fizz

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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

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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 12 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 8, 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 36 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;
```

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

}
```

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"*:

```
@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 33 for all the supported *primitives*. If we wanted to use a *primitive* we would have omitted the `@` like in this example:

```
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:

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

`~` is another prefix that can be used for a *predicate*. When used in conjunction with the *predicate* label `self`, it indicates a self referencing *predicate* (a recursive *predicate*). When using with any other *elemental* label, it will cause the *query* to be sent to one (picked randomly) of the *elemental* in the *substrate* with that label.

Using `self` instead has the advantage of being often shorter to type and to enable the *elemental* to be cloned since such *predicate* will always point to the right *elemental*. For example, here's an *elemental* which calculate the sum of a all the *numbers* in a *list*:

```
lst.sum {

    ([],0)^         :- true;
    ([:h],:h)^      :- true;
    ([:h|:r],:s)    :- ~self(:r,:s.r), add(:h,:s.r,:s);

}
```

The difference between `#self` and `~self`, is that when the tilde is use, the *predicate* will only be send to the *elemental* itself. No other *elemental* with the same label will get the query.

The fourth prefix that can be used with *predicates* is `*`. When used, the *query* will *round-robin* between all *elementals* that can answer the *query*. This prefix allows *queries* to be distributed amongst multiple *elementals*, potentially executing concurrently on different CPUs.

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:

```
str.default {

    (:a,:b,:b) :- console.puts("1>"), !is.string(:a)^;
    (:a,:b,:b) :- console.puts("2>"), is.string(:a) , str.length(:a,0)^;
    (:a,:b,:a) :- console.puts("3>"), is.string(:a) , str.length(:a,_?[gt(0)]);

}
```

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 13 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 77 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 12) 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
`clone`	a *symbol* indicating the *elemental* object to be used as the model
`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*
`nosy`	when set to `yes` (the default), any reply to a query that wasn't initiated by the *elemental* will be checked to see if it can be used as trigger.
`chatty`	when set to `yes` (the default), the *elemental* will publish the *statements* it uses as replies to queries.
`ttl`	when set, the *elemental* will use the value (in seconds) as the value for the TTL of any queries it send out instead of the global value.

An *elemental*'s properties can be accessed at runtime by any *prototype* being executed by the *elemental*. Either by using the `primitives` `peek` and `poke` (see Section 5.2 on page 41) or by using the *constant* access syntax (e.g. `$guid`). When using the *constant* form, the label of the *elemental* can be retreived at runtime with `$self`.

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`. If the `clone` property is given, the first *elemental* that answers to that label will be cloned and any properties specifies in the source *elemental* will be replaced by the value in the target *elemental*.

Depending on the situation, setting the properties `nosy` and `chatty` to `no` can help improve the performances of the system by lowering the unecessary background inferring.

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 8 on page 97 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 different kinds of *atoms* in *fizz* :

- Number
- String
- Symbol
- Binary
- Guid
- Regexp

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:

```
yearly_stats {

    (2001,0.4,45u,3f);

}
```

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 17).

3.1.2 String

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

```
quotes {

    (DrSeuss,"Don't cry because it's over, smile because it happened.");
    (OscarWilde,"Be yourself; everyone else is already taken.");
    (Gandhi,"Be the change that you wish to see in the world.");

}
```

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 *terms* uses `base64` to encode binary contents into a string, and they are specified in *fizz* code using a single quoted functor as in the following example:

```
blobs {

    ('binary("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.

3.1.5 Guid

Guid terms are a way to represent globally unique identifier. Such *terms* are specified in *fizz* code using a single quoted functor as in the following example:

```
guids {

    ('guid("71cfade6-3cab-c34e-3ca6-e7a43e6fb5f7"));

}
```

3.1.6 Regexp

A *Regexp* term is a way to represent a regular expression with which to unify *strings*. Such *terms* are specified in *fizz* code using a single quoted functor as shown in the following example:

```
?- rex.match('regexp("(the|a)?\s?(dog|cat)\sis\s(wet|cold|sick)"),"cat is sick",:m)
-> ( ["cat is sick", "", "cat", "sick"] ) := 1.00 (0.001) 1
```

As *fizz* uses the PCRE2 library[2] to implement the regular expression support, the following flags (to be provided within a *list*) can be used to modify the way the expression is compiled:

[2] see https://www.pcre.org/

`ANCHORED`	Force pattern anchoring
`ALLOW_EMPTY_CLASS`	Allow empty classes
`ALT_BSUX`	Alternative handling of \u, \U, and \x
`ALT_CIRCUMFLEX`	Alternative handling of în multiline mode
`ALT_VERBNAMES`	Process backslashes in verb names
`AUTO_CALLOUT`	Compile automatic callouts
`CASELESS`	Do caseless matching
`DOLLAR_ENDONLY`	$ not to match newline at end
`DOTALL`	. matches anything including NL
`DUPNAMES`	Allow duplicate names for subpatterns
`ENDANCHORED`	Pattern can match only at end of subject
`EXTENDED`	Ignore white space and comments
`FIRSTLINE`	Force matching to be before newline
`LITERAL`	Pattern characters are all literal
`MATCH_UNSET_BACKREF`	Match unset backreferences
`MULTILINE`	ând $ match newlines within data
`NEVER_BACKSLASH_C`	Lock out the use of \C in patterns
`NO_AUTO_CAPTURE`	Disable numbered capturing parentheses (named ones available)
`NO_AUTO_POSSESS`	Disable auto-possessification
`NO_DOTSTAR_ANCHOR`	Disable automatic anchoring for .*
`NO_START_OPTIMIZE`	Disable match-time start optimizations
`UNGREEDY`	Invert greediness of quantifiers
`USE_OFFSET_LIMIT`	Enable offset limit for unanchored matching

The `CASELESS` flag can be used to ignore the case during matching (note that flags are case-insensitive):

```
?- rex.match('regexp("[a|b]+"),"aabb",:l)
-> ( ["aabb"] ) := 1.00 (0.001) 1
?- rex.match('regexp("[a|b]+"),"ABABA",:l)
?- rex.match('regexp("[a|b]+",[caseless]),"ABABA",:l)
-> ( ["ABABA"] ) := 1.00 (0.001) 1
```

Since, *regexp* are full fledged *terms*, they can be used in *predicates* and *prototype*'s entrypoint as shown in this example:

```
str.is {

    ('regexp("[+-]?([0-9]*[.])?[0-9]+"),number)^     :- true;
    (_,string)                                        :- true;

}
```

Lastly, the *primitive* `rex.match` which we have used above can be used within a *contrained variable*. This allow the matching content to be accessed:

```
test {

    (:s?[rex.match('regexp("(the|a)?\s?(dog|cat)\sis\s(wet|cold|sick)"),:s,[_,_,_,:c])],:c) :- true;

}
```

```
?- #test("dog is sick",:l)
-> ( "sick" ) := 1.00 (0.002) 1
?- #test("dog is wet",:l)
```

```
-> ( "wet" ) := 1.00 (0.002) 1
?- #test("dog is gone",:l)
```

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
`eq`	equal/unify
`lst.member`	value is present in a *list*
`lst.except`	value is not present in a *list*
`lst.incl`	value is a list that include the items in a *list*
`lst.excl`	value is a list that exclude the items 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.regexp`	value is a *regexp term*
`is.guid`	value is a *guid 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.bound`	a value is bound
`is.unbound`	no value is bound yet
`is.even`	value is an even *number*
`is.odd`	value is an odd *number*
`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:

```
lst.zip {

    ([],[])^                          :- true;
    ([:e],[:e])^                      :- true;
    ([:e,:e|:r],:l)                   :- #lst.zip([:e|:r],:l);
    ([:e,:f?[neq(:e)]|:r],[:e|:l])    :- #lst.zip([:f|:r],:l);

}
```

Some of the *primitives* can be used directly as constraints. Check the specific details for a *primitive* to know if it supports this situation.

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*
`%sym.3`	a randomly generated *symbol* of 3 characters length
`%sym.4`	a randomly generated *symbol* of 4 characters length
`%sym.10`	a randomly generated *symbol* of 10 characters length
`%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:

```
help {

    () :- @console.keypress(_), hush, console.puts("press ESC to enter input mode");

}
```

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:

