

Guix Workflow Language Reference Manual

Reproducible Scientific Workflows based on Guix

The developers of the GNU Guix Workflow Language

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1 Introduction

This package provides the *Guix Workflow Language* (GWL), a scientific computing extension to the Guix package manager. It combines the specification of work units and their relationship to one another with the reproducible software deployment facilities of the functional package manager GNU Guix. A GWL workflow will always run in a reproducible environment that GNU Guix automatically prepares. The GWL extends your Guix installation with a single new sub-command: `guix workflow`.

In the GWL there are two concepts we need to know about: processes and workflows. We describe a computation (running a program, or evaluating a Scheme expression) using a process. A workflow describes how individual processes relate to each other (e.g. “process B must run after process A, and process C must run before process A”).

GWL workflows are executable code. The workflow language is embedded in the powerful general purpose language Guile Scheme (<https://gnu.org/software/guile/>), so you can compute arbitrarily complex process and workflow definitions. The GWL supports a classic Lisp syntax as well as a Python-like syntax called Wisp (<https://www.draketo.de/light/english/wisp-lisp-indentation-preprocessor>).

2 Installation

There really is no point in using the GWL without Guix. If you already have a Guix installation, you can install the GWL with `guix install gwl`.

The Guix Workflow Language uses the GNU build system. To install it from a release tarball just unpack it and run the usual commands:

```
./configure
make
make install
```

If you want to build the sources from the source repository you need to bootstrap the build system first. Run `autoreconf -vif` first and then perform the above steps.

Note that in order for Guix to learn about the “workflow” sub-command provided by the GWL, the Guile module (`guix scripts workflow`) must be found in a directory on the `GUIX_EXTENSIONS_PATH`.

3 A Simple Workflow

To get a little taste of what the workflow language looks like, let's start by writing a simple workflow.

Here is a simple workflow example:

```

process greet
  packages "hello"
  # { hello }

process sleep
  packages "coreutils"
  # {
    echo "Sleeping..."
    sleep 10
  }

process eat (with something)
  name
    string-append "eat-" something
  # {
    echo "Eating {{something}}"
  }

process bye
  # { echo "Farewell, world!" }

workflow simple-wisp
  processes
    define eat-fruit
      eat "fruit"
    define eat-veges
      eat "vegetables"
  graph
    eat-fruit -> greet
    eat-veges -> greet
    sleep      -> eat-fruit eat-veges
    bye        -> sleep

```

This white-space sensitive syntax is called Wisp and if you're familiar with Python or YAML you should feel right at home. To use this syntax simply save your workflow to a file ending on `.w`, `.wisp`, or `.gwl`.

The workflow language really is a *domain specific language* (DSL) embedded in Guile Scheme, so if you're a Lisper you may prefer to write your workflows directly in Scheme while basking in its parenthetical glow:

```

(define-public greet
  (make-process
    (name "greet")

```

```

    (packages (list "hello"))
    (procedure '(system "hello"))))

(define-public sleep
  (make-process
    (name "sleep")
    (packages (list "coreutils"))
    (procedure
      '(begin
        (display "Sleeping...\n")
        (system "sleep 10")))))

(define-public (eat something)
  (make-process
    (name (string-append "eat-" something))
    (procedure
      '(format #t "Eating ~a\n" ,something))))

(define-public bye
  (make-process
    (name "bye")
    (procedure
      '(display "Farewell, world!\n"))))

(make-workflow
  (name "simple")
  (processes
    (let ((eat-fruit (eat "fruit"))
          (eat-veges (eat "vegetables")))
      (graph (eat-fruit -> greet)
              (eat-veges -> greet)
              (sleep    -> eat-fruit eat-veges)
              (bye      -> sleep))))))

```

Everything you can express in Scheme can also be expressed with the Wisp syntax, so the choice is down to personal preference.

4 Defining a Process

In the GWL a “process” is a combination of some kind of command or script to be executed, the software packages that need to be available when executing the commands, and declarations of inputs and generated outputs. A process has a name, and optionally a synopsis and a description, for display purposes.

We create a process with the `make-process` constructor like this:

```
make-process
  name "hello"
  procedure
    ' display "hello"
```

This creates a process with the name “hello”, which will print the string “hello” once the process is executed. The `procedure` field holds the Scheme code that does all the work of saying “hello”. We will talk about the `procedure` field a little later and show how to write code snippets in languages other than Scheme.

