0.001) 1
```

mao.round

`mao.round(`*number*|*variable*`,`*number*|*variable*`)`

This *primitive* will unify or bind the second *term* with the nearest integer value to the first *term*. For example:

```
?- mao.round(2.1,:v)
-> ( 2 ) := 1.00 (0.000) 1
?- mao.round(2.5,:v)
-> ( 3 ) := 1.00 (0.000) 1
?- mao.round(2.9,:v)
-> ( 3 ) := 1.00 (0.000) 1
```

If the second *term* is a *number* and the first one is an unbound *variable*, the *primitive* will bind the *variable* with a *range* value:

```
?- mao.round(:r,3)
-> ( <2.500001|3> ) := 1.00 (0.000) 1
```

mao.sign

`mao.sign(`*number*`,`*number*|*variable*`)`

This *primitive* will unify or bind the second *term* with the sign of the first *term*. For example:

```
?- mao.sign(42,:s)
-> ( 1 ) := 1.00 (0.000) 1
?- mao.sign(-42,:s)
-> ( -1 ) := 1.00 (0.000) 1
```

mao.sqrt

`mao.sqrt(`*number*|*variable*,*number*|*variable*`)`

This *primitive* will unify or bind its second *terms* with the square root of its first *term*. For example:

```
?- mao.sqrt(25,:v)
-> ( 5 ) := 1.00 (0.001) 1
```

If the first *term* is an unbound *variable* and the second *term* is a number, the inverse square root will computed:

```
?- mao.sqrt(:v,5)
-> ( 25 ) := 1.00 (0.000) 1
```

5.9 Miscellaneous

fzz.lst

`fzz.lst(`*variable*|*list*`)`
`fzz.lst(`*symbol*,*variable*|*list*`)`

This *primitive* will unify it's last *term* with a list containing the GUID of all the *elemental* objects on the substrate. When two *terms* are provided, the first one is expected to be a *symbol*, indicating which group of objects to be listed. Calling this *primitive* will only work when offloaded. For example:

```
?- &fzz.lst(:l)
-> ( ["3561e484-3824-4543-6ca3-5e0bac9413bc", "ad4f2128-1361-5646-b18b-3ae6bc853378", "ffd5baef-6
    b48-5f48-2090-46843b9f2ac4", "2d608dc0-af83-7d46-22b2-feeb87a80a78", "dd0c959e-8311-4247-3390-
    a54c41901650", "acfc843a-cc06-0d40-d68d-a57b64f876d1", "6e3b5f90-6b5f-7343-8c9f-1c2d3293c40e",
    "2fe97aa8-4bd6-914b-ef97-0114ed2f35d5", "0e06f04c-1103-3c40-9190-11b34de70ddc", "e42bfe25-a6fa
    -3847-5bbc-8242a63523e0", "af0aba62-656a-6643-7898-bfa97e1e412a", "1025c680-d7bd-534b-65b8-2
    e155d2d0507", "00fc6faa-4df7-de4d-539f-5e47313e2dbd", "a5e79cf0-3029-5346-c9aa-39dca17bd779", "
    f05b53c1-15a2-3642-fc81-46dbd3e41107", "8c8c4fa0-ca8d-3441-77ab-951fb4c77ddb", "d81d91e8-c89e-6
    b41-74a9-1e75165efba8", "7f8ae10d-4c53-bf4b-1d93-71fab072abf6", "704e781b-a118-7346-42b4-9
    caf40bbde87", "b116be72-e19f-db41-4180-3cd5334b93e0"] ) := 1.00 (0.002) 1
?- &fzz.lst(color,:l)
-> ( ["ffd5baef-6b48-5f48-2090-46843b9f2ac4"] ) := 1.00 (0.001) 1
```

guid.sym

`guid.sym(`*symbol*|*variable*`)`

This *primitive* will unify or substitue its *term* with a randomly generated *symbol*. Here's an example:

```
?- guid.sym(:g)
-> ( yzrxzqubtaxcqrubbuyeaaqfcuysbfuw ) := 1.00 (0.000) 1
```

The generated symbol is a *globally unique identifier* (GUID).

guid.str

`guid.str(`*symbol*|*variable*`)`

This *primitive* will unify or substitue its *term* with a randomly generated *string*. Here's an example:

```
?- guid.str(:g)
-> ( "005a7ce9-433f-574c-d1ba-5a03240eb98e" ) := 1.00 (0.000) 1
```

5.10 Random

This section describes *primitives* that generate random *numbers*.

rnd.real

`rnd.real(`*number*`,`*number*|*variable*`,`*number?*`,`*number?*`)`

This *primitive* will unify or bind the second *term* with a series of (floating point) random *number* picked in the range defined in between the third and fourth *terms*. The first *term* is the count of random *numbers* to be provided. For example:

```
?- rnd.real(5,:v,1,100)
-> ( 86.598612 ) := 1.00 (0.000) 1
-> ( 80.759627 ) := 1.00 (0.000) 2
-> ( 41.959139 ) := 1.00 (0.000) 3
-> ( 30.452654 ) := 1.00 (0.001) 4
-> ( 20.528407 ) := 1.00 (0.001) 5
```

When no range is provided, the random number will all be in between `0` and `1`:

```
?- rnd.real(5,:v)
-> ( 0.791721 ) := 1.00 (0.000) 1
-> ( 0.829935 ) := 1.00 (0.000) 2
-> ( 0.496939 ) := 1.00 (0.000) 3
-> ( 0.007982 ) := 1.00 (0.001) 4
-> ( 0.891288 ) := 1.00 (0.001) 5
```

rnd.rsnd

`rnd.rsnd(`*number*`,`*number*`,|`*variable*`,`*number*`,`*number*`)`

This *primitive* will unify or bind the third *term* with a serie of (floating point) random *numbers* picked from a standard normal deviation where the first *term* is the *mean* and the second is the *standard deviation*. The first *term* is the count of random *numbers* to be provided. For example:

```
?- rnd.rsnd(10,:x,0,1)
-> ( -1 ) := 1.00 (0.001) 1
-> ( 0.488077 ) := 1.00 (0.001) 2
-> ( -2 ) := 1.00 (0.002) 3
-> ( 0 ) := 1.00 (0.002) 4
-> ( 0.807786 ) := 1.00 (0.002) 5
-> ( 0.913344 ) := 1.00 (0.002) 6
-> ( 0 ) := 1.00 (0.003) 7
-> ( 0.327671 ) := 1.00 (0.003) 8
-> ( 0.000954 ) := 1.00 (0.003) 9
-> ( 0.762686 ) := 1.00 (0.004) 10
```

rnd.uint

`rnd.uint(`*number*`,`*number*`|`*variable*`,`*number?*`,`*number?*`)`

This *primitive* will unify or bind the second *term* with a series of (unsigned integer) random *numbers* picked in the range defined between the third and fourth *terms*. The first *term* is the count of random *numbers* to be provided. For example:

```
?- rnd.uint(5,:v,1,100)
-> ( 36 ) := 1.00 (0.000) 1
-> ( 44 ) := 1.00 (0.000) 2
-> ( 90 ) := 1.00 (0.001) 3
-> ( 17 ) := 1.00 (0.001) 4
-> ( 55 ) := 1.00 (0.001) 5
```

When no range is provided, the random *numbers* will all be in between `0` and the maximum value for a 64-bit unsigned integer:

```
?- rnd.uint(5,:v)
-> ( 227958570 ) := 1.00 (0.000) 1
-> ( 2008933850 ) := 1.00 (0.000) 2
-> ( 834617219 ) := 1.00 (0.001) 3
-> ( 351245525 ) := 1.00 (0.001) 4
-> ( 1962305856 ) := 1.00 (0.001) 5
```

5.11 Range

This section describes *primitives* that handle *ranges* or generate *numbers* based on range.

rng.uint

`rng.uint(`*number*`,`*number*`,`*number*`|`*variable*`)`

This *primitive* will unify or bind its third *term* with any *number* between the first and second *terms*. For example:

```
?- rng.uint(1,10,11)
-> (  ) := 0.00 (0.001) 1
?- rng.uint(1,10,2)
-> (  ) := 1.00 (0.000) 1
```

If the third *term* is an unbound variable, the *primitive* will generate as many solutions as there are unsigned integers in the range:

```
?- rng.uint(1,10,:x)
-> ( 1 ) := 1.00 (0.001) 1
-> ( 2 ) := 1.00 (0.001) 2
-> ( 3 ) := 1.00 (0.001) 3
-> ( 4 ) := 1.00 (0.001) 4
-> ( 5 ) := 1.00 (0.001) 5
-> ( 6 ) := 1.00 (0.002) 6
-> ( 7 ) := 1.00 (0.002) 7
-> ( 8 ) := 1.00 (0.002) 8
-> ( 9 ) := 1.00 (0.002) 9
-> ( 10 ) := 1.00 (0.002) 10
```

rng.clamp

`rng.clamp`(*range*,*number*,*number*|*variable*)

The *primitive* will unify or bind its third *term* with its second *term* clamped to the *range* provided as first *term*. For example:

```
?- rng.clamp(<1|10>,11,:v)
-> ( 10 ) := 1.00 (0.001) 1
?- rng.clamp(<1|10>,-2,:v)
-> ( 1 ) := 1.00 (0.001) 1
?- rng.clamp(<1|10>,5,:v)
-> ( 5 ) := 1.00 (0.001) 1
```

rng.span

`rng.span`(*range*,*number*,*number*|*variable*)

The *primitive* will unify or bind its third *term* with any *number* that is included in the *range* provided as first *term*. The second *term* is the difference between consecutive values to be used to traverse the range. For example:

```
?- rng.span(<0|1>,0.1,:v)
-> ( 0 ) := 1.00 (0.001) 1
-> ( 0.100000 ) := 1.00 (0.002) 2
-> ( 0.200000 ) := 1.00 (0.002) 3
-> ( 0.300000 ) := 1.00 (0.003) 4
-> ( 0.400000 ) := 1.00 (0.003) 5
-> ( 0.500000 ) := 1.00 (0.004) 6
-> ( 0.600000 ) := 1.00 (0.004) 7
-> ( 0.700000 ) := 1.00 (0.005) 8
-> ( 0.800000 ) := 1.00 (0.005) 9
-> ( 0.900000 ) := 1.00 (0.006) 10
-> ( 1 ) := 1.00 (0.006) 11
```

rng.union

`rng.union`(*range*,*range*,*range*|*variable*)

This *primitive* unifies/binds its third *term* with the union of the two *ranges* provided as the first *terms*. For example:

```
?- rng.union(<10.3|26.7>,<17.34|43>,:r)
-> ( <10.300000|43> ) := 1.00 (0.000) 1
```

rng.inter

`rng.inter`(*range*,*range*,*range*|*variable*)

This *primitive* unifies/binds its third *term* with the intersection of the two *ranges* provided as the first *terms*. For example:

```
?- rng.inter(<10.3|26.7>,<17.34|43>,:r)
-> ( <17.340000|26.700000> ) := 1.00 (0.000) 1
```

If there is no intersection between the two *ranges*, the call will resolve with a *truth value* of `0`.

rng.min

`rng.min`(*range*,*number*|*variable*)

The `rng.min` *primitive* will unify or bind its second *term* with the minimum value of the *range* given as first *term*. For example:

```
?- rng.min(<10.3|26.7>,:min)
-> ( 10.300000 ) := 1.00 (0.000) 1
```

rng.max

`rng.max`(*range*,*number*|*variable*)

The `rng.max` *primitive* will unify or bind its second *term* with the maximum value of the *range* given as first *term*. For example:

```
?- rng.max(<10.3|26.7>,:max)
-> ( 26.700000 ) := 1.00 (0.000) 1
```

rng.inc

`rng.inc`(*range*,*number*)

The `rng.inc` *primitive* will resolve to a *truth value* of `1.0` if the second *term* is a *number* whose value is within the *range* given as first *term*. For example:

```
?- rng.inc(<10.3|26.7>,11)
-> (  ) := 1.00 (0.000) 1
?- rng.inc(<10.3|26.7>,10)
-> (  ) := 0.00 (0.000) 1
```

Unlike `rng.span`, this *primitive* will not generate values within the range if the second *term* is an unbound *variable*.

5.12 Symbol

This section describes *primitives* related to handling *symbols*.

sym.cat

`sym.cat`(*term+*,*string*|*variable*)

This *primitive* will unify or substitue the concatenation of all its *terms* but the last one, with the last one. Then turns that into a *symbol*. For example:

```
?- sym.cat(hello,".",4,:x)
-> ( hello.4 ) := 1.00 (0.001) 1
```

sym.sub

`sym.sub`(*symbol*, *number*, *number*, *symbol*|*variable*)

The `sym.sub` *primitive* will unify or substitue its fourth *terms* with a subpart of the *symbol* given as first *term*. The subpart is defined by an offset (second *term*) and a length (third *term*). For example:

```
?- sym.sub(truck,0,1,:c)
-> ( t ) := 1.00 (0.001) 1
```

5.13 String

This section describes *primitives* related to handling *strings*.

str.cat

`str.cat`(*term+*, *string*|*variable*)

This *primitive* will unify or substitue the concatenation of all its *terms* but the last one, with the last one. For example:

```
?- str.cat(hello," ",how," ",are," ",you,:s)
-> ( "hello how are you" ) := 1.00 (0.000) 1
```

str.cmp

`str.cmp`(*string*, *string*, *number*|*variable*, *symbol?*)

The `str.cmp` *primitive* will unify or substitue its third *term* with the result of the comparison of its first two *string terms*. When the first *term* is greater than the second *term*, the third *term* will unify with the value `1`. If less, it will be unified with the value `-1`. When both *strings* are identical, the value will be `0`. For example:

```
?- str.cmp("abcdef","ABCDEF",:c)
-> ( 1 ) := 1.00 (0.000) 1
?- str.cmp("abcdef","ABCDEF",:c,insensitive)
-> ( 0 ) := 1.00 (0.001) 1
```

The optional fourth *term* can be the *symbol* `insensitive` to indicate that the comparison must be case insensitive.

str.find

`str.find`(*string*, *string*, *number?*|*variable?*)

The `str.find` *primitive* will unify or substitue its third *term* with the offset (starting from 0) within its first *term* where the second *term* was find. If there is no occurence of the second *term*, the third will unify with the value `-1`. For example:

```
?- str.find("abcdef","bc",:o)
-> ( 1 ) := 1.00 (0.000) 1
?- str.find("abcdef","ef",:o)
-> ( 4 ) := 1.00 (0.000) 1
?- str.find("abcdef","ef",4)
```

```
-> (  ) := 1.00 (0.000) 1
?- str.find("abcdef","g",:p)
-> ( -1 ) := 1.00 (0.000) 1
```

The *primitive* will generate as many solutions as there is occurences of the second *term* in the *string*:

```
?- str.find("abcdefcc","c",:p)
-> ( 2 ) := 1.00 (0.000) 1
-> ( 6 ) := 1.00 (0.001) 2
-> ( 7 ) := 1.00 (0.001) 3
```

If no third *term* is given, then the *primitive* will resolve to a *truth value* of `1` if the second *term* is found anywhere in the first *term*.

str.flip

`str.flip`(*string*,*string*|*variable*)

The `str.flip` *primitive* will unify or substitue its second *term* with a *string* containing the content of the first *term* inverted:

```
?- str.flip("hello, world!",:s)
-> ( "!dlrow ,olleh" ) := 1.00 (0.001) 1
```

str.length

`str.length`(*string*,*number*|*variable*)

This *primitive* will unify or substitue its second *term* with the length (that is the number of characters) in the *string* passed as first *term*.

```
?- str.length("hello, world!",:l)
-> ( 13 ) := 1.00 (0.000) 1
```

str.rest

`str.rest`(*string*,*number*,*string*|*variable*)

The `str.rest` *primitive* will unify or substitue its third *terms* with a subpart of the *string* given as first *term*. The subpart is defined as starting at a given position (the second *term*) in the *string* and runs up to the end of the *string*. For example:

```
?- str.rest("hello, how are you?",7,:w)
-> ( "how are you?" ) := 1.00 (0.001) 1
```

str.sub

`str.sub`(*string*,*number*,*number*,*string*|*variable*)

The `str.sub` *primitive* will unify or substitue its fourth *terms* with a subpart of the *string* given as first *term*. The subpart is defined by an offset (second *term*) and a length (third *term*). For example:

```
?- str.sub("hello, how are you?",7,3,:w)
-> ( "how" ) := 1.00 (0.000) 1
```

str.swap

`str.swap(`*string*`,`*list*`,`*string*`|`*variable*`)`

The `str.swap` *primitive* will unify or substitue its third *term* with it's first *term* where all occurences of specified *strings* will have been replaced by provided *strings*. For example:

```
?- str.swap("GATTACA",[["A","T"],["C","G"],["G","C"],["T","A"]],:s)
-> ( "CTAATGT" ) := 1.00 (0.000) 1
?- str.swap("abc123abc456789abc",["abc","A"],:s)
-> ( "A123A456789A" ) := 1.00 (0.000) 1
```

str.tokenize

`str.tokenize(`*string*`,`*string*`,`*list*`|`*variable*`)`

This *primitive* will unify or substitue its third *term* with a *list* of tokens, which are substring of its first *term* separated by any of the characters that are part of the second *term*. For example:

```
?- str.tokenize("66;3.14;22",";",:l)
-> ( ["66", "3.14", "22"] ) := 1.00 (0.000) 1
?- str.tokenize("66;3.14,22",";,",:l)
-> ( ["66", "3.14", "22"] ) := 1.00 (0.000) 1
```

If the first *term* is an unbound *variable* and the 3rd *term* is a *list*, the *primitive* will generate a string from the concatenation of all items in the list (but only if the *terms* are *string, symbol, number* or *list*). For example:

```
?- str.tokenize(:s," ",[a,b,c,[d,e,f]])
-> ( "a b c d e f" ) := 1.00 (0.000) 1
```

str.tolower

`str.tolower(`*string*`,`*string*`|`*variable*`)`

The `str.tolower` *primitive* will unify or substitue its second *term* with a copy of first *term* where all alphabetic characters have been converted to lowercase:

```
?- str.tolower("HeLLo",:s)
-> ( "hello" ) := 1.00 (0.000) 1
```

str.tonum

`str.tonum(`*string*`|`*variable*`,`*number*`|`*variable*`)`

The `str.tonum` *primitive* will unify or substitue its second *term* with a *number* parsed from its first *term*. For example:

```
?- str.tonum("45f",:v)
-> ( 45 ) := 1.00 (0.000) 1
?- str.tonum("-125",:v)
-> ( -125 ) := 1.00 (0.000) 1
```

If the first *term* is an unbound *variable* and the second *term* is a *number*, the *primitive* will unify the *variable* with a *string* eersion of the *number*:

```
?- str.tonum(:x,12.42)
-> ( "12.420" ) := 1.00 (0.000) 1
?- str.tonum(:x,66)
-> ( "66" ) := 1.00 (0.000) 1
```

str.toupper

`str.toupper`(*string*,*string*|*variable*)

The `str.toupper` *primitive* will unify or substitue its second *term* with a copy of first *term* where all alphabetic characters have been converted to uppercase:

```
?- str.toupper("HeLLo",:s)
-> ( "HELLO" ) := 1.00 (0.000) 1
```

str.tosym

`str.tosym`(*string*,*symbol*|*variable*)

The `str.tosym` *primitive* will unify or substitue its second *term* with *symbol* based on its first *term*. For example:

```
?- str.tosym("HeLLo",:s)
-> ( HeLLo ) := 1.00 (0.000) 1
?- str.tosym("3.14",:s)
-> ( a3.14 ) := 1.00 (0.000) 1
?- str.tosym("hello, world.",:s)
-> ( hello._world. ) := 1.00 (0.000) 1
```

str.trim

`str.trim`(*string*,*variable*)

This *primitive* will unify or substitue its second *term* with its first *term* trimmed of any empty spaces at the start and end of the *string*. For example:

```
?- str.trim(" this is my string  ",:s)
-> ( "this is my string" ) := 1.00 (0.001) 1
```

5.14 Typing

This section describes *primitives* that can be used to check the type of any *terms*.

is.atom

`is.atom`(*term*)

The *primitive* will resolve to a *truth value* of `1` if the *term* is an *atom*, `0` otherwise. For example:

```
?- is.atom(4)
-> (  ) := 1.00 (0.000) 1
?- is.atom("hello world")
-> (  ) := 1.00 (0.000) 1
?- is.atom([a,b,c,d])
-> (  ) := 0.00 (0.000) 1
?- is.atom(neat)
-> (  ) := 1.00 (0.000) 1
```

is.binary

`is.binary(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is a *binary*, `0` otherwise. For example:

```
?- is.binary(42)
-> (  ) := 0.00 (0.000) 1
?- is.binary(hello)
-> (  ) := 0.00 (0.001) 1
?- is.binary("the quick fox ...")
-> (  ) := 0.00 (0.000) 1
?- is.binary('aGVsbG8sIHdvcmxkIQA=')
-> (  ) := 1.00 (0.000) 1
```

is.list

`is.list(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is a *list*, `0` otherwise. For example:

```
?- is.list(34)
-> (  ) := 0.00 (0.000) 1
?- is.list([a,b,c,d])
-> (  ) := 1.00 (0.000) 1
```

is.final

`is.final(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is *final* that is isn't an unbound variable or doesn't (recursively) contains any unbound variable. For example:

```
?- is.final(5)
-> (  ) := 1.00 (0.000) 1
?- is.final([5,a])
-> (  ) := 1.00 (0.000) 1
?- is.final([5,:a])
-> ( :a ) := 0.00 (0.000) 1
```

is.func

`is.func(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is a *functor*, `0` otherwise. For example:

```
?- is.func(66)
-> (  ) := 0.00 (0.000) 1
?- is.func(hello)
-> (  ) := 0.00 (0.000) 1
?- is.func(hello(world))
-> (  ) := 1.00 (0.000) 1
```

is.frame

`is.frame(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is a *frame*, `0` otherwise. For example:

```
?- is.frame(hello)
-> (  ) := 0.00 (0.000) 1
?- is.frame({})
-> (  ) := 1.00 (0.000) 1
?- is.frame({a = 1, b = 2})
-> (  ) := 1.00 (0.000) 1
```

is.number

`is.number(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is a *number*, `0` otherwise. For example:

```
?- is.number(3)
-> (  ) := 1.00 (0.055) 1
?- is.number(hello)
-> (  ) := 0.00 (0.000) 1
```

is.range

`is.range(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is a *range*, `0` otherwise. For example:

```
?- is.range(<1|10>)
-> (  ) := 1.00 (0.000) 1
?- is.range(231)
-> (  ) := 0.00 (0.000) 1
```

is.string

`is.string(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is a *string*, `0` otherwise. For example:

```
?- is.string(3)
-> (  ) := 0.00 (0.000) 1
?- is.string(hello)
-> (  ) := 0.00 (0.001) 1
?- is.string("hello, world!")
-> (  ) := 1.00 (0.000) 1
```

is.symbol

`is.symbol(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is a *symbol*, `0` otherwise. For example:

```
?- is.symbol(3)
-> (  ) := 0.00 (0.000) 1
?- is.symbol(hello)
-> (  ) := 1.00 (0.000) 1
?- is.symbol("hello, world!")
-> (  ) := 0.00 (0.000) 1
```

is.variable

`is.variable(`*term*`)`

The *primitive* will resolve to a *truth value* of `1` if the *term* is an unbound *variable*, `0` otherwise. For example:

```
?- is.variable(:h)
-> ( :h ) := 1.00 (0.000) 1
?- is.variable(5)
-> (  ) := 0.00 (0.000) 1
?- set(:h,5), !is.variable(:h)
-> ( 5 ) := 1.00 (0.000) 1
```

6 Elementals

This section provides some details on all the *elementals* supported by the *runtime*. For each one, the list of supported *properties* and accepted values will be given as well as some explanation on their use cases.

`MRKCBFSolver`

This *elemental* class is the most common one used in *fizz* . It is in fact the default and can handle *statements* as well as *prototypes*. It implement a *breadth-first* solving which is optimized for concurrency, therefore it is not the most efficient *solver* with regard to time and memory usage. However, at this moment, it is the only *elemental* capable of handling *prototypes*.

This *elemental* supports the following *properties*:

`p.limit`	the maximum number of *prototype* the object will accept when they are defined.
`s.limit`	the maximum number of *statement* the object will accept when they are asserted.
`replies.are.triggers`	set to `no` to instruct the *elemental* to not considere *replies* as potential triggers.

`FZZCWebAPIGetter`

The `FZZCWebAPIGetter` *elemental* performs a connection to a specific HTTP web service in order to respond to a received query. Part of the query will be used to compose the URL. When the service replies, the JSON document will be parsed and its content converted into a *frame*.

The *elemental*'s properties are the following:

`headers`	an optional *frame* describing all the headers to be added to the request
`flags`	a set of *symbols* modifying the behavior of the JSON to *frame* convertor. The flag `stringify` will keep all strings as *string terms*, `symbolize` will force all strings to be converted as *symbols*. The default behavior is to convert the strings that can be considered *symbol* as such
`url.host`	the scheme and hostname of the web service (http or https)
`url.path`	the path of the requested resource
`verbose`	an optional *boolean* value (or a *symbol* `true, false`) to instructs the *elemental* to output more traces in the console

For example, to *get* any conversion rate from `api.fixer.io`, we would define the *elemental* as follow:

```
1 fixer.get {
2
3     class           = FZZCWebAPIGetter,
4     url.host        = "http://api.fixer.io",
5     url.path        = "/latest",
6
7 } {
8
9 }
```

Whenever we want to query the latest conversion for said, the US Dollar, we woul query it as such:

```
1  ?- #fixer.get({ base = USD },:l)
2  -> ( [1525392000, 200, {Date = "Sun, 06 May 2018 02:40:35 GMT", Connection = "keep-alive",
3  Set-Cookie = "__cfduid=d70c6e9991dfeb2ae1ee6e8293a1622341525574434; expires=Mon, 06-May-19
4  02:40:34 GMT; path=/; domain=.fixer.io; HttpOnly", Cache-Control = "public, must-revalidate,
5  max-age=900", Last-Modified = "Fri, 04 May 2018 00:00:00 GMT", X-Deprecation-Message = "This
6  API endpoint is deprecated and will stop working on June 1st, 2018. For more information please
7  visit: https://github.com/fixerAPI/fixer#readme", Vary = "Origin", X-Content-Type-Options =
8  "nosniff", Server = "cloudflare", CF-RAY = "41681539a27192f4-SJC"}, {a__deprecation_message__ =
9  "This API endpoint is deprecated and will stop working on June 1st, 2018. For more information
10 please visit: https://github.com/fixerAPI/fixer#readme", base = USD, date = "2018-05-04",
11 rates = {AUD = 1.329700, BGN = 1.634100, BRL = 3.546300, CAD = 1.287500, CHF = 0.998410,
12 CNY = 6.359200, CZK = 21.308000, DKK = 6.223700, EUR = 0.835490, GBP = 0.737200,
13 HKD = 7.849600, HRK = 6.186000, HUF = 262.240000, IDR = 13978, ILS = 3.621200,
14 INR = 66.862000, ISK = 102.100000, JPY = 108.920000, KRW = 1076.400000, MXN = 19.156000,
15 MYR = 3.938000, NOK = 8.057500, NZD = 1.425900, PHP = 51.673000, PLN = 3.554400, RON = 3.895100,
16 RUB = 63.065000, SEK = 8.832800, SGD = 1.333600, THB = 31.755000, TRY = 4.257900,
17 ZAR = 12.628000}}] ) := 1.00 (0.400) 1
```

The *list* unified with the *variable* `:l` will contains four *terms*: a time stamp (UTC, expressed in seconds since Unix epoch), an HTTP response status number (200 for Okay), a *frame* containing the response *headers* received from the web site and a *frame* containing the data received as response.

`FZZCWebAPIPuller`

The `FZZCWebAPIPuller` *elemental* handles a temporary (but repeatable) connection to an HTTP web service, from which data (in JSON format) are to be retreived. When the JSON document received as reply has been parsed, its content will be converted into a *frame*, and the *elemental* will publish a statement containing it.

The *elemental*'s properties are the following:

`tick`	the frequency (in seconds) at which the web service is to be pulled. When that property isn't set, the *elemental* will only fetch the data once
`headers`	an optional *frame* describing all the headers to be added to the request
`flags`	a set of *symbols* modifying the behavior of the JSON to *frame* convertor. The flag `stringify` will keep all strings as *string terms*, `symbolize` will force all strings to be converted as *symbols*. The default behavior is to convert the strings that can be considered *symbol* as such
`url`	a single string containing the URL of the requested service/path/query, or:
`url.host`	the scheme and hostname of the web service (http or https)
`url.path`	the path of the requested resource
`url.query`	a frame describing the query, each of the label/value pair will be concatenated into a query string
`verbose`	an optional *boolean* value (or a *symbol* `true, false`) to instructs the *elemental* to output more traces in the console

For example, to *pull* the conversion USD conversion rate from `api.fixer.io`, we would have:

```
1  web.conv.puller {
2
3      class           = FZZCWebAPIPuller,
4      tick            = 60.0,
5      url.host        = "http://api.fixer.io",
6      url.path        = "/latest",
7      url.query       = { base = USD }
8
9  } {
10
11 }
```

The *statement* published at each successful *pull*, will have four *terms*: a time stamp (UTC, expressed in seconds since Unix epoch), an HTTP response status number (200 for Okay), a *frame* containing the response *headers* received from the web site and a *frame* containing the data received as response. For the example above, a possible *statement* will be:

```
1  web.conv.puller(1518998400, 200, {Server = "nginx/1.13.8", Date = "Tue, 20 Feb 2018 04:44:55 GMT",
2  Connection = "keep-alive", Cache-Control = "public, must-revalidate, max-age=900",
3  Last-Modified = "Mon, 19 Feb 2018 00:00:00 GMT", Vary = "Origin",
4  X-Content-Type-Options = "nosniff"}, {base = USD, date = "2018-02-19", rates = {AUD = 1.263200,
5  BGN = 1.576000, BRL = 3.233400, CAD = 1.256400, CHF = 0.927720, CNY = 6.344400, CZK = 20.409000,
6  DKK = 6.001600, EUR = 0.805800, GBP = 0.713860, HKD = 7.822300, HRK = 5.994000, HUF = 250.730000,
7  IDR = 13553, ILS = 3.519200, INR = 64.253000, ISK = 100.480000, JPY = 106.560000, KRW = 1066.900000,
8  MXN = 18.544000, MYR = 3.890500, NOK = 7.782000, NZD = 1.355400, PHP = 52.458000, PLN = 3.340900,
9  RON = 3.756100, RUB = 56.463000, SEK = 7.989900, SGD = 1.313100, THB = 31.380000, TRY = 3.753000,
10 ZAR = 11.653000}})
```

`FZZCFFBNetwork`

The `FZZCFFBNetwork` *elemental* manages a collection of *feed-forward back propagation neural networks* all built from the same training data whose are collected by querying the *runtime environment*. Once they

have been trained, the *elemental* can be used for *classification* as well as *regression*. From *runtime* session to session, the trained models can be saved as part of the *properties*.

In order to be usable, this *elemental* requieres various values to be provided in its *properties*. The following table contains them:

`query`	the *predicate* (in the form of a *functor*) to be used to query for *statements* to be used as training data.
`generalize`	a *list* of *lists* describing which of the *statements terms* will be considered an input or an output.
`formatting`	a *list* describing how each of the *terms* in a *statement* is to be understood (data or label).
`hidden_layers`	a *number* providing the number of hidden layers to be used by the *neural networks*.
`neurons_in_hidden_layers`	a *number* providing the number of *neurons* in each hidden layers.

To dive in the details, have a look at the file `iris.fizz` in the `samples` folder. As the name indicates, this samples uses the famous *Iris dataset* (which you can find in `https://archive.ics.uci.edu/ml/datasets/iris`) which, have been processed into a *fizz Knowledge*. Let's look at how we have set up the *elemental*:

```
1  iris {  class = FZZCFFBNetwork,
2          alias = iris.ffbn,
3          query = iris(_,_,_,_,_),
4          generalize = [[i,i,i,i,o],[o,i,i,i,i]],
5          formatting = [d,d,d,d,l],
6          hidden_layers = 1,
7          neurons_in_hidden_layers = 4,
8  } {
9
10 }
```

In the example we request the *elemental* object to create two *neural networks* (with the `generalize` label/-value). Both will have four *inputs* and a single *output* neurons, however which of the *terms* is an output is the difference. For the first *network*, we specified `[i,i,i,i,o]` which means the last *term* will be the output. For the second *network*, we have `[o,i,i,i,i]` where the first *term* will be the output. The `formatting` label indicates that the first four *terms* are data while the last *term* is a label.

Unless the *elemental* is already trained, you will need to use the `/tells` console command to instruct the object to collect training data as well as use them to train the networks. Here's an example of this:

```
?- /tells(iris.ffbn,acquires)
?- /tells(iris.ffbn,practice(1.0,1500,0.1))
iris - practice completed (0.000138,0.000000)
iris - practice completed (0.000398,0.000000)
```

Sending the *symbol* `acquires` to the *elemental* will set it into a training data acquisition state in which the `query` you provided in the *properties* (or by using the `/poke` command) will be used to collect *statements*. Depending on how much data can be collected (there's no console feedback) you can wait a little bit before entering the second `/tells` command which instructs the *elemental* to train (*practice*) using the *statements* it has received so far. The parameters provided in the *functor* are (in order): split between training and validation data (a *number* between 0 and 1), the count of *epochs* to train the models for and the learning rate. In this case, we are requesting all received *statements* to be used as training data, the epoch to be `1500`

and the learning rate to be `0.1`.

The output on the console for the second `/tells` command will indicate when the training is completed for each *networks*. The numbers in the parantheses are the *training error* and *validation error*. In this case, since we have no validation data, the *validation error* is `0`.

Once the *networks* are trained, the *models* can be used. For example, we can classify:

```
?- #iris(4.40,2.90,1.40,0.20,:x)
-> ( setosa ) := 0.98 (0.001) 1
```

Note the *truth value* for the `iris` statement that was returned by the *elemental* (`0.98`). We can also do a regression to find out a value for the first *term*:

```
?- #iris(:x,2.90,1.40,0.20,setosa)
-> ( 4.838565 ) := 0.99 (0.001) 1
```

Note that having more than one unbound *variable* in your *query* isn't supported. When the *elemental* is saved, the *models* will be saved in the *properties* as a *binary term* under the label `data`.

`FZZCRandomizer`

This *elemental* can be used to inject some random activations by firing *statements* with a random *number* or *term* at a given interval. For example, we can define such *elemental* and instruct it to pick a random number between `1550` and `1650`:

```
1 rand {
2     class = FZZCRandomizer,
3     min   = 1550,
4     max   = 1670,
5     mod   = 2
6 } {
7
8 }
```

If we then load it in the *runtime* environment, it will starts firing at regular interval (the `mod` value indicates every other interval). If we use the `/spy` command, we can observe the generated *statements* being broadcasted through the *substrate*:

```
?- /spy(append,rand)
spy : observing rand
spy : S rand(1637) := 1.00
spy : S rand(1643) := 1.00
spy : S rand(1576) := 1.00
spy : S rand(1610) := 1.00
spy : S rand(1608) := 1.00
spy : S rand(1597) := 1.00
spy : S rand(1636) := 1.00
spy : S rand(1618) := 1.00
spy : S rand(1563) := 1.00
spy : S rand(1565) := 1.00
```

If we now make use of a `rand` *predicate* in a *prototype* as follows:

```
male {

    (james1, 1566)    := 1.0;
    (charles1, 1600)  := 1.0;
    (charles2, 1630)  := 1.0;
    (james2, 1633)    := 1.0;
    (george1, 1660)   := 1.0;
    (_,_)             := 0.0;

}

dad {

    (:x) :- @rand(:y) , #male(:x,:y);

}
```

We will activate a query on the `male` *predicate* each time a new `rand` *statement* is broadcasted as we can see below:

```
?- /spy(append,rand,dad)
spy : observing rand
spy : observing dad
spy : S rand(1627) := 1.00
spy : S rand(1580) := 1.00
spy : S rand(1618) := 1.00
spy : S rand(1571) := 1.00
spy : S rand(1654) := 1.00
spy : S rand(1630) := 1.00
spy : S dad(charles2) := 1.00
spy : S rand(1622) := 1.00
spy : S rand(1579) := 1.00
spy : S rand(1582) := 1.00
spy : S rand(1632) := 1.00
spy : S rand(1617) := 1.00
spy : S rand(1566) := 1.00
spy : S dad(james1) := 1.00
spy : S rand(1598) := 1.00
spy : S rand(1663) := 1.00
spy : S rand(1666) := 1.00
```

If the `min` and `max` *properties* are not specified, the *elemental* will generate random *numbers* between `0` and `1`. If only the minimum value is omitted, it will default to `0`. If it is the maximum value that is missing, it will default to the maximum possible value for a floating point *number*.

Instead of generating *number*, we can instructs the *elemental* to randomly pick an element from a *list*. To do that, we simply specify the *list* using the label `values` in the *properties*. Here's the *elemental* we used earlier rewritten to restrict the possible *numbers*:

```
rand {
    class = FZZCRandomizer,
    values = [1566,1600,1630,1633,1660]
} {
```

```
5
6 }
```

This time around, since we are only picking from the years present in the `male` *knowledge* we get `dad` *statements* right away:

```
?- /spy(append,rand,dad)
spy : observing rand
spy : observing dad
spy : S rand(1566) := 1.00
spy : S dad(james1) := 1.00
spy : S rand(1600) := 1.00
spy : S dad(charles1) := 1.00
spy : S rand(1633) := 1.00
spy : S dad(james2) := 1.00
spy : S rand(1633) := 1.00
spy : S dad(james2) := 1.00
spy : S rand(1630) := 1.00
spy : S dad(charles2) := 1.00
spy : S rand(1566) := 1.00
spy : S dad(james1) := 1.00
spy : S rand(1600) := 1.00
spy : S dad(charles1) := 1.00
spy : S rand(1633) := 1.00
spy : S dad(james2) := 1.00
```

`FZZCTicker`

This *elemental* can be used to activate other *elemental* at a regular interval by firing a *statement*. For example:

```
1 tick {
2     class = FZZCTicker,
3     mod   = 4
4 } {
5
6 }
```

If we then load it in the *runtime* environment, it will starts firing at regular interval (the `mod` value indicates how often based on the *substrate*'s pulse). If we use the `/spy` command, we can observe the generated *statements* being broadcasted through the *substrate*:

```
?- /spy(append,tick)
spy : observing tick
spy : S tick(9, 1512157341.254642) := 1.00 (15.000000)
spy : S tick(10, 1512157342.254716) := 1.00 (15.000000)
spy : S tick(11, 1512157343.254030) := 1.00 (15.000000)
spy : S tick(12, 1512157344.254033) := 1.00 (15.000000)
spy : S tick(13, 1512157345.253880) := 1.00 (15.000000)
spy : S tick(14, 1512157346.254291) := 1.00 (15.000000)
spy : S tick(15, 1512157347.254672) := 1.00 (15.000000)
```

The first *term* in the published *statement* is a cycle counter (which will be saved by the *elemental* when it is saved or frozen). The second *term* is the current time (in seconds since Epoc, GMT). Instead of basing

the ticking on the *substrate*'s pulse, the property *tick* can be used to indicate the interval in seconds. For example, to have the *tick* statement firing every 1.5 seconds, we would write:

```
1 tick {
2     class = FZZCTicker,
3     tick  = 1.5
4 } {
5
6 }
```

`MRKCLettered`

The `MRKCLettered` *elemental* can only handle *statements*. It is meant to be used as a way to lower *runtime* cost when it is known that a particular *Knowledge* will never contains any *prototypes*. Here are the *properties* specific to this class:

`s.limit`	the maximum number of *statement* the object will accept when they are asserted.
`no.match`	if set to the *symbol* `fail`, the object will always produce a statement with a truth value of `0` when there was no match to a query.
`index`	the property is interpreted as the (or multiple when a *list* is given) index of the *statement*'s terms that we which the *statements* to be indexed upon. Judicious indexing will speed-up retreival of *statements* (see the sample `cars.fizz` for an example).
`nearest.only`	if set to the *symbol* `yes`, the object will always answers queries with *constrained variables* using the primtive `aeq` with the closest match possible.

7 Advanced topics

Miscellaneous

`Escaper`

An *Escaper* is a special kind of *term* which utility comes to light, mainly, when used with *volatiles*. It provides a way to protect a *term* from an upcoming *substitution*. As example, let's look at using the `define` *primitive* to create a *prototype* which will provide a function similar to the `assert` *primitive* but with the difference that we will stamp the created *statements*. If we were to create that in a text editor we would do something like this:

```
1 assert.stamp {
2
3     (:f, :v) :- assert(:f, :v, {stamp = %now});
4
5 }
```

To create it from the console, we would type this:

```
?- define(assert.stamp,[\:f,\:v],[],[[[primitive],assert(\:f,\:v,{stamp = \%now})]])
-> (  ) := 1.00 (0.000) 1
```

In it, we have use \ to indicate each of the *terms* which need to be escaped. This will prevent the *volatile* `now` from being substituted when the `define` primitive is called. An *escape* sequence only works for a single substitution, therefore, we could have used multiple \, one for each level of depth to protect the *term* for. For convenience, we have also escaped the *variables* `:f` and `:t`. This will prevent the console from expecting the call to `define` to bound the *variables*.

We can now test the new `assert.stamp` *prototype* and verify that each of the *statements* is created with a timestamp in its *properties*:

```
?- #assert.stamp(hello(bob),1)
-> (  ) := 1.00 (0.001) 1
?- #assert.stamp(hello(alice),1)
-> (  ) := 1.00 (0.001) 1
?- #hello(:x) {stamp = :s}
-> ( bob , 1509431500.377723 ) := 1.00 (0.001) 1
-> ( alice , 1509431507.226000 ) := 1.00 (0.001) 2
```

Have we not escaped the `now` *volatile*, it will have been substitued during the `define` call and each of the *statements* we would have created will have had the same value for timestamp:

```
?- define(assert.stamp,[\:f,\:v],[],[[[primitive],assert(\:f,\:v,{stamp = %now})]])
-> (  ) := 1.00 (0.000) 1
?- #assert.stamp(hello(bob),1)
-> (  ) := 1.00 (0.001) 1
?- #assert.stamp(hello(alice),1)
-> (  ) := 1.00 (0.001) 1
?- #hello(:x) {stamp = :s}
-> ( bob , 1509433383.169334 ) := 1.00 (0.001) 1
-> ( alice , 1509433383.169334 ) := 1.00 (0.001) 2
```

Lastly, the *runtime environment* defines a primitive called `is.escaper` which can be used to test if a *term* is an *escaper* or not. To force such *term* to surrender the *term* it is protecting, you can use the *primitive* `set` to assign the *escaper* to a *variable*.

Services

This section provides some details on all the *services* supported by the *runtime*.

`MRKCCollector`

The `MRKCCollector` *service* provides a way to assemble all the *statements* generated by a *predicate* and provide them as *lists*. It can be used by use of the `fzz.collect` *predicate*:

`fzz.collect`(*list*,*functor*,*list*|*variable*,*frame?*)

The first *term* is a *list* which can contains *symbol* and/or a *range*. Its purpose is to indicate if the *predicate* to collect is negated (`negate` *symbol*) and/or a primitive (`primitive` *symbol*). When a *range* is expressed in the *list*, it will be used as the *predicate* truth value range. The second *term* is a *functor* which express the *predicate* to be collected. Each of the unbound *variables* that will be used in the *functor* will be considered as a target for collection. The third *term* will unify or substitue with a *list* containing the *truth value* of all received *statements*. If provided, the fourth *term* is a *frame* which can specify a timeout value (in seconds) after which the collection will be terminated (with the label `tmo`) if no more *statements* are being collected. When no timeout is provided, the default is half a second. The service will only returns what was collected once the timeout occurs.

As an example, let's consider the following knowledges:

```
product {

    (model_e,tesla,2012);
    (iphone_x,apple,2018);
    (vive,htc,2015);
    (coconut_water,zico,2000);

}

product {

    (iphone,apple,2007);
    (iphone_3GS,apple,2009);
    (7710,nokia,2005) := 0.9;

}
```

If we wanted to get the name and year of release of all products with a truth value above `0.9`, we would query:

```
?- #product(:label,_,:years) <0.91|1>
-> ( model_e , 2012 ) := 1.00 (0.001) 1
-> ( iphone_x , 2018 ) := 1.00 (0.001) 2
-> ( vive , 2015 ) := 1.00 (0.001) 3
-> ( coconut_water , 2000 ) := 1.00 (0.001) 4
-> ( iphone , 2007 ) := 1.00 (0.001) 5
-> ( iphone_3GS , 2009 ) := 1.00 (0.001) 6
```

Now, to generate *lists* from the *statements* of all the possible values of the *variables*, we would kick the *predicate* to the service and chain the call like any other *predicate* dealing with *knowledge*:

```
?- #fzz.collect([<0.91~1>],product(:values,_,:years),_), lst.length(:values,:length)
-> ( [iphone, iphone_3GS, model_e, iphone_x, vive, coconut_water] ,
     [2007, 2009, 2012, 2018, 2015, 2000] , 6 ) := 1.00 (0.488) 1
```

`MRKCEvaluator`

The `MRKCEvaluator` *service* provides a way to evaluate a *functor* like if it was a *predicate*. It can be used by using a `fzz.eval` *predicate*:

`fzz.eval`(*list*,*functor*|*list*,*frame?*)

The first *term* is a *list* which can contains *symbol* and/or a *range*. Its purpose is to indicate if the *predicate* to collect is negated (`negate` *symbol*) and/or a primitive (`primitive` *symbol*). When a *range* is expressed in the *list*, it will be used as the *predicate* truth value range. The second *term* is a *functor* or a *list* which express the *predicate* to be evaluated. If provided, the third *term* is a *frame* which can specify a timeout value (in seconds) after which the evaluation will be terminated (with the label `tmo`). When no timeout is provided, the default is half a second.

If we look at the previous example, we could have used it as follow:

```
?- #fzz.eval([],product(:name,apple,_),{tmo=2})
-> ( iphone_x ) := 1.00 (2.029) 1
-> ( iphone ) := 1.00 (2.029) 2
-> ( iphone_3GS ) := 1.00 (2.029) 3
```

This service can get more interesting when combined with the use of `fun.make` (see Section 5.5 on page 45) to create the *functor* to be evaluated:

```
?- fun.make(product,[:name,apple,_],:func), #fzz.eval([],:func)
-> ( iphone , product(iphone, apple, 2007) ) := 1.00 (0.733) 1
-> ( iphone_3GS , product(iphone_3GS, apple, 2009) ) := 1.00 (0.733) 2
-> ( iphone_x , product(iphone_x, apple, 2018) ) := 1.00 (0.733) 3
```

Release notes

`0.3.0-X`

Additions

- *live code reload* functionality
- new *constant* `$cores`
- new *primitives*:
  - `aeq` (see section 5.3 on page 40)
  - `bundle` (see section 5.2 on page 33)
  - `div.int` (see section 5.1 on page 30)
  - `fzz.lst` (see section 5.9 on page 55)
  - `lst.remove` (see section 5.6 on page 47)
  - `mao.sign` (see section 5.8 on page 54)
  - `str.find` (see section 5.13 on page 60)
  - `str.flip` (see section 5.13 on page 61)
  - `str.trim` (see section 5.13 on page 63)
  - `str.rest` (see section 5.13 on page 61)
  - `str.swap` (see section 5.13 on page 62)
  - `sym.cat` (see section 5.12 on page 59)
- new *console commands*:
  - `/reload` (see section 4.3 on page 26)
  - `/import.txt` (see section 4.3 on page 24)
- new *class* `FZZCWebAPIGetter` (see section 6 on page 66)

Changes

- increased the maximum number of threads that can be used by the console
- added support for `str.find` as a *variable's constraint*
- *primitive* `frm.fetch` allows for a fourth *term* to specify a default value to use if the label isn't found
- when the first *term* of the `/peek` and `/poke` *console commands* is a *symbol*, all *elemental* of that label will be targetted
- the `fzz.eval` service now accept a *list* as second *term* to describe the *functor* to be evaluated
- changed *class* `FZZCTicker` to support the property `tick.on.attach`
- changed *class* `MRKCBFSolver` to support the property `replies.are.triggers`
- changed *class* `MRKCLettered` to support the property `nearest.only`

Bug Fixes

- minor performance tweaks when parsing *list* in *fizz* source files
- *primitive* `str.sub` was not properly handling negative offset
- on occasion queries/replies where not being sent/received
- JSON support wasn't handling 'null' value (causing crash)
- chunked transfer encoding wasn't supported by the builtin web client

`0.2.0-X`

Additions

- added console commands `/import.json` and `/export.json` to import and export JSON files (see section 4.3 on page 22 and 4.3 on page 19)
- added *primitive* `change` (see section 5.2 on page 33)
- added *primitive* `console.exec` (see section 5.2 on page 33)
- added *primitive* `then` (see section 5.2 on page 39)
- added *primitive* `tme.str` (see section 5.2 on page 39)
- added *primitive* `str.cmp` (see section 5.13 on page 60)
- added *elemental* class `FZZCWebAPIPuller` for fetching JSON data from web services (see section 6 on page 67)

Changes

- console commands `/import` and `/export` were renamed `/import.csv` and `/export.csv`
- the *elemental* class `FZZCTicker` now also supports time interval expressed in seconds (see section 6 on page 72)

Bug Fixes

- published statements could stop from being received by *elementals* referencing them as trigger
- *primitive* `str.tosym` was failing when the first *term* was already a *symbol*

`0.1.4-X`

Changes

Initial Release

Bug Fixes

Initial Release

Known issues

- Poor performance with *inferences* that involves *combinatorial exploration*
- Parser's error handling is too terse
- An empty comment line will cause a parsing error in a `fizz` file

Index