```
{
    "runtime" : {
        "scheduler" : {
            "threads"  : 4,
            "affinity" : true,
            "spinning" : 4
        },
        "offloader" : {
            "minpool"  : 1,
            "maxpool"  : 4,
            "timeout"  : 750,
            "affinity" : false
        },
        "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
        },
        "mzttl" : {
            "type" : "real",
            "data" : 1.5
        },
    },
    "modules" : {
        "www" : {
            "dnstimeout" : 3.5,
            "maxconnect" : 8,
            "maxrequest" : 4,
            "maxresolve" : 4,
            "maxcontent" : 2048
        }
    }
}
```

It contains three sections: the `runtime`, `substrate` and `modules`. The former adjusts the threading and multi-cores models of the *runtime* while `substrate` adjusts the common behavior of all *elemental* objects will use. The later provides parameters for the modules that may be loaded.

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 maximum number of consecutive time an *elemental* will get time on a core before it gets swapped out for another *elemental*. The lesser the value the more the *scheduler* will *round-robin* between the *elementals*.

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 `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.
`mzttl`	this is the *time to live* for any statements that is cached by an *elemental* set to *memoize* (in seconds).

The `httpclient` section (in the `www` section of `modules`) is responsible for tuning the built-in HTTP client used by the *elemental* class `FZZCHttpPuller`. 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.

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 Solution

A *solution* is a `JSON` file that can be loaded by *fizz* and describe a given set of source files, global constants and modules to be loaded. Here's an example of such file for the `linkg.fizz` sample:

```
{
    "solution" : {
        "modules" :   ["modLGR"],
        "sources" :   ["linkg.fizz"],
        "globals" :   [],
        "queries" :   []
    }
}
```

To be valid, such file much constains a `solution` object, itself containing the following (all optional) labels:

- `modules` a list of modules to be loaded (without file extensions)
- `sources` a list of sources to be loaded (which path is relative to the path of the *solution* file)
- `globals` a list of objects describing the *constants* to be created. Each of the objects must contains two label/value pairs: `label` and `value`.
- `queries` a list of queries (in the form of strings containing *predicates*) to be executed once all the sources and modules files have been loaded.

Here's an example of the solution file for the *weather.fizz* sample:

```
{
    "solution" : {
        "modules" :   [],
        "sources" :   [
            "weather.fizz"
        ],
        "globals" :  [
            {
                "label" : "api.key",
                "value" : "XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX"
            }
        ],
        "queries" : []
    }
}
```

To use this *solution* you will need to replace the value for `api.key` by your own key.

4.4 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*:

```
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;

}
```

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[3]. For the sake of simplicity, the JSON file below was abbreviated:

```
{
    "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:

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

```
?- /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);

}
```

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*`|`*guid*`)`

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* or a *guid*). 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 4.4 on page 32) 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*`|`*guid*,*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 re-loaded 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*`|`*guid*`,`*functor*`|`*symbol*`)`

Sends a *message* (in the form of a *functor* or a *symbol*) to an *elemental* object identified by its label, alias or GUID, the first argument. Not all *elemental* object can handle *message*. If the object is identified by its label, all objects with the same label will receive the 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
```

use

`/use(`*string+*`)`

The `use` command allows for one or more module(s) (shared library) to be loaded. All terms in the `predicate` are expected to be *strings*. Once loaded, the *module* contents will be available (e.g. *elemental classes*, *primitives*). A loaded *module* cannot be unloaded.

```
?- /use("modLGR")
use : loading ./mod/lnx/x64/modLGR.so ...
use : loaded  ./mod/lnx/x64/modLGR.so in 0.001s
?- /use("./modLGR.so")
use : sorry, ./modLGR.so doesn't exists
```

When no extension is given, the *command* assumes the *module* to be loaded is located in the *fizz* modules folder that correspond to the architecture used by the host computer.

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*`|`*guid,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
```

sim

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

This *primitive* will unify its third *term* with a value representing the similarity between the first two *terms*. For example:

```
?- sim(3.21,3.33,:s)
-> ( 0.785714 ) := 1.00 (0.000) 1
?- sim(3.21,10,:s)
-> ( -0.743261 ) := 1.00 (0.000) 1
?- sim(3.21,-100,:s)
-> ( -0.980808 ) := 1.00 (0.000) 1
?- sim(3.21,2.211,:s)
-> ( 0.000500 ) := 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:

```
import.frag {

    () :- @line.f(:i,:s), bundle(frag(:i,:s),1,{},1024), hush;

}
```

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:

```
lst.print {

    ([]) ^ :- true;
    ([:h| :t]) :- console.puts(:h), #lst.print(:t);

}
```

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 42.

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.

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*:

```
multiplier { factor = 2 } {

    (:v,:v2) :- peek(factor,:f), mul(:v,:f,:v2);

}
```

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 39). 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.erase

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

This *primitive* unifies or substitues the last *term* with the first *term* after the required label (the second a*terms*) have been removed in the *frame*. If the label isn't found in the *frame*, the *predicate* will still evaluate to `1.0`. For example:

```
?- frm.erase({a=4,b=5},a,:f)
-> ( {b = 5} ) := 1.00 (0.001) 1
?- frm.erase({a=4,b=5},c,:f)
-> ( {a = 4, b = 5} ) := 1.00 (0.000) 1
```

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.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.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.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.excl

`lst.excl(`*list*`,`*list*`)`

The `lst.excl` *primitive* will resolve to a *truth value* of `1.0` if all *terms* in its second *term* are not present in the *list* given as first *term*. For example:

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

`lst.incl(`*list*, *list*`)`

The `lst.incl` *primitive* will resolve to a *truth value* of `1.0` if all *terms* in its second *term* are present in the *list* given as first *term*. For example:

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

lst.init

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

The `lst.init` *primitive* will unify its second *term* with a *list* containing all the items from the *list* given as first *term* but the last item. For example:

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

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

The `lst.join` *primitive* will combine the content of its first two *terms* (without duplicates) into a *list* to be unified with the third *term*. For example:

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

lst.length

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

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
```

An optional third *term* can be given when a *list* is being created to be the *term* to be used to fill the *list* instead of the *wilcard variable*. For example:

```
?- lst.length(:l,5,0)
-> ( [0, 0, 0, 0, 0] ) := 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.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.mix

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

This *primitive* will unify or bind its second *term* with a copy of its first *term* where the elements have been scrambled randomly within the *list*. For example:

```
?- lst.mix([1,2,3,4,5,6,7,8,9,0],:l)
-> ( [9, 1, 2, 8, 7, 5, 3, 0, 6, 4] ) := 1.00 (0.001) 1
?- lst.mix([1,2,3,4,5,6,7,8,9,0],:l)
-> ( [2, 6, 7, 0, 1, 9, 5, 3, 8, 4] ) := 1.00 (0.001) 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.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.sort

`lst.sort(`*list*, *list*`)`
`lst.sort(`*list*, *list*, *number*`)`

This *primitive* will unify or bind its last *term* with a copy of its first *term* where the elements have been sorted in increasing order. If a third *term* is given, it will be assumed that the *list* to sort contains *lists* and that the number is the index of the element to be used for sorting the *lists*. For example:

```
?- lst.sort([3,7,1,9,4,3],:l)
-> ( [1, 3, 3, 4, 7, 9] ) := 1.00 (0.001) 1
?- lst.sort([[3,a],[7,b],[1,d],[9,f],[4,e],[3,z]],:l,1)
-> ( [[3, a], [7, b], [1, d], [4, e], [9, f], [3, z]] ) := 1.00 (0.001) 1
```

Only *atoms* and *lists* (when a third *term* is given) can be sorted.

lst.sub

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

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

```
?- lst.sub([1,2,3,4,5,6],4,2,[5,:x])
-> ( 6 ) := 1.00 (0.000) 1
```

If the first and fourth *terms* are both *lists* and the offset is a un-bound *variable*, the call will unify the offset will possible occurences of the fourth *term* in the list. As in this example:

```
?- lst.sub([1,2,3,4,5,6,8,5,6],:i,:v,[5,6])
-> ( 4 , 2 ) := 1.00 (0.001) 1
-> ( 7 , 2 ) := 1.00 (0.001) 2
```

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
```

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
```

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 (as *guid term*) 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)
-> ( ['guid("263e7d79-c5e4-1f48-6a99-c8c022a2dbf3"), 'guid("1e9618ff-8e93-0147-efb6-5527b88c99cb"),
     'guid("8cbb3f79-6456-d94b-3393-8766fb3d4c72"), 'guid("f4608c21-6a8f-ab4c-4d92-5b092fa4171e"),
    'guid("40b3f684-f545-0241-99be-998167b99ab6"), 'guid("a099afdb-93a7-db4c-40b8-0341ea987ed9"), '
    guid("71cfade6-3cab-c34e-3ca6-e7a43e6fb5f7"), 'guid("330a4f04-e64c-8949-ec9e-83490c365dcb"), '
    guid("2aeb490e-bc61-2e43-99ac-3e6a11834049"), 'guid("2b5a6fef-7b4b-394b-dfa5-261d8c07a6f6"), '
    guid("2541b553-b2bc-444b-e2ac-398a9e75229c"), 'guid("7d6cb4d0-1012-554f-efbb-21e68971e496"), '
    guid("2148bc22-1f6c-0443-c59a-ed6185699715"), 'guid("24da8140-5f87-9849-be9a-f7c4aa4d5c0c"), '
    guid("91448fe7-0dd7-bc43-2795-3ec6e3a71537"), 'guid("9c5ab238-d08e-d148-a998-203f8096878c"), '
    guid("adae7700-7605-114d-2492-45e3d69b9a23"), 'guid("29a0e5fe-a979-7542-0bb3-c275d09e0190"), '
    guid("0513542a-ed1b-474b-e099-fa92fa234295"), 'guid("e291a61e-fb51-0747-9da4-d03bf24d22a4")] )
    := 1.00 (0.002) 1
```

gid.make

`gid.make(`*guid*`|`*variable*`)`

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