Often we will want to refer to previously created processes later, for example to combine them in a workflow definition. To do that we need to bind the created processes to variable names. Here we bind the above process to a variable named `hello`:

```
define hello
  make-process
    name "hello"
    procedure
      ' display "hello"
```

This is a very common thing to do, so the GWL offers a shorter syntax for not only creating a process but also binding it to a variable. The following example is equivalent to the above definition:

```
process hello
  procedure
    ' display "hello"
```

4.1 process Fields

Both `make-process` and `process` accept the same fields, which we describe below.

- name** The readable name of the process as a string. This is used for display purposes and to select processes by name. When the `process` constructor is used, the `name` field need not be provided explicitly.
- version** This field holds an arbitrary version string. This can be used to disambiguate between different implementations of a process when searching by name.
- synopsis** A short summary of what this process intends to accomplish.
- description** A longer description about the purpose of this process.
- packages** This field is used to specify what software packages need to be available when executing the process. Packages can either be Guix package specifications —

such as the string "guile@3.0" for Guile version 3.0 — or package variable names.

By default, package specifications are looked up in the context of the current Guix, i.e. the same version of Guix that you used to invoke `guix workflow`. This is to ensure that you get exactly those packages that you would expect given the Guix channels you have configured.

We strongly advise against using package variables from Guix modules. The workflow language uses Guix as a library and is compiled and tested with the version of Guix that is currently available as the `guix` package in (`gnu packages package-management`). The version of this Guix will likely be older than the version of Guix you use to invoke `guix workflow`.

Package variables are useful for one-off ad-hoc packages that are not contained in any channel and are defined in the workflow file itself. You suggest you use the procedure `lookup-package` from the (`gwl packages`) module to look up inputs in the context of the current Guix. To ensure reproducibility, however, we urge you to publish packages in a version-controlled channel. See the Guix reference manual to learn all there is to know about channels.

The `packages` field accepts a list of packages as well as multiple values (an “implicit list”). All of the following specifications are valid. A single package:

```
process
  packages "guile"
  ...
```

More than one package:

```
process
  packages "guile" "python"
  ...
```

A single list of packages:

```
process
  packages
    list "guile" "python"
  ...
```

inputs This field holds inputs to the process. Commonly, this will be a list of file names that the process requires to be present. The GWL can automatically connect processes by matching up their declared inputs and outputs, so that processes generating certain outputs are executed before those that declare the same item as an input.

As with the `packages` field, the `inputs` field accepts an “implicit list” of multiple values as well as an explicit list. Additionally, individual inputs can be “tagged” or named by prefixing it with a keyword (see Section “Keywords” in *GNU Guile Reference Manual*). Here’s an example of an implicit list of inputs spread across multiple lines where two inputs have been tagged:

```
process
  inputs
    . genome: "hg19.fa"
```

```

    . "cookie-recipes.txt"
    . samples: "foo.fq"
    ...

```

The leading period is Wisp syntax to continue the previous line. You can, of course, do without the periods, but this may look a little more cluttered:

```

process
  inputs genome: "hg19.fa" "cookie-recipes.txt" samples: "foo.fq"
  ...

```

Why tag inputs at all? Because you can reference them in other parts of your process definition without having to awkwardly traverse the whole list of inputs. Here is one way to select the first input that was tagged with the `samples:` keyword:

```

pick genome: inputs

```

To select the second item after the tag `genome:` do this:

```

pick second genome: inputs

```

or using a numerical zero-based index:

```

pick 1 genome: inputs

```

Chapter 5 [Code Snippets], page 18, for a convenient way to access named items in code snippets without having to define your picks beforehand.

The procedure `process-inputs` can be used to access the list of inputs of any given process. By default, tags are removed from the list. If you want to include tags (e.g. to select specific inputs with `pick`), you can pass the keyword `with-tags`.

Here is an example of two processes where the second process refers to the inputs of the first.

```

process count-reads (with sample)
  packages
    . "r-minimal"
  inputs
    . bam:
      file sample "_Aligned.sortedByCoord.out.bam"
    . bai:
      file sample "_Aligned.sortedByCoord.out.bam.bai"
    . script:
      file "count-reads.R"
  outputs
    file sample ".read_counts.csv"
  # {
    R {{inputs:script}} {{inputs:bam}} {{inputs:bai}} > {{outputs}}
  }

```

```

process genome-coverage (with sample)
  packages
    . "r-minimal"

```

```

inputs
  define other-inputs
    process-inputs
      count-reads sample with-tags:
        . files:
          pick bam: others
          pick bai: others
        . script:
          file "genome-coverage.R"
outputs
  files sample / (list ".forward" ".reverse") ".bigwig"
# {
  R {{inputs:script}} {{inputs::files}} > {{outputs}}
}

```

outputs This field holds a list of outputs that are expected to appear after executing the process. Usually this will be a list of file names. Just like the **inputs** field, this field accepts a plain list, an implicit list of one or more values, and lists with named items.

The GWL can automatically connect processes by matching up their declared inputs and outputs, so that processes generating certain outputs are executed before those that declare the same item as an input.

The procedure **process-outputs** can be used to access the list of outputs of any given process. By default, tags are removed from the list. If you want to include tags (e.g. to select specific outputs with **pick**), you can pass the keyword **with-tags**.

Here is an example of two processes where the second process refers to the outputs of the first.

```

process one
  packages
    . "coreutils"
  inputs
    . "input.txt"
  outputs
    . log: "first.log"
    . text: "first.txt"
# { tail {{inputs}} > {{outputs:text}} }

process two
  packages
    . "coreutils"
  inputs
    pick text:
      process-outputs one with-tags:
  outputs
    . done: "second.txt"
    . log: "second.log"

```

```
# { head {{inputs}} > {{outputs:done}} }
```

output-path

This is a directory prefix for all outputs.

run-time This field is used to specify run-time resource estimates, such as the memory requirement of the process or the maximum time it should run. This is especially useful when submitting jobs to an HPC cluster scheduler such as Grid Engine, as these schedulers may give higher priority to jobs that declare a short run time.

Resources are specified as a complexity value with the fields **space** (for memory requirements), **time** (for the expected duration of the computation), and **threads** (to control the number of CPU threads). For convenience, memory requirements can be specified with the units **kibibytes** (or **KiB**), **mebibytes** (or **MiB**), or **gibibytes** (or **GiB**). Supported time units are **seconds**, **minutes**, and **hours**.

Here is an example of a single-threaded process that is granted 20 MiB of run-time memory for a duration of 10 seconds:

```
process stamp-inputs
  inputs "first" "second" "third"
  outputs "inputs.txt"
  run-time
    complexity
      space 20 mebibytes
      time 10 seconds
      threads 1
  # { echo {{inputs}} > {{outputs}} }
```

When this process is executed by a scheduler that honors resource limits, the process will be granted at most 20 MiB of memory and will be killed if it has not concluded after 10 seconds.

values This field holds a list with keyword-tagged items that can be used in code snippets. Values defined here are passed to the process script at execution time (rather than preparation time), so this field can be used to avoid embedding literal values in code snippets when generating processes from a template. To learn more about code snippets Chapter 5 [Code Snippets], page 18.

Here is a simple example of a process template with values:

```
process greet (with name)
  packages
    . "hello"
    . "coreutils"
  outputs
    file name ".txt"
  values
    . capitalized:
      string-upcase name
  # {
```

```

    echo "This is a greeting for {{values:capitalized}}."
    hello >> {{outputs}}
  }

```

```

map greet
  list "rekado" "civodul" "zimoun"

```

The generated script from this process does not embed any specific value for `name` or even `capitalized`. Instead it looks up the value for `capitalized` in the arguments passed to the script at execution time. So instead of generating three scripts that only differ in one value (the capitalized name), the GWL will only generate *one* script and pass it three different values for the three processes.

For another example and further discussion of embedding values versus referencing them at execution time Section 4.2 [Process templates], page 10.

procedure

This field holds an expression of code that should be run when the process is executed. This is the “work” that a process should perform. By default that’s a quoted Scheme expression, but code snippets in other languages are also supported (see Chapter 5 [Code Snippets], page 18).

Here’s an example of a process with a procedure that writes a haiku to a file:

```

process haiku
  outputs "haiku.txt"
  synopsis "Write a haiku to a file"
  description
    . "This process writes a haiku by Gary Hotham \
to the file \"haiku.txt\"."
  procedure
    ` with-output-to-file ,outputs
      lambda ()
        display "\
the library book
overdue?
slow falling snow"

```

The Scheme expression here is quasiquoted (with a leading ```) to allow for unquoting (with `,`) of variables, such as `outputs`.