```
?- gid.make(:g)
-> ( 'guid("e30f998a-020d-fd4c-c0b8-e384d2dc8020") ) := 1.00 (0.001) 1
?- gid.make(:g)
-> ( 'guid("ce0c25e6-5adc-9e48-0c80-57b70db9a2e0") ) := 1.00 (0.000) 1
```

gid.sym

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

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

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

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

gid.str

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

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

```
?- gid.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
```

rnd.sint

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

This *primitive* will unify or bind the second *term* with a series of (signed 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.sint(3,:v,-100,100)
-> ( -48 ) := 1.00 (0.001) 1
-> ( 90 ) := 1.00 (0.001) 2
-> ( -29 ) := 1.00 (0.001) 3
```

When no range is provided, the random *numbers* will all be in between the possible value for a 64-bit signed integer:

```
?- rnd.sint(5,:v)
-> ( -3832553529235211065 ) := 1.00 (0.001) 1
-> ( 2840651865658580059 ) := 1.00 (0.001) 2
-> ( -4585361323621985541 ) := 1.00 (0.001) 3
-> ( 8886134878488290534 ) := 1.00 (0.001) 4
-> ( 4799459735435763595 ) := 1.00 (0.001) 5
```

5.11 Range

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

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.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.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.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.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*.

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.uint

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

This *primitive* will unify or bind its third *term* with any *unsigned 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.rand

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

This *primitive* will unify or bind its second *term* with a random *number* picked from the first *term*. For example:

```
?- rng.rand(<0|1>,:v)
-> ( 0.359032 ) := 1.00 (0.001) 1
?- rng.rand(<0|1>,:v)
-> ( 0.751194 ) := 1.00 (0.000) 1
?- rng.rand(<0|1>,:v)
-> ( 0.320658 ) := 1.00 (0.000) 1
```

5.12 Regexp

This section describes *primitives* that handle regular expressions.

rex.make

`rex.make(`*string*`,`*regexp*`|`*variable*`)`
`rex.make(`*string*`,`*list*`,`*regexp*`|`*variable*`)`

This *primitive* creates a new *regexp* using the pattern provided as the first *term* and an optional *list* of flags, and unify it with the last *term*. For example:

```
?- rex.make("(the|a)?\s?(dog|cat)\sis\s(wet|cold|sick)",[caseless],:r), rex.match(:r,"dog is wet",:
    l)
-> ( 'regexp("(the|a)?\s?(dog|cat)\sis\s(wet|cold|sick)",[CASELESS]) , ["dog is wet", "", "dog", "
    wet"] ) := 1.00 (0.000) 1
```

For the list of supported compilation flags, see Section 3.1.6 on page 10.

rex.match

`rex.match(`*regexp*`,`*string*`,`*list*`|`*variable?*`)`

The *primitive* `rex.match` will match a *string* given as its second *term* with the *regular expression* provided as first *term* and will resolve to a *truth value* of `1.0` if it is a match.

```
?- rex.match('regexp("[a|b]+"),"ABAB")
-> (  ) := 0.00 (0.000) 1
?- rex.match('regexp("^[a|b]+$"),"abab")
-> (  ) := 1.00 (0.000) 1
?- rex.match('regexp("^[a|b]+$"),"ababc")
-> (  ) := 0.00 (0.000) 1
```

If a third *term* is provided, the *primitive* will unify it with all the matchs between the *regexp* and the *string*:

```
?- rex.match('regexp("\d+"),"12 drummers drumming, 11 pipers piping, 10 lords a-leaping",:l)
-> ( ["12", "11", "10"] ) := 1.00 (0.000) 1
```

5.13 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.cmp

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

The `sym.cmp` *primitive* will unify or substitue its third *term* with the result of the comparison of its first two *symbol 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:

```
?- sym.cmp(hello,hello4,:c)
-> ( -1 ) := 1.00 (0.001) 1
?- sym.cmp(hello,hello,:c)
-> ( 0 ) := 1.00 (0.000) 1
?- sym.cmp(hello,Hello,:c)
-> ( 1 ) := 1.00 (0.000) 1
?- sym.cmp(hello,Hello,:c,insensitive)
-> ( 0 ) := 1.00 (0.000) 1
```

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

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
```

5.14 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.head

`str.head`(*string*, *string*)
`str.head`(*string*, *string*, *symbol*)

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

```
?- str.head("hello world!","hello")
-> (  ) := 1.00 (0.000) 1
?- str.head("hello world!","world")
-> (  ) := 0.00 (0.000) 1
?- str.head("hello world!","HELLO")
-> (  ) := 0.00 (0.000) 1
```

An optional third *term* (a *symbol*) can indicate of the case of the strings should not matter (`insensitive`) or should (`sensitive`) in the *comparison*. When no third *term* is specified, the default behavior is to be case sensitive:

```
?- str.head("hello world!","HELLO",insensitive)
-> (  ) := 1.00 (0.000) 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.tail

`str.tail(`*string*`,`*string*`)`
`str.tail(`*string*`,`*string*`,`*symbol*`)`

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

```
?- str.tail("hello world!","world!")
-> (  ) := 1.00 (0.000) 1
?- str.tail("hello world!","world!")
-> (  ) := 0.00 (0.000) 1
?- str.tail("hello world!","WORLD!")
-> (  ) := 0.00 (0.000) 1
```

An optional third *term* (a *symbol*) can indicate of the case of the strings should not matter (`insensitive`) or should (`sensitive`) in the *comparison*. When no third *term* is specified, the default behavior is to be case sensitive:

```
?- str.tail("hello world!","WORLD!",insensitive)
-> (  ) := 1.00 (0.000) 1
```

str.tokenize

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

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
```

When a fourth *term* is provided, it is expected to be a *list* of *symbols* acting as *flags*. The only flag supported at the moment is `include` which instructs the *primitive* to include the delimiters as elements of the tokenized *list*. For example:

```
?- str.tokenize("66;3.14;22",";",:l,[include])
-> ( ["66", ";", "3.14", ";", "22"] ) := 1.00 (0.001) 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*`)`
`str.trim(`*string*, *variable*, *string*`)`

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
```

When a third *term* is given, it will be a *string* which content will be trimmed from the first *term* instead of the empty spaces:

```
?- str.trim("555-1234",:s,"555-")
-> ( "1234" ) := 1.00 (0.000) 1
```

str.trim.head

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

This *primitive* will unify or substitue its second *term* with its first *term* trimmed of any empty spaces at the start of the *string*. When a third *term* is given, it will be a *string* which content will be trimmed from the first *term*. For example:

```
?- str.trim.head(" this is my string  ",:s)
-> ( "this is my string  " ) := 1.00 (0.001) 1
?- str.trim.head("555-1234-555",:s,"555")
-> ( "-1234-555" ) := 1.00 (0.000) 1
```

str.trim.tail

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

This *primitive* will unify or substitue its second *term* with its first *term* trimmed of any empty spaces at the end of the *string*. When a third *term* is given, it will be a *string* which content will be trimmed from the first *term*. For example:

```
?- str.trim.tail(" this is my string  ",:s)
-> ( " this is my string" ) := 1.00 (0.001) 1
?- str.trim.head("555-1234-555",:s,"555")
-> ( "555-1234-" ) := 1.00 (0.000) 1
```

5.15 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.even

`is.even(`*number*`)`

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

```
?- is.even(3)
-> (  ) := 0.00 (0.000) 1
?- is.even(4)
-> (  ) := 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.odd

`is.odd(`*number*`)`

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

```
?- is.odd(3)
-> (  ) := 1.00 (0.000) 1
?- is.odd(4)
-> (  ) := 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.regexp

`is.regexp(`*term*`)`

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

```
?- is.regexp(42)
-> (  ) := 0.00 (0.001) 1
?- is.regexp('regexp("\d+"))
-> (  ) := 1.00 (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.
`memoize`	set to `yes` to instruct the *elemental* to use memoization (that is to temporary cache replies to queries in order to avoid inferring the same thing multiple time).

When such *elemental* is set to memoize, cached *statements* will be periodically cleared at a a frequency set by the `mzttl` *substrate* configuration.

`MRKCCSVStore`

The *elemental* `MRKCCSVStore` provides a way to access *statements* stored inside a `CSV` file without having to import the file. While this a slowest way to retreive *statements*, it has the advantage of having lower memory consumption as none of the data stored in the `CSV` file are loaded in memory until it is returned as answers to a query.