Not always will Scheme be the best choice for a process procedure. Sometimes all you want to do is fire off a few shell commands. While this is, of course, possible to express in Scheme, it is admittedly somewhat verbose. For convenience we offer a simple and surprisingly short syntax for this common use case. As a bonus you can even leave off the field name “procedure” and write your code snippet right there. How? Chapter 5 [Code Snippets], page 18.

4.2 Process templates

When defining many similar processes, it can be useful to parameterize a single process template. This can be accomplished by defining a procedure that takes any number of

arguments and returns a parameterized process. Here's how to do this somewhat verbosely in plain Scheme:

```
(define (build-me-a-process thing)
  "Return a process that displays THING."
  (make-process
    (name (string-append "show-" thing))
    (procedure '(display ,thing))))

;; Now use this procedure to build concrete processes.
(define show-fruit
  (build-me-a-process "fruit"))
(define show-kitchen
  (build-me-a-process "kitchen"))
(define show-table
  (build-me-a-process "table"))
```

As this is a somewhat common thing to do in real workflows, the GWL provides simplified syntax to express the same concepts with a little less effort:

```
process build-me-a-process (with thing)
  name
    string-append "show-" thing
  procedure
    ' display ,thing

define show-fruit
  build-me-a-process "fruit"
define show-kitchen
  build-me-a-process "kitchen"
define show-table
  build-me-a-process "table"
```

The result is the same: you get a procedure `build-me-a-process` that you can use to define a number of similar processes. In the end you have the three processes `show-fruit`, `show-kitchen`, and `show-table`.

In a real-life workflow, the above example would not be very efficient. The GWL generates an executable script for every process, passing the process properties (such as `name`, `inputs`, `outputs`, etc) as arguments. It is a good idea to only generate one script per process *template* instead of producing one script per process, as this *vastly* reduces preparation work that the GWL has to perform.

The GWL can arrange for scripts to be reused as long as you take care not to embed arbitrary variables in the process `procedure` field. To this end the GWL offers the `values` field for arbitrary value definitions that should be passed to process scripts as arguments.

Another thing to avoid is to make the process name dependent on template arguments. This prevents script reuse as the GWL is forced to generate scripts that are virtually identical except for their names. Here's an example with ten processes that all share the same process script:

```
define LOG_DIR
```

```

    file "logs"

define SAMPLES
  list
    . "first-sample"
    . "second"
    . "third-sample"
    . "sample-no4"
    . "take-five"
    . "666"
    . "se7en"
    . "who-eight-nine?"
    . "NEIN!"
  reverse-string "net"

process index-bam (with sample)
  inputs
    file "mapped-reads" / sample "_Aligned.sortedByCoord.out.bam"
  outputs
    . bai:
      file "mapped-reads" / sample "_Aligned.sortedByCoord.out.bam.bai"
    . log:
      file LOG_DIR / "samtools_index_" sample ".log"
  packages
    . "samtools"
    . "coreutils"
  values
    . sample-id: sample
    . backwards:
      string-reverse
        first inputs
  # {
    mkdir -p {{LOG_DIR}}
    echo "The sample identifier is {{values:sample-id}}"
    samtools index {{inputs}} {{outputs:bai}} >> {{outputs:log}} 2>&1
    echo "By the way, the sample's file name in reverse is {{values:backwards}}."
  }

workflow test
  processes
    map index-bam SAMPLES

```

Here the value of the variable `LOG_DIR` is embedded in the generated script, but that's fine because it is independent of the template argument `sample`. While we could have used `sample` directly, we instead defined it as a value in the `values` field and tagged it with the keyword `sample-id:`. For the fun of it we also defined a value with the tag `backwards:`, which is defined in terms of another process field (`inputs`).

References to the fields `inputs`, `outputs`, `name`, and `values` are resolved via arguments passed to the process script at execution time. They do not interfere with script reuse as their values are not embedded in the generated script.

4.3 Useful procedures and macros

The (`gwl utils`) module provides a number of useful helpers that are intended to simplify common tasks when defining processes. The helpers defined by this module are all available by default.