This *elemental* supports the following *properties*:

`filepath`	the path and file name of the `CSV` file to be used as source.
`delimiter`	a *string* representing the character used as the column separator.
`columns`	a list describing the conversion to be applied to each of the columns that will be read from the file. The number of *terms* in the *list* is considered to be the expected number of columns in each lines of the file. If this property is not specified, each columns will be converted to best fit its content.
`offset`	the number of lines from the file to be skipped from the start of the file (e.g. to skip a header). If this property is not specified no offset will be applied.
`length`	the number of lines (from the `offset`) to be considered when scanning the file. If this property is not specified, the file will be scanned to its end.
`no.match`	if set to the *symbol* `fail`, the *elemental* will always produce a statement with a truth value of `0` when there was no match to a query.
`offloaded`	if set to the value `yes`, the scanning of the file will be offloaded to a background thread. This will lower the load on the *substrate* at the cost of a bit more lag in getting answers.

The *terms* in the `columns` *list* can be any of the following:

`number`	the column is a *number*.
`symbol`	the column is a *symbol*.
`string`	the column is a *string*.
`ignore`	the colum is to be ignored.
`select`	the colum format should be selected based on the content of each line.

For example, the following *elemental* provides *statements* based on the `cars` database stored in a CSV file:

```
car {

    class       = MRKCCSVStore,
    filepath    = "./etc/data/cars.csv",
    delimiter   = ";",
    offset      = 2,
    no.match    = fail,
    offloaded   = yes

} {}
```

`MRKCSBFStore`

This *elemental* provides a way to store and retreive *statements* from a *binary* file. While it is a slower way to retreive *statements*, it has the advantage of having lower memory consumption as none of the data stored in the file is loaded in memory until it is returned as answers to a query.

This *elemental* supports the following *properties*:

`filepath`	the path and file name of the `binary` file to be used as source.
`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*.
`no.match`	if set to the *symbol* `fail`, the *elemental* will always produce a statement with a truth value of `0` when there was no match to a query.
`offloaded`	if set to the value `yes`, access to the file will be offloaded to a background thread. This will lower the load on the *substrate* at the cost of a bit more lag in processing.
`verbose`	an optional *boolean* value (or a *symbol* `true, false`) to instructs the *elemental* to output more traces in the console.

For example, the following *elemental* setup a *statement* store in which we will import the data from `./etc/data/cars.csv`:

```
car {

    class       = MRKCSBFStore,
    filepath    = "./cars.sbfz",
    offloaded   = yes,
    index       = [0,9],
    verbose     = yes,
    no.match    = fail

} {}
```

The `/tells` console command can be used to instruct the *elemental* to perform any of the following actions:

`compact`	requests the store to attempt to reduce its file size.
`optimize`	requests the store to be optimized for better performance.
`stats`	prints some statistics about the content of the store.
`validate`	forces a sanity check on the store.
`clear`	empties the store of all stored *statements*.

Note that depending on the number of stored *statements*, many of the above command may take a while to complete.

`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`:

```
rand {
    class = FZZCRandomizer,
    min   = 1550,
    max   = 1670,
    mod   = 2
} {

}
```

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]
} {

}
```

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:

```
tick {
    class = FZZCTicker,
    mod   = 4
} {

}
```

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:

```
tick {
    class = FZZCTicker,
    tick  = 1.5
} {

}
```

`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.
`recall.frq`	how often to check stored statements for possible ones to purge.
`recall.ttl`	initial time-to-live value for any asserted statements.
`recall.add`	how much to add to a statement time-to-live each time it is used in a reply.
`recall.mul`	how much to increase (ttl + mul * ttl) to a statement time-to-live each time it is used in a reply.
`recall.thd`	threshold for committing statement to permanent storaga.

In order for the *recall* ability of the class to work. The *statements* must include a property called `stp` which contains the timestamp of the *statement* (assigned to `%now` for example when the *statement* is created). As long as the timestamp of the *statement* plus its `time-to-live` is after the current time each time the *elemental* checks, the *statement* will be conserved. Otherwise, it will be removed.

7 Modules

This section provides some details on all the optional *modules* that can be loaded in the *runtime* and which *elementals* they provides. Like in the previous section, the list of supported *properties* and accepted values will be given as well as some explanation on their use cases. In order to be able to use the *elementals* detailed in this section, the corresponding module in which it resides must be loaded in *fizz* using either the `/use` *command* or via a *solution* file.

LGR

The `modLGR` module provides an interface to the *Link Grammar Parser*[4] by the Carnegie Mellon University. It is a syntactic parser for (mainly) English sentences. The integration of the parser to *fizz* allows for a *string* to be parsed and its syntactic components bto e made available in a series of *lists*.

`FZZCLGRProcessor`

This *elemental* is the main interface to *Link Grammar Parser*. It supports the following *properties*:

`datapath`	the path to the root folder containing the parser's data. A version of it is included in fizz in `etc/data/lgr`
`language`	the language to be parsed by the *elemental*. At this moment, only English (`us` is supported.
`load.on.attach`	when set to `yes`, the *elemental* will preload the parser data when it is attached to the *substrate*. Otherwise, it will wait the first *query* to do so.

Let's look at an example (for more details, check the sample `etc/samples/linkg.fizz`). In a new *fizz* source file, we add the following:

```
lgr.parse {
    class          = FZZCLGRProcessor,
    datapath       = "./etc/data/lgr",
    language       = "us",
    load.on.attach  = yes
} {}
```

The expected arity for any query to the *elemental* we have now created in the *substrate* is five. The first term is the *string* to be parsed followed by four unbound *variables*:

```
?- #lgr.parse("the quick brown fox jumps over the lazy dog.",:ws,:ls,:ln,:cn)
-> ( [[[], nil], [[], "the"], [[a], "quick"], [[a], "brown"], [[n], "fox"], [[v], "jumps"], [[], "
    over"], [[], "the"], [[a], "lazy"], [[n], "dog"], [[], "."], [[], nil]] , [[X, [p], 0, 10], [WV
    , [], 0, 5], [W, [d], 0, 4], [S, [s, s], 4, 5], [D, [s, x], 1, 4], [A, [], 2, 4], [A, [], 3,
    4], [MV, [p], 5, 6], [J, [s], 6, 9], [D, [s, x], 7, 9], [A, [], 8, 9], [RW, [], 10, 11]] , [0,
    [1, [2, 0, [3, [4, 1, [5, 2, [6, 3, 4]]], [7, 5, [8, 6, [9, 7, [10, 8, 9]]]]]]], 5], [11, 10,
    11]] , [S, [[NP, [1, 2, 3, 4]], [VP, [5, [PP, [6, [NP, [7, 8, 9]]]]]], 10]] ) := 1.00 (0.011) 1
```

The first *variable* will be unified with the list of all the *words* which have been detected in the sentence. The second *variable* will be unified with the list of all *links* (that is the relationships between *words*). The third *variable* will unify with a *tree* describing how the sentence is structured. The fourth, and final, *variable* will be unified to a *tree* which describes the components in the sentence as generated by the *Phrase Parser*[5].

[4] http://www.link.cs.cmu.edu/link/

[5] http://www.link.cs.cmu.edu/link/ph-explanation.html

We will now defines the contents of each of the *list*, starting with the *words list*:

```
?- #lgr.parse("the quick brown fox jumps over the lazy dog.",:ws,_,_,_)
-> ( [[[], nil], [[], "the"], [[a], "quick"], [[a], "brown"], [[n], "fox"], [[v], "jumps"], [[], "
    over"], [[], "the"], [[a], "lazy"], [[n], "dog"], [[], "."], [[], nil]] ) := 1.00 (0.021) 1
```

Each of the *word* is described as a *list* containing first a *list* of symbols which the parser calls *subscripts*, followed by the actual *word*. In most cases, the *word* is represented as a *string*, except when the *word* isn't really a word, but what the parser calls `LEFT-WALL` or `RIGHT-WALL` (that is the start or the end of the sentence). In this example, the *word* `brown` is flagged with `a` indicating that it is an *adjective* where the *word* `jumps` is flagged with a `v` as it is a *verb*.[6]

```
?- #lgr.parse("the quick brown fox jumps over the lazy dog.",_,:ls,_,_)
-> ( [[X, [p], 0, 10], [WV, [], 0, 5], [W, [d], 0, 4], [S, [s, s], 4, 5], [D, [s, x], 1, 4], [A,
    [], 2, 4], [A, [], 3, 4], [MV, [p], 5, 6], [J, [s], 6, 9], [D, [s, x], 7, 9], [A, [], 8, 9], [
    RW, [], 10, 11]] ) := 1.00 (0.011) 1
```

The second *list* contains all the *links* that compose the parsed sentence. Each of which is described by a *list* containing four *terms*. The first one is a *symbol* representing the *link-type*[7], followed by a *list* of the *subscripts*. The third and fourth *terms* in the *list* are the index (in the *words list*) of the *words* that are associated with the *link*.