`on collection higher proc` [Scheme Procedure]

The `on` procedure is an alternative way to express the application of a higher order function to some collection. The only purpose of this procedure is to improve legibility when using Wisp syntax, as it allows one to avoid leading dots. The following two expressions are equivalent:

```
;; With "on"
on numbers map
  lambda (number)
    + number 10

;; Without "on"
map
  lambda (number)
    + number 10
. samples
```

`file file-name-part...` [Scheme Macro]

This macro enables you to construct a normalized file name out of any number of file name parts given as arguments. A file name part can either be a string literal or a variable or expression that evaluates to a string.

Directories are separated with a literal slash. This allows you to construct file names where parts of a directory or file name are computed from other values.

```
define user
  . "rekado"

define my-list
  iota 32

define num
  number->string
  + 10
  length my-list

file / "home" / user / "file_" num ".txt"

=> "/home/rekado/file_42.txt"
```


`files file-name-part...` [Scheme Macro]

Much like the `file` macro, the `files` macro enables you to construct multiple normalized file names out of any number of file name parts given as arguments. A file name part can either be a string literal, a variable or expression that evaluates to a string, or a variable or expression that evaluates to a list of strings.

Any list of strings will lead to the construction of a combinatorial variant. This is very useful when you need to generate a list of input or output file names.

Directories are separated with a literal slash. This allows you to construct file names where parts of a directory or file name are computed from other values.

```
define users
  list "rekado" "zimoun"

define projects
  list "foo" "bar"

define extensions
  list "txt" "tar.gz" "scm"

files / "home" / users / "proj_" projects / "file." extensions

=> '("/home/rekado/proj_foo/file.txt"
     "/home/rekado/proj_foo/file.tar.gz"
     "/home/rekado/proj_foo/file.scm"
     "/home/rekado/proj_bar/file.txt"
     "/home/rekado/proj_bar/file.tar.gz"
     "/home/rekado/proj_bar/file.scm"
     "/home/zimoun/proj_foo/file.txt"
     "/home/zimoun/proj_foo/file.tar.gz"
     "/home/zimoun/proj_foo/file.scm"
     "/home/zimoun/proj_bar/file.txt"
     "/home/zimoun/proj_bar/file.tar.gz"
     "/home/zimoun/proj_bar/file.scm")
```

`pick [n] key collection` [Scheme Procedure]

This procedure allows you to pick a named item from a *collection* by looking for the specified keyword *key*. Optionally, you can provide a selector procedure or index *n* as the first argument. Without a selector the first item matching the given *key* will be returned. When the selector is `*` all items following the *key* (up to the next tag) will be returned. If the selector is a number it is used as a zero-based index into the list of items following the *key*. If the selector is a procedure it is applied to the list of items following the *key*.

```
define collection
  list
    . "one"
    . "two"
    . "three"
```

```

    . mine: "four"
    . "five"
    . yours: "six"

pick mine: collection

; => "four"

pick * mine: collection

; => '("four" "five")

pick second mine: collection

; => "five"

pick 0 yours: collection

; => "six"

```

`load-workflow` *file* [Scheme Syntax]

This macro lets you load a workflow from the given *file*. The file must evaluate to a workflow value. This macro is useful for when you want to extend previously defined workflows. The argument *file* is expected to be a file name relative to the file invoking `load-workflow`.

`get` *collection* [*#:default default*] *path*... [Scheme Procedure]

This procedure allows you to select an item from a (potentially nested) *collection* by traversing the specified *path*, a sequence of string or symbols that are keys in the collection. This becomes much clearer with an example:

```

(define config
  '(("locations"
    . (("input" . "/home/rekado/foo")
      ("output" . "/dev/null")))
    ("resources"
    . (("R"
      . (("memory" . "2GB")
        ("cores" . 2)))
      ("samtools"
      . (("memory" . "128kB")
        ("cores" . 1)))))))

(get config "locations" "output")

; => "/dev/null"

(get config "resources" "R" "cores")

```

```
; => 2
```

The variable *config* here is a so-called association list that associates string keys with values. Some of these values are again association lists. `get` simply traverses the provided path of keys and “enters” each specified collection in turn.