```
?- #lgr.parse("the quick brown fox jumps over the lazy dog.",_,_,:ln,_)
-> ( [0, [1, [2, 0, [3, [4, 1, [5, 2, [6, 3, 4]]], [7, 5, [8, 6, [9, 7, [10, 8, 9]]]]]], 5], [11,
    10, 11]] ) := 1.00 (0.011) 1
```

The third *list* contains how the *links* are connected into a *tree* describing the structure of the sentence. Each of the *sub-lists* is composed of three *terms*, the first one being the index of the *link* in the links *list*. The second and third *terms* can either be the index of the *word* or another node in the *tree*.

```
?- #lgr.parse("the quick brown fox jumps over the lazy dog.",_,_,_,:cn)
-> ( [S, [[NP, [1, 2, 3, 4]], [VP, [5, [PP, [6, [NP, [7, 8, 9]]]]]], 10]] ) := 1.00 (0.010) 1
```

Thr fourth *list* is a *Penn tree-bank* style phrase structure (a tree). Each *lists* that forms the tree has two *terms*. The first one is a *Penn type* (as a *symbol*) and the second one is a *list*. Each *terms* in that *list* can either be the index of the *word* or a *list* describing a new *Penn type* node of the tree.

WWW

The `modWWW` module provides ways for *fizz* to fetch data from existing `REST` services.

`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:

[6] see section 3.3 in https://www.abisource.com/projects/link-grammar/dict/introduction.html for a list of the subscripts
[7] see https://www.abisource.com/projects/link-grammar/dict/index.html for details

`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:

```
fixer.get {

    class           = FZZCWebAPIGetter,
    url.host        = "http://api.fixer.io",
    url.path        = "/latest",

} {

}
```

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

```
?- #fixer.get({ base = USD },:l)
-> ( [1525392000, 200, {Date = "Sun, 06 May 2018 02:40:35 GMT", Connection = "keep-alive",
Set-Cookie = "__cfduid=d70c6e9991dfeb2ae1ee6e8293a1622341525574434; expires=Mon, 06-May-19
02:40:34 GMT; path=/; domain=.fixer.io; HttpOnly", Cache-Control = "public, must-revalidate,
max-age=900", Last-Modified = "Fri, 04 May 2018 00:00:00 GMT", X-Deprecation-Message = "This
API endpoint is deprecated and will stop working on June 1st, 2018. For more information please
visit: https://github.com/fixerAPI/fixer#readme", Vary = "Origin", X-Content-Type-Options =
"nosniff", Server = "cloudflare", CF-RAY = "41681539a27192f4-SJC"}, {a__deprecation_message__ =
"This API endpoint is deprecated and will stop working on June 1st, 2018. For more information
please visit: https://github.com/fixerAPI/fixer#readme", base = USD, date = "2018-05-04",
rates = {AUD = 1.329700, BGN = 1.634100, BRL = 3.546300, CAD = 1.287500, CHF = 0.998410,
CNY = 6.359200, CZK = 21.308000, DKK = 6.223700, EUR = 0.835490, GBP = 0.737200,
HKD = 7.849600, HRK = 6.186000, HUF = 262.240000, IDR = 13978, ILS = 3.621200,
INR = 66.862000, ISK = 102.100000, JPY = 108.920000, KRW = 1076.400000, MXN = 19.156000,
MYR = 3.938000, NOK = 8.057500, NZD = 1.425900, PHP = 51.673000, PLN = 3.554400, RON = 3.895100,
RUB = 63.065000, SEK = 8.832800, SGD = 1.333600, THB = 31.755000, TRY = 4.257900,
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. In order to be able to use this *elemental*, the module in which it resides (`modWWW`) must be loaded in *fizz* using either the `/use` *command* or a *solution* file.

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:

```
web.conv.puller {

    class           = FZZCWebAPIPuller,
    tick            = 60.0,
    url.host        = "http://api.fixer.io",
    url.path        = "/latest",
    url.query       = { base = USD }

} {

}
```

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:

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

CLU

The `modCLU` module supports the building of a *cluster* from instances of *fizz* running on several computers (on the same network). This use a custom protocol build on top of UDP (multicast and unicast). While transmission between multiple hosts isn't garanteed to be delivered, the protocol does account for packet losses and will attempt to resend packets when needed.

`FZZCCLUGateway`

`FZZCCLUGateway` is the *elemental* which provides a link between the local instance of *fizz* and the cluster. For a cluster to work, most of the *properties* specific to this class must be identical on each instances. They are:

`MCAddress`	Multicast group address (as a string)
`TXUDPPort`	Multicast group UDP port (for message)
`CLUDPPort`	Multicast group UDP port (for control)
`CLCadence`	Multicast group heartbeat frequency (in ms)
`MCTimeout`	missing peer timeout (in ms)
`XXTimeout`	RX/TX timeout (in ms per packet)
`TXTimeout`	how long to keep a transmission around (in ms) for possible resends
`SyCadence`	sync timestamp frequency (in ms, 0 for off)
`TXCadence`	transmission frequency (in ms)
`Bandwidth`	bandwidth restriction (in byte per ms)
`TXSpacing`	interval of time between two consecutive transmissions (0 for none, the value is assumed to be for a TX at capacity)
`PkBLength`	usable UDP packet length (in bytes)
`PkRetries`	missing packets retry count (0 for no limit)
`PkWinSize`	size of the sliding window used to determinate if packets are considering missing (0 for default)
`RXCadence`	maximum elapsed time to spend processing received packets in one batch (in ms, 0 for no limit)
`filters`	a list of the *statements* and *predicates* labels to be accepted for incoming and outgoing transmissions

Default values will be used for most of the *properties* except: `MCAddress`, `TXUDPPort` and `CLUDPPort`. It is highly recommended to also provide a value for `Bandwidth`. It indicates how much of the bandwidth can be used to send data, taking in consideration the medium (e.g. WiFi vs GigE) and the number of computers that compose the cluster. For example, for 3 instances connected via a 100Mbps Ethernet, we would take the theoretical bandwidth value of `12500` bytes per milliseconds and divide it by 3. To that we can also take away a certain percentage (said 5) of it to account for other traffic, resulting in a value of `3958` bytes. When it comes to minimizing lost packets, the receive and send buffers of the computers may need to be adjusted.

As an alternative to tweaking the *Bandwidth* value yourself, you can use the following three properties to specify the cluster's setup:

`Bandwidth.value`	bandwidth available for the cluster (in byte per ms)
`Bandwidth.peers`	number of peers in the cluster
`Bandwidth.limit`	percentage of the bandwidth to reserve for the cluster usage

MLK

The `modMLK` module provides *elementals* dealing with *Machine Learning* tasks.

`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*:

```
iris {  class = FZZCFFBNetwork,
        alias = iris.ffbn,
        query = iris(_,_,_,_,_),
        generalize = [[i,i,i,i,o],[o,i,i,i,i]],
        formatting = [d,d,d,d,l],
        hidden_layers = 1,
        neurons_in_hidden_layers = 4,
} {

}
```

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`.

EV3

The `modEV3` module provides access to the *LEGO Mindstorms EV3*[8] sensors and motors when running *fizz* on the *EV3 Intelligent brick* (it-self running the `Linux` distribution `ev3dev`[9]).

All of the *elementals* provided by the module follows the same patterns when it comes to interacting with them. That is using specific queries to read (peek) values, write (poke) values and execute specific *functions* (call) or cancel running *functions* (halt).

More information on each sensor and motor can be found within the `ev3dev` documentation[10].

`EV3CSYSLEGOSystem`

Along with providing a way to read the device's battery status, the *elemental* watches over plugging and unplugging of sensors or motors. It also provides some core functionalities for the other *elementals* in the modules, and as such its presence in the *substrate* is mandatory.

The *elemental* has the following single *property*:

`bat.technology`	because the `EV3` cannot tell what type of the battery powering it, this property provides that information so that the estimation of the battery status can be more accurate. Accepted values are: `liion` and `nimh`.

Several values can be read from the *elemental* using a `peek` *predicate*:

`bat.current`	battery current in *microamps*.
`bat.voltage.min`	nominal battery voltage when *empty* (the value depends on the technology).
`bat.voltage.max`	nominal battery voltage when *full* (the value depends on the technology).
`bat.voltage`	battery voltage in *microvolts*.
`bat.voltage.p`	naive estimation of the battery percentage based on the voltage.

[8] https://www.lego.com/en-us/mindstorms/products/mindstorms-ev3-31313
[9] https://www.ev3dev.org/
[10] http://docs.ev3dev.org/projects/lego-linux-drivers/en/ev3dev-stretch/index.html

For example, if the *elemental* is labeled `ev3.sys`, we would query any of the above values as follow:

```
?- #ev3.sys(peek,bat.current(:c))
-> ( 188000 ) := 1.00 (0.069) 1
```

Multiple values can be peeked at in the same query by using a *list* of *functor* as the second argument. For example:

```
?- #ev3.sys(peek,[bat.voltage(:v),bat.voltage.p(:p)])
-> ( 7421066 , 0.595722 ) := 1.00 (0.098) 1
```

When sensors or motors are plugged or unplugged from the device ports, the *elemental* will publish *statements* that provide information on such events. For instance:

```
ev3.sys(enum, removed, sensor, 2)
ev3.sys(enum, plugged, sensor, 3)
```

The first one indicate that the sensor identified by the id `2` was removed, and the second one indicates that a sensor was plugged with the id `3`. If the event relate to a motor, the third *term* of the *statement* will be the symbol `motor`.

`EV3CSYSLEGOLed`

The `EV3CSYSLEGOLed` provides a way to control one of the LED available on the *EV3 Intelligent brick*. Each of two LEDs is actually composed of two LEDS, one red and one green. When they are both set to the same value, the LED will be orange.

The *elemental* has the following single *property*:

`index`	indicate which of the LED the *elemental* should access. The value can be `0` for the left LED or `1` for the right one.

The color of the LED can be changed (or queried) using a `peek` or `poke` *predicate*:

`r`	the brightness of the red LED (from 0 to 1).
`g`	the brightness of the green LED (from 0 to 1).

For example, if the *elemental* is labeled `ev3.sys.led.1`, we would change the color of the LED to a not so bright orange as follow:

```
?- #ev3.sys.led.1(poke,[r(0.2),g(0.2)])
-> (  ) := 1.00 (0.028) 1
```

The brightness of the LED can be read as follow:

```
?- #ev3.sys.led.1(peek,r(:b))
-> ( 0.200000 ) := 1.00 (0.046) 1
```

EV3CACTLEGOMotor

This *elemental* controls a single LEGO *tacho motor*. The following *properties* can be set at load time but also modified at runtime:

`dutycycle`	the *duty cycle* setpoint of the motor. Accepted range is `-100` to `100`.
`polarity`	polarity of the motor; either the *symbol* `normal` or `inversed`.
`port`	the port on which the motor is connected. Accepted *symbols* are: `portA`, `portB`, `portC` and `portD`.
`rampdw`	ramp down setpoint (in ms).
`rampup`	ramp up setpoint (in ms).
`speed`	target speed in tacho counts per second.
`stopaction`	stop action to be applied at the end of a run (or when the stop command is used). Accepted values are: `coast`, `brake` and `hold`.

Other *properties* can only be set or get at runtime:

`maxspeed`	the maximum speed value for the motor (peek only) in tacho count per second.
`position`	the current position (on peek) or the target position (on poke) in tacho count.
`count`	the number of tacho count in one rotation of the motor.
`state`	the current state of the motor (peek only), as a *list* of any of the following *symbols*: `running`, `ramping`, `holding`, `overloaded`, `stalled`.
`running`	is the motor currently running (peek only) as a boolean value.
`holding`	is the motor currently holding (peek only) as a boolean value.

For example, if the *elemental* is labeled `ev3.act.motor.t`, we would read the position as follow:

```
?- #ev3.act.motor.t(peek,position(:p))
-> ( -44 ) := 1.00 (0.052) 1
```

When it comes to executing *functions*, the *elementals* implements the following:

`by`	runs the motor until its position is offset by a given value.
`for`	runs the motor for a given amount of time (in ms).
`go`	runs the motor until it is stopped.
`reset`	stops the motor and reset the position to 0.
`stop`	stops the motor.
`to`	runs the motor until its position reachs the given value.

When requesting the *elemental* to execute a specify function, the query will be answered right away, even if the *function* has yet to be completed. For example:

```
?- #ev3.act.motor.t(call,by(-45))
-> (  ) := 1.00 (0.037) 1
```

Unlike some of the other *elementals* in the module, the motor one doesn't provide a way to monitor the progress of a *function*. The way to do so, will be to frequently peek at the `position` and/or `state` of the motor.

EV3CSENLEGOColor

This *elemental* provides access to a LEGO *color sensor*, which can be use to sense the reflected or ambient light. The following *properties* can be set at load time but also modified at runtime:

`port`	the port on which the sensor is connected. Accepted *symbols* are: `port1`, `port2`, `port3` and `port4`.
`mode`	the mode of operation of the sensor: `reflected`, `ambient`, `index` or `value`

Depending on the `mode` in which the sensor is set, the reading (via the `value` *property*) from the sensor will be different. The following table details the various supported modes:

`ambient`	ambient light intensity (0 to 1).
`reflected`	reflected light intensity (0 to 1).
`index`	the detected color (any of the *symbols*: `black`, `blue`, `green`, `yellow`, `red`, `white`, `brown`.
`value`	raw color expressed in a `list` of three numbers (red, green, blue).

For example, if the *elemental* is labeled `ev3.sen.color`, we would read the sensor (set in reflected mode) as follow:

```
?- #ev3.sen.color(peek,value(:c))
-> ( 0.010000 ) := 1.00 (0.112) 1
```

`EV3CSENLEGOGyros`

This *elemental* provides access to the LEGO *gyroscope sensor*, which can be use to sense the direction in which a particular robot is facing. The following *properties* can be set at load time but also modified at runtime:

`port`	the port on which the sensor is connected. Accepted *symbols* are: `port1`, `port2`, `port3` and `port4`.
`mode`	the mode of operation of the sensor (as a *symbol*).

The supported modes are:

`angle1axis`	the sensor provides the rotation angle along the first axis (in degrees).
`rrate1axis`	the sensor provides the rotational speed along the first axis (in degrees per second).
`angle2axis`	the sensor provides the rotation angle along the second axis (in degrees).
`rrate2axis`	the sensor provides the rotational speed along the first axis (in degrees per second).

Just like the other sensor based *elementals*, the sensor can be read with a `peek` query. For example, if the *elemental* is labeled `ev3.sen.gyros`, we can get the current value as follow:

```
?- #ev3.sen.gyros(peek,value(:h))
-> ( -46 ) := 1.00 (0.092) 1
```

`EV3CSENLEGOPower`

The *elemental* `EV3CSENLEGOPower` provides access to the LEGO *Energy Display* (part of a science kit). The following *properties* can be set at load time but also modified at runtime:

`port`	the port on which the sensor is connected. Accepted *symbols* are: `port1`, `port2`, `port3` and `port4`.

At runtime, the reading from the sensor can be retreive using a `peek` query. The `value` is a *list* which contains three *terms*. The first two are *lists* holding the readings (voltage in mili-volts, current in mili-amps and power in mili-watt) respectivelu for the *input* and *output* ports. The last *term* in the list is the energy stored by the device (in Joules).

For example, assuming an *elemental* labeled `ev3.sen.power`:

```
?- #ev3.sen.power(peek,value(:r))
-> ( [[7.969000, 188, 1485], [9.840000, 0, 0], 48] ) := 1.00 (0.093) 1
```

EV3CSENLEGOSonic

This *elemental* provides access to the LEGO *Ultrasonic Sensor*, which gives an estimation of the distance between the sensor and a possible object. The following *properties* can be set at load time but also modified at runtime:

`port`	the port on which the sensor is connected. Accepted *symbols* are: `port1`, `port2`, `port3` and `port4`.
`mode`	the mode of operation of the sensor (as a `symbole`.)

The supported modes are:

`continuous`	continuous measurement.
`occasional`	Single measurement.
`listening`	Listen (for another Ultrasonic sensor)

Independently the `mode` in which the sensor is set (except `listening`), the reading (via the `value` *property*) from the sensor will always be expressed in meters, within the range `0.0` to `2.55`. Note that `2.54` is the maximum range of the sensor. When the sensor is in `listening` mode, the `value` will be either `0` or `1`. The later meaning another device was heard.

Assuming an *elemental* labeled `ev3.sen.sonic`, we would fetch the latest `value` from it as follow:

```
?- #ev3.sen.sonic(peek,value(:r))
-> ( 1.227000 ) := 1.00 (0.079) 1
```

EV3CSENLEGOTouch

This *elemental* provides support for the LEGO *Touch Sensor* which can be used to detect contact will objects or act as a button that can be pressed by somebody. The following *properties* can be set at load time but also modified at runtime:

`port`	the port on which the sensor is connected. Accepted *symbols* are: `port1`, `port2`, `port3` and `port4`.