Association lists are very common in Scheme, and they are also used as an intermediate representation for many parsed files. Here is an example of using `get` on a parsed JSON file (this depends on the `guile-json` package):

```
;; Declare packages
require-packages
  . "guile-json"

;; Load it
import
  json

define config
  json-string->scm "\
{
  \"locations\": {
    \"input\": \"/home/rekado/foo\",
    \"output\": \"/dev/null\"
  },
  \"resources\": {
    \"R\": {
      \"memory\": \"2GB\",
      \"cores\": 2
    },
    \"samtools\": {
      \"memory\": \"128kB\",
      \"cores\": 1
    }
  }
}
"

get config "locations" "output"

; => "/dev/null"

get config "resources" "R" "cores"

; => 2
```

If the provided path cannot be followed because one or more of the keys do not exist or the value after looking up an intermediate key does not result in a collection, `get` will raise an error condition. If you only want to look up an optional value in a

collection that may or may not exist, you can provide a default value to `get`. That value will be returned instead of raising an error.

```
;; Declare packages
require-packages
  . "guile-json"

;; Load it
import
  json

define config
  json-string->scm "\
{
  \"locations\": {
    \"input\": \"/home/rekado/foo\",
    \"output\": \"/dev/null\"
  },
  \"resources\": {
    \"R\": {
      \"memory\": \"2GB\",
      \"cores\": 2
    },
    \"samtools\": {
      \"memory\": \"128kB\",
      \"cores\": 1
    }
  }
}
"

get config default: "/tmp" "locations" "temp-directory"

; => "/tmp"
```

5 Code Snippets

The Guix Workflow Language is embedded in Guile Scheme, so it makes sense to use Scheme to define the work that a process should perform. Sometimes it may be more convenient, though, to express the procedure in a different language, such as GNU R, Python, or maybe even in Bash.

The GWL provides special syntax for embedding code snippets. The special syntax is provided in the (`gwl sugar`) module, and is loaded by default. Here is an example of a process that runs an embedded Bash shell script:

```
process run-bash
  packages "bash"
  # bash { echo "hello from bash!" }
```

Notice how the “procedure” field name was not used here, because the code snippet came last. This cuts down on boilerplate.

Code snippets are introduced with `# interpreter {`, where `interpreter` is the command line for running an interpreter, such as `/bin/bash -c`. Code snippets must end with a closing brace, `}`.

Make sure that the package inputs include a package providing the interpreter. For convenience we provide the special interpreters `bash`, `R`, and `python`, so that you don’t have to specify a more complicated command line. When no interpreter is provided the generic shell interpreter `/bin/sh` will be used:

```
process run-sh
  # { echo "hello from a shell!" }
```

Within code snippets a special syntax is supported for accessing variables. Any uninterupted value enclosed in double braces is considered a reference to a variable, which may also be the name of other process fields. In the following example, the shell snippet refers to the `name` and `inputs` fields of the current process:

```
process run-bash
  packages "bash"
  inputs
    . "a"
    . "b"
    . "c"
  # bash {
    echo "The name of this process: {{name}}."
    echo "The data inputs are: {{inputs}}."
  }
```

You can even access named or tagged values in lists. In the following example, the shell snippet refers to only selected values of the `inputs` field of the current process:

```
process run-bash
  packages "bash"
  inputs
    . "a"
    . mine: "b"
```

```

    . "c"
    . yours: "d"
# bash {
    echo "This is mine: {{inputs:mine}}, and this is yours: {{inputs:yours}}."
}

```

As expected, this will output the following text when run:

```
This is mine: b, and this is yours: d.
```

You can also access tagged sub-lists with the `::` accessor:

```

process frobnicate
  packages "frobnicator"
  inputs
    . genome: "hg19.fa"
    . samples: "a" "b" "c"
  outputs
    . "result"
# {
  frobnicate -g {{inputs:genome}} --files {{inputs::samples}} > {{outputs}}
}

```

This process will cause the following command to be executed:

```
frobnicate -g hg19.fa --files a b c > result
```

If these two ways to access elements of a list are not enough, we recommend defining a variable using `pick` (Section 4.3 [Useful procedures and macros], page 13). In the following example we define a variable *second-sample* inside of the `procedure` field to hold the second of the inputs after the keyword `samples:`, i.e. the string `the`. We can then refer to that variable by name in the code snippet.

```

process foo
  inputs
    . "something"
    . samples: "in" "the" "way"
  procedure
    define second-sample
      pick second samples: inputs
    # { echo {{second-sample}} }

```

You can also access process meta data through environment variables. The following variables may be set:

- `_GWL_PROCESS_NAME`
- `_GWL_PROCESS_SYNOPSIS`
- `_GWL_PROCESS_DESCRIPTION`
- `_GWL_PROCESS_INPUTS`
- `_GWL_PROCESS_OUTPUT_PATH`
- `_GWL_PROCESS_OUTPUTS`
- `_GWL_PROCESS_COMPLEXITY_TIME`
- `_GWL_PROCESS_COMPLEXITY_SPACE`

- `_GWL_PROCESS_COMPLEXITY_THREADS`
- `_GWL_PROCESS_VALUES`

6 Defining a Workflow

A workflow is a combination of processes that run in a certain order or simultaneously. You can specify the dependencies of processes manually or let the GWL figure it out by matching up the declared inputs and outputs of all processes.

A workflow definition will look something like this:

```
workflow do-stuff
  processes
    . this
    . that
    . something-else
```

This defines a workflow with the name “do-stuff”, binds it to a variable `do-stuff`, and declares that it consists of the three processes `this`, `that`, and `something-else`. All of these processes will be run at the same time. This may not be what you want when the processes depend on each other.

If the processes all declare inputs and outputs, the GWL can connect the processes and ensure that only independent processes are run simultaneously. Use the `auto-connect` procedure on your processes:

```
workflow do-stuff
  processes
    auto-connect
      . this
      . that
      . something-else
```

You can also explicitly construct a graph of processes with the aptly named `graph` macro. The following workflow definition lets the process `combine` run after `generate-A` and `generate-B`, which will both run in parallel. The process `compress` will run after `combine`, and thus at the very end.

```
workflow frobnicate
  processes
    graph
      combine -> generate-A generate-B
      compress -> combine
```

6.1 Declaring package requirements

Sometimes it may be desirable to use features from external packages in the definition of the workflow. For example, you may want to parse a configuration file with Guile DSV before even defining any processes. Or perhaps you may need to use an application to prepare state or query a database before the workflow is executed.

You can declare any package requirements with a `require-packages` form at the very top of your workflow file. This must be the first code expression after any commented lines. Before a workflow file is evaluated, the current environment is modified to make the specified packages available. Any specified Guile libraries are added to the load path, so care should be taken to ensure that the libraries are in fact compatible with the version of Guile used by the Workflow Language.

`require-packages package...` [Scheme Procedure]

The `require-packages` procedure takes any number of package specifications. A package specification is the package name, optionally followed by `@` and a version string. The Workflow Language guarantees that the declared packages will be available when the workflow file is evaluated.

```
;; Declare packages
require-packages
  . "guile-dsv"      ; for parsing CSV files
  . "guile-libyaml" ; for parsing YAML files

;; Load them
import
  dsv
  yaml

;; Use them
define : load-config file
  if : file-exists? file
    read-yaml-file file
    error "Could not find configuration file!"
...

```

6.2 workflow Fields

Both `make-workflow` and `workflow` accept the same fields, which we describe below. Of all these fields only `name` and `processes` are required.

name The readable name of the workflow as a string. This is used for display purposes. When the `workflow` constructor is used, the `name` field need not be provided explicitly.

version A version string to distinguish different releases of the workflow.

synopsis A short summary of what this workflow is about.

description A description of what the workflow is supposed to accomplish.

processes This field contains a list of processes that should be scheduled when the workflow is executed. A plain list of processes specifies processes that may run in parallel. A list of process lists is used to specify process dependencies. This is best done with the `graph` macro:

The following workflow definition lets the process `combine` run after `generate-A` and `generate-B`, which will both run in parallel. The process `compress` will run after `combine`, and thus at the very end.

```
workflow frobnicate
  processes
    graph

```

```

    combine -> generate-A generate-B
    compress -> combine

```

This can be expressed just as well with lists of process lists, but it looks a little dense. Here is the same thing in Scheme without the `graph` macro:

```

(workflow frobnicate
 (processes
  (list (list combine generate-A generate-B)
        (compress combine))))

```

If the processes all declare inputs and outputs, the GWL can connect the processes and ensure that only independent processes are run simultaneously. Use the `auto-connect` procedure on your processes:

```

workflow do-stuff
  processes
  auto-connect
  . this
  . that
  . something-else