At runtime, the state of the button can be checked by using a *peek* query on `pressed` as follow:

```
?- #ev3.sen.touch(peek,pressed(:r))
-> ( 0 ) := 1.00 (0.172) 1
?- #ev3.sen.touch(peek,pressed(:r))
-> ( 1 ) := 1.00 (0.098) 1
```

When the button is currently not pressed, the value will be `0`. And it will be `1` when pressed. Whenever the button is pressed or depressed, the *elemental* will publish a *statement* indicating the occurence of such event. The *statement* will be formatted as follow:

```
ev3.sen.touch(hint, pressed(1))
ev3.sen.touch(hint, pressed(0))
```

EV3CBEVDrive

This *elemental* provides a more advanced functionality that combines multiple motors and sensors to perform *Tank steering* driving. The following *properties* can be set at load time but also modified at runtime:

`hints`	control loop frequency (in ms)
`ticks`	how often to publish a hint when driving (modulo on the hints)
`gyros`	label of the gyros sensor *elemental*
`motor.l`	label of the left motor *elemental*
`motor.r`	label of the right motor *elemental*
`odometry`	a *frame* that describes the odometry characteristics to be used. That is: `wheel.c` for the circumference of the wheel (in m), `motor.d` for the measured distance in between the center of the motors (in m)
`move`	a *frame* that describes the setting to be used when the robot is actually driving. That is: `speed` for the speed to be applied to both motors when at full power level. `pid.Kp` for the PID's proportional constant, `pid.Kd` for PID's derivative constant and `pid.Ki` for the PID's integral constant.
`turn`	a *frame* that describes the setting to be used when the robot is turning in place. That is: `speed` for the speed to be applied to both motors when at full power level. `pid.Kp` for the PID's proportional constant, `pid.Kd` for PID's derivative constant and `pid.Ki` for the PID's integral constant.

A few other *properties* can only be set or get at runtime:

`heading`	The target heading (in degree) that should be reached.
`pwlevel`	The power level (as a *number* betweeb `0` to `1`) to be applied.
`position`	A *list* of two *numbers* giving the position of the robot as estimated by the odometry (X,Y). If poked, the odometry will be reset to the given value.

To get the robot to drive or turn, the *elemental* implements the following *functions*:

`move`	when this *function* executes, the *elemental* will attempt to drive in the direction given by the `heading`. Note that it will not re-orient itself in-place before driving forward. Use the `turn.to` *function* first if that is needed.
`turn.by`	when this *function* executes, the *elemental* will orient the robot to face the current `heading` offsets by a value given as argument to the function.
`turn.to`	when this *function* executes, the *elemental* will orient the robot to face a specific heading, given as argument to the function.

While any of the above *functions* are in progress, the *elemental* will publish *hint statements*. For example, with the `move` *function*, the second *term* of the *statement* will be a *functor* with an arity of three:

```
?- #ev3.bev.drive(poke,pwlevel(0.5)), #ev3.bev.drive(call,move)
spy : Q #ev3.bev.drive(poke, pwlevel(0.500000)) (14.994122)
spy : R ev3.bev.drive(poke, pwlevel(0.500000)) (14.975505)
spy : Q #ev3.bev.drive(call, move) (14.924033)
spy : R ev3.bev.drive(call, move) (14.915030)
-> (  ) := 1.00 (0.149) 1
spy : S ev3.bev.drive(hint, move(-7, [0.017187, -0.002415], 7)) (15.000000)
spy : S ev3.bev.drive(hint, move(-6, [0.049698, -0.006407], 6)) (15.000000)
spy : S ev3.bev.drive(hint, move(-5, [0.084466, -0.010019], 5)) (15.000000)
spy : S ev3.bev.drive(hint, move(-2, [0.136583, -0.014501], 2)) (15.000000)
spy : S ev3.bev.drive(hint, move(-1, [0.151241, -0.014996], 1)) (15.000000)
spy : S ev3.bev.drive(hint, move(1, [0.211121, -0.016041], -1)) (15.000000)
spy : S ev3.bev.drive(hint, move(1, [0.214054, -0.015990], -1)) (15.000000)
spy : S ev3.bev.drive(hint, move(3, [0.263421, -0.015043], -3)) (15.000000)
spy : S ev3.bev.drive(hint, move(4, [0.300769, -0.013077], -4)) (15.000000)
```

The first *term* is the current heading (read from the *gyroscope*), the second *term* is the current position (as estimated by the odometry) and the last term is the error in heading (in degrees).

Once started, the *functions* will keep on running until they are implicitely terminated by commanding the *elemental* with the single *term* `halt`. For example:

```
?- #ev3.bev.drive(halt)
-> (  ) := 1.00 (2.255) 1
```

`EV3CBEVSonar`

This *elemental* provides combines a single motor, a gyroscope and an Ultrasonic sensor as well as the `EV3CBEVDrive` *elemental* to implement a *sonar* like functionality. The motor is expected to allow for the Ultrasonic sensor to be rotated around the Y (Up) axis. The *elemental* implements two *functions*: `scan`, which supports reading the distance to possible obstacles along a set list of heading offsets from the current orientation of the robot; and `skim` which supports collecting the distance to possible obstacles between two heading offsets in a more continuous way.

The following *properties* can be set at load time but also modified at runtime:

`gyros`	label of the gyros sensor (optional)
`sonic`	label of the ultrasonic sensor
`motor`	label of the motor (that can turn the ultrasonic sensor)
`drive`	label of the drive behavior (optional)
`scan.mtime`	how often to check if the motor has reached the target position (in ms).
`scan.itime`	how long after a step before reading the sonic sensor (in ms).
`scan.speed`	speed of the motor to be applied in scan mode.
`skim.mtime`	how often to read from the sensor while the motor is turning in skim mode (in ms).
`skim.speed`	speed of the motor to be applied in skim mode.

After each runs of a *function*, the *elemental* will publish a *hint statement* containing the readings that were collected (as well as a timestamp value). Each reading is given as a *list* of three *terms*. For example:

```
?- #ev3.bev.sonar(call,scan([-90,-45,0,45,90]))
spy : Q #ev3.bev.sonar(call, scan([-90, -45, 0, 45, 90])) (14.994852)
spy : R ev3.bev.sonar(call, scan([-90, -45, 0, 45, 90])) (14.978301)
-> (  ) := 1.00 (0.117) 1
spy : S ev3.bev.sonar(hint, scan(1558410099.485098, [[-147, 0.757000, [0, 0]], [-102, 1.904000, [0,
     0]], [-59, 2.550000, [0, 0]], [-15, 2.550000, [0, 0]], [30, 1.002000, [0, 0]]])) (15.000000)
```

The first *term* in the *list* is the heading at which the distance was sample. The second *term* is the distance (in meters) and the third is the position of the robot at the time of the sensing.

If the minimum or maximum readings are what is most needed. The *elemental* also support four *functions* that are variation on the two main ones: `scan.min`, `scan.max` and `skim.min`, `skim.max`. Their *hint statements* will still contains the *list* of all readings, but they will also provides the minimum or maximum value (as the last *term* in the *functor*). For example:

```
?- #ev3.bev.sonar(call,scan.max([-90,-45,0,45,90]))
spy : Q #ev3.bev.sonar(call, scan.max([-90, -45, 0, 45, 90])) (14.991117)
spy : R ev3.bev.sonar(call, scan.max([-90, -45, 0, 45, 90])) (14.951246)
-> (  ) := 1.00 (0.166) 1
```

```
spy : S ev3.bev.sonar(hint, scan.max(1558410277.380321, [[-147, 2.550000, [0, 0]], [-102, 1.906000,
     [0, 0]], [-59, 2.550000, [0, 0]], [-14, 2.550000, [0, 0]], [30, 1.006000, [0, 0]]], [-147,
    2.550000, [0, 0]])) (15.000000)
```

Unlike with the *drive elemental*, these *functions* will not continuously run. If cyclic execution of any of the *functions* is needed, it can be requested from the *elemental* by providing a time interval as the last *term* in the `call` query. For example:

```
?- #ev3.bev.sonar(call,scan.max([-90,-45,0,45,90],1500))
spy : Q #ev3.bev.sonar(call, scan.max([-90, -45, 0, 45, 90], 1500)) (14.991325)
spy : R ev3.bev.sonar(call, scan.max([-90, -45, 0, 45, 90], 1500)) (14.977512)
-> (  ) := 1.00 (0.146) 1
spy : S ev3.bev.sonar(hint, scan.max(1558410741.919013, [[-146, 1.301000, [0, 0]], [-102, 1.906000,
     [0, 0]], [-59, 2.550000, [0, 0]], [-14, 2.550000, [0, 0]], [30, 1.007000, [0, 0]]], [-59,
    2.550000, [0, 0]])) (15.000000)
spy : S ev3.bev.sonar(hint, scan.max(1558410746.059581, [[-147, 1.305000, [0, 0]], [-102, 1.913000,
     [0, 0]], [-59, 2.550000, [0, 0]], [-14, 2.550000, [0, 0]], [30, 1.006000, [0, 0]]], [-59,
    2.550000, [0, 0]])) (15.000000)
spy : S ev3.bev.sonar(hint, scan.max(1558410749.724064, [[-147, 1.305000, [0, 0]], [-102, 1.904000,
     [0, 0]], [-59, 2.550000, [0, 0]], [-14, 2.550000, [0, 0]], [30, 1.006000, [0, 0]]], [-59,
    2.550000, [0, 0]])) (15.000000)
spy : S ev3.bev.sonar(hint, scan.max(1558410753.130281, [[-147, 1.302000, [0, 0]], [-103, 1.913000,
     [0, 0]], [-58, 2.550000, [0, 0]], [-13, 2.550000, [0, 0]], [30, 1.007000, [0, 0]]], [-58,
    2.550000, [0, 0]])) (15.000000)
```

8 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:

```
assert.stamp {

    (:f, :v) :- assert(:f, :v, {stamp = %now});

}
```

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 will be the *substrate's* (or the *elemental's*) Time-to-live value (`ttl`).