```

before This field holds a Scheme procedure that will be executed before the workflow processes are scheduled. This can be useful for printing introduction banners or logos.

```

workflow fancy-hello
  before
  lambda _
    display "\

      -           - -           .
      | |           | | |           .
      | |__  ___| | | ___           .
      | ' _ \\ / _ \\ | | / _ \\           .
      | | | | __/ | | ( _ ) |           .
      | _ | | | \\ \\ ___ | | | \\ \\ ___ /           .
      "
    newline
    display "Now that I've got your attention, let's compute!"
    newline
    newline
  processes
  list hello

```

after This field holds a Scheme procedure that will be executed after all workflow processes have been executed. This can be useful for printing further instructions or hints as to where the user may find important output files.

```

workflow fancy-bye
  after
  lambda _
    newline
    display "The main report file is called 'report2021_final_really_appro

```

```
    newline  
    newline  
processes  
    list generate-report
```

7 Process Engines

Once you have defined a workflow, there are different ways to run the processes it consists of. The simplest way is to turn the workflow into a Guile script that sets up the desired environment and then executes the workflow processes on the current machine. This is what the `simple-engine` does.

The `grid-engine` is similar to the `simple-engine` in that it generates a shell script, with the difference that it also includes resource variable definitions for submission to a Grid Engine scheduling system. The resource variables are derived from the process `run-time` field.

8 Invoking guix workflow

The Guix Workflow Language extends your Guix installation with a new command: `guix workflow`. There are three sub-commands:

- `run` To run (or prepare to run) a workflow from a file.
- `graph` Load a workflow from a file and generate a graph in Graphviz Dot-format.
- `web` The GWL includes a web interface. This command starts it.

8.1 Options for guix workflow run

This is the command to run (or prepare to run) a workflow from a file. It generate the process scripts, builds or downloads all dependencies, and then runs the workflow process scripts corresponding to the workflow defined in the given file.

The following options can be provided to change the behavior of this command.

`--input=name[=file]`

`-i name[=file]`

A workflow may have so-called free inputs, inputs that are not provided by any of the workflow's processes. By default, the GWL will pick files from the current working directory that match the names of free inputs. This option can be used to map a *file* with an arbitrary name to a free input in the workflow with the given *name*. This option can be provided more than once.

In the following example, the free input called `genome` is mapped to the file `/data/hg19.fa` before running the workflow defined in `analysis.w`:

```
guix workflow run --input=genome=/data/hg19.fa analysis.w
```

`--output=location`

`-o location`

This option currently has no effect.

`--engine=engine`

`-e engine` Select the process engine *engine* as the target of the generated process scripts. See Chapter 7 [Process Engines], page 25.

`--prepare=file`

`-p file` Generate the process scripts and build or download all dependencies, but do not run the workflow process scripts corresponding to the workflow defined in *file*.

`--log-events=event,...`

`-l events,...`

Print messages for the comma-separated list of events. This defaults to logging the events `error`, `execute` (for fatal errors) (for processes that are run), and `info` (for status information).

`--dry-run`

`-n` Prepare the scripts and the environments but don't actually run the processes. Only show what commands would be run.

`--force`
`-f` Execute all processes, even if their outputs may have been cached from previous runs.

`--container`
`-c` Run each process inside of an isolated environment with file system virtualization and user namespaces. Only declared input files will be available at execution time, and only declared output files will be stored. This is a great option to use when you want to make sure that your processes only depend on state that you have declared. A downside is that generated output files cannot be written to the target directories directly but are copied from the container to the file system.

8.2 Options for `guix workflow web`

`--port=port`
`-p port` The network port on which the web interface listens for connections.

`--host=host`
`-H host` The network host on which to listen for connections. This defaults to `localhost`.

`--workflows-directory=location`
This is a location containing other workflows that the web interface may access to visualize them.

The following options are only rarely used:

`--max-file-size=bytes`
The maximum size (in bytes) of files served by the web interface.

`--dot=/path/to/dot`
Use this to provide an alternative variant of the `dot` executable.

`--root=location`
Use this to override the root location of the workflow web interface.

`--assets-directory=location`
Use this to override the location of web assets (CSS, JavaScript, images).

`--examples-root-directory=location`
Use this to override the default name of the directory containing workflow examples.

9 Acknowledgments

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- Kyle Meyer kyle@kyleam.com

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- Mike Gerwitz mtg@gnu.org

Thank you.

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