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 50) 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

0.6.0-X

Breaking Changes

- `MRKCSBFStore` *elemental class* is impacted by a bug in storing `GUID` *term*.
- Many of the non-core *elementals* have been moved to individual modules (see 7 on page 83).

Changes

- primitives:
  - `str.tokenize` support optional fourth *term* which is a *list* of flags.
  - `peek` accepts a third *term* which is a value to be unified to the 2nd *term* if the label doesn't exists in the properties.
- config:
  - `spinning` meaning changed (see 4.2 on page 17)
- elementals:
  - new `ttl` property to set the time-to-live of any query sent by the *elemental* (instead of using the system default)
  - `MRKCEvaluator`: when no "tmo" is specified, the *substrate* or *elemental* TTL value is used
- predicates:
  - `~` can be used with any label other than `self` (see section 2.3 on page 4).

Additions

- samples:
  - bigrams
  - clu
  - ecalculus
  - robin
- modules:
  - CLU (see section 7 on page 87)
  - EV3 (see section 7 on page 89)
- elementals:
  - constants `$self` and `$guid`
- primitives:
  - `rnd.sint` (see section 5.10 on page 64)
- predicates:
  - `*` prefix for *predicate* (see section 2.3 on page 4)

Bug Fixes

- `guid` *term* wasn't flattened and thus wouldn't get saved in *SBFStore*.
- trigger based *prototypes* where not respecting the 'cut' directives.
- Unfrequent crashes when pasting into the console (outside of the input mode)

0.5.0-X

Breaking Changes

- Pre 0.5 *kindled runtime* (`.bizz`) files can't be loaded
- `MRKCSBFStore` *elemental class* is impacted by hashing changes to *numbers*

Changes

- support for modules (shared library) that can be loaded at runtime (SDK to come in a future release)
- console:
  - previous query is no longer cancelled when a new one is issued
  - query specified via the *command line* gets executed once all the files specified in the *command line* have been loaded
- new *elemental* properties:
  - `chatty` (see section 2.5 on page 7)
  - `noisy` (see section 2.5 on page 7)
  - `clone` (see section 2.5 on page 7)
- any *elemental* property can be read using the *constant* syntax
- new property for *elemental* of class `MRKCBSSolver`:
  - `memoize` (see. fibonacci sample)
- new property for *elemental* of class `MRKCLettered`:
  - `recall.frq`, `recall.ttl`, `recall.add`, `recall.mul`, `recall.thd` (see section 6 on page 82)
- *primitives* `gt`, `gte`, `lt` and `lte` now also works with *strings* and *symbols*

Additions

- *solution* files (see section 4.3 on page 20)
- new console *command*: `/use` (see section 4.4 on page 32)
- new *syntax*:
  - `~` prefix for *predicate* (see section 2.3 on page 4)
  - `self` *predicate* (see section 2.3 on page 4)
- new *terms*:
  - *regexp* (see section 3.1.6 on page 10)
- new *primitives*:
  - `frm.erase` (see section 5.4 on page 46)
  - `lst.mix` (see section 5.6 on page 54)
  - `lst.sort` (see section 5.6 on page 55)
  - `lst.sub` (see section 5.6 on page 56)
  - `rex.make` (see section 5.12 on page 67)
  - `rex.match` (see section 5.12 on page 67)
  - `rng.rand` (see section 5.11 on page 66)
- new *constraints*:
  - `eq`
  - `is.regexp`
  - `is.bound`
- new *volatiles*: `sym.3`, `sym.4` and `sym.10` (see section 3.8 on page 15)

Bug Fixes

- `lst.item`, `lst.head`, `lst.tail` would not unify theirs last *term* with a *list*.
- `MRKCTicker` wouldn't accept a property as a *constant*.
- `peek(guid,:x)` was unifying `:x` with a *string* instead of a *guid*.
- `frm.fetch(a = [1,2],a,[_,:v])` wasn't returning `2`.
- re-saving an *elemental* into a *fizz* file was failing.
- *terms* in a *range* couldn't be a *constant*.
- the hashcode of real *number* was the same regardless of the sign.
- `lst.tail` was not unifying its second *term* with `[]` when the first *term* was an empty *list*.

0.4.0-X

Additions

- new *elementals*:
  - `MRKCSBFStore` (see section 6 on page 78)
  - `MRKCCSVStore` (see section 6 on page 77)
  - `FZZCLGRProcessor` (see section 7 on page 83)
- new *terms*:
  - *guid* (see section 3.1.5 on page 10)
- new *primitives*:
  - `str.trim.head` (see section 5.14 on page 73)
  - `str.trim.tail` (see section 5.14 on page 73)
  - `str.tail` (see section 5.14 on page 71)
  - `str.head` (see section 5.14 on page 69)
  - `lst.incl` (see section 5.6 on page 52)
  - `lst.excl` (see section 5.6 on page 51)
  - `lst.join` (see section 5.6 on page 53)
  - `lst.init` (see section 5.6 on page 52)
  - `sym.cmp` (see section 5.13 on page 68)
  - `sim` (see section 5.1 on page 35)
  - `is.even` (see section 5.15 on page 74)
  - `is.odd` (see section 5.15 on page 76)
  - `gid.make` (see section 5.9 on page 62)
- new *constraints*:
  - `lst.incl`
  - `lst.excl`
  - `is.guid`
  - `is.even`
  - `is.odd`

Changes

- modified *primitives*:
  - `lst.remove` was changed to succeed when the item to remove isn't found in the *list*.
  - `str.trim` was changed to accept an optional third *term*: the *string* to be trimmed from the 1st *term*.
  - `lst.length` was changed to accept a third *term* which is the *term* to be assigned to each of the *list's terms* when the first *term* of the primitive is an *unbound variable*.
  - `fzz.lst` was changed to returns a *list* of *guid terms* instead of a *list* of *strings*.
  - `guid.str` and `guid.sym` were renamed `gid.str` and `gid.sym`.
- modified *console commands*:
  - `/peek` now accepts a *guid*.
  - `/poke` now accepts a *guid*.
  - `/tells` now accepts a *guid* as well as a *symbol*.
  - `/knows` now accepts a *guid*.
- modified *terms*:
  - *binary* syntax has changed to single quote *functor*.
  - *symbol* can now include `+` or `*` as long as they are not on the first character.

Bug Fixes

- *constraint* `is.string` was testing for a variable to be bound to a *symbol*
- *primitive* `str.swap` in some condition was repeating part of the tail of the *string* where the replacement was occuring
- *primitive* `add` was returning 0 when used with an unsigned number as the first term and a negative number as the second term (e.g. `add(23u,-18,:v)`)
- *string terms* with control characters were not rendered properly when they are embedded in other terms

0.3.0-X

Additions

- *live code reload* functionality
- new *constant* `$cores`
- new *primitives*:
  - `aeq` (see section 5.3 on page 44)
  - `bundle` (see section 5.2 on page 37)
  - `div.int` (see section 5.1 on page 34)
  - `fzz.lst` (see section 5.9 on page 61)
  - `lst.remove` (see section 5.6 on page 54)
  - `mao.sign` (see section 5.8 on page 61)
  - `str.find` (see section 5.14 on page 69)
  - `str.flip` (see section 5.14 on page 69)
  - `str.trim` (see section 5.14 on page 73)
  - `str.rest` (see section 5.14 on page 70)
  - `str.swap` (see section 5.14 on page 70)
  - `sym.cat` (see section 5.13 on page 67)
- new *console commands*:
  - `/reload` (see section 4.4 on page 30)
  - `/import.txt` (see section 4.4 on page 27)
- new *class* `FZZCWebAPIGetter` (see section 7 on page 84)

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 4.4 on page 26 and 4.4 on page 23)
- added *primitive* `change` (see section 5.2 on page 38)
- added *primitive* `console.exec` (see section 5.2 on page 38)
- added *primitive* `then` (see section 5.2 on page 43)
- added *primitive* `tme.str` (see section 5.2 on page 43)
- added *primitive* `str.cmp` (see section 5.14 on page 68)
- added *elemental* class `FZZCWebAPIPuller` for fetching JSON data from web services (see section 7 on page 85)

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 81)

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

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