

# Melon - a Task Scheduling Package for Todo List Applications

## using Markov Chain Monte-Carlo Methods

An MMSC Special Topic on [PYTHON IN SCIENTIFIC COMPUTING](#)

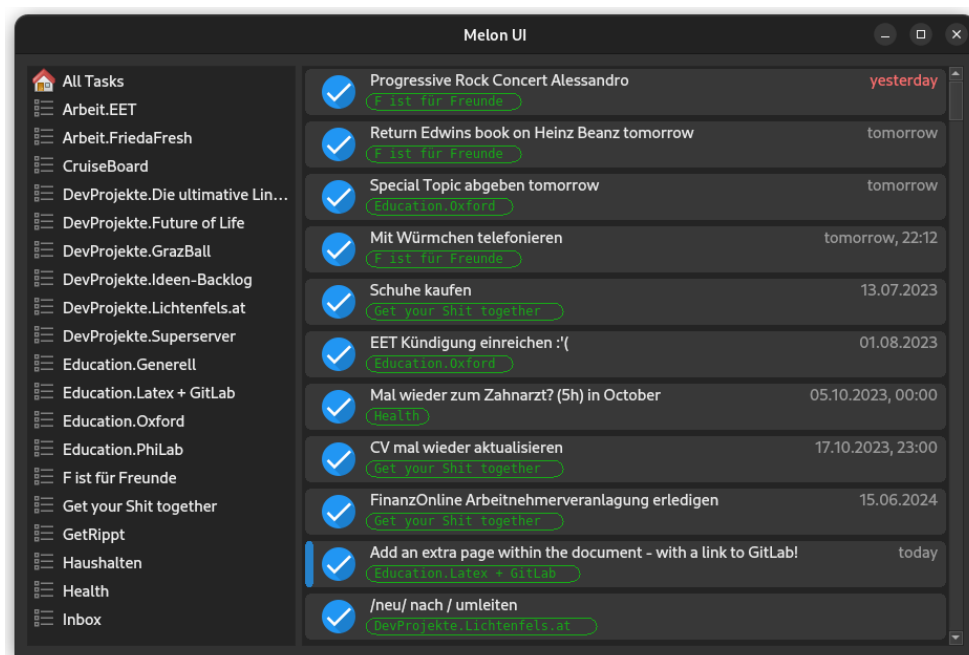
Candidate Number: [1072462](#)

### Abstract

In this project we will implement a task scheduling method on the basis of a Markov chain Monte-Carlo (MCMC) method with Simulated Annealing. The project is publicly available as a software package **melon-scheduler** on PyPi and entirely original. The package can download tasks from a CalDAV server, store and load them locally, synchronise with updates from the server and finally, schedule them into a calendar. It also comes with a GUI, cf. Figure 1.

The key algorithm described in this report is the MCMC scheduling procedure, taking a set of tasks as an input and returning an ordered set of time slots as output. The attached code contains four original implementations of the algorithm in three different languages: Python, Rust and C++.

We will compare the performance of the four different implementations to see whether outsourcing performance-critical sections of code to low-level languages is worth the effort in the context of scientific computing.



**Figure 1:** The Graphical User Interface (GUI) accompanying the scheduler. Double clicking tasks allows the user to edit them. Clicking the blue check icon marks them as completed. The grey text on the side represents the relevant due date. Selecting a calendar (todo-list) from the list on the left-hand side will filter the task list to only that category.

# 1 Problem Introduction

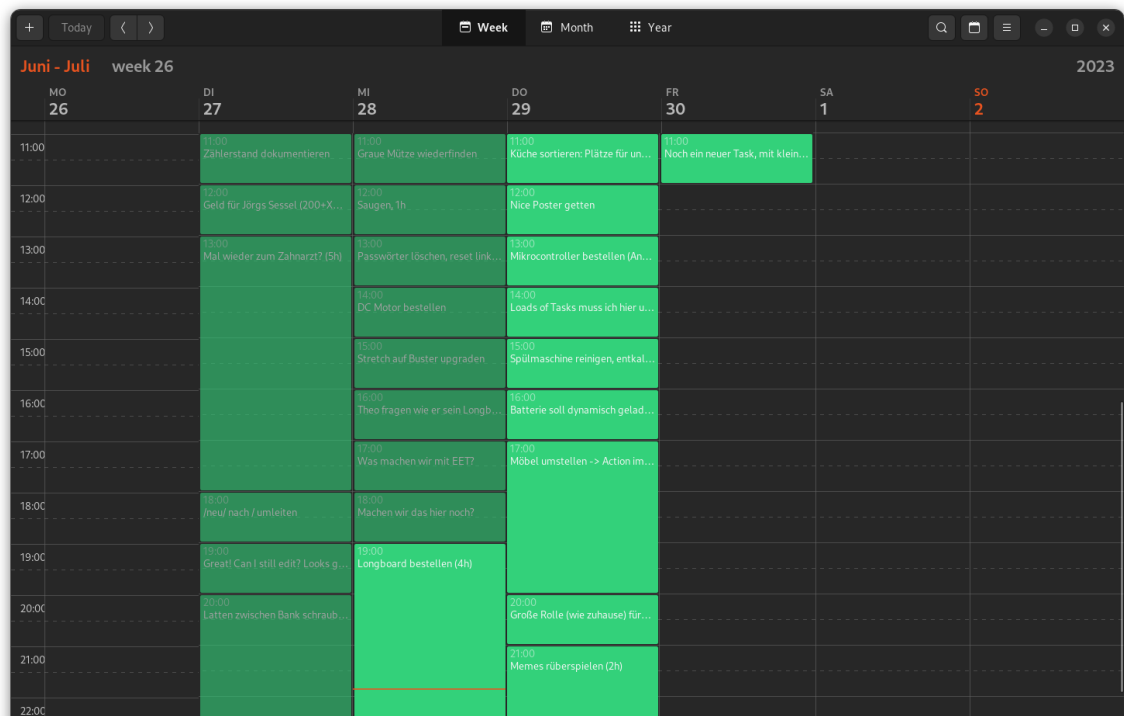
This report is concerned with finding a good scheduling approach for a given set of tasks (todos) with duration, priority, location and due date. The software attached with this report, going by the name of *Melon*, consists of two parts: the `melon` task scheduling package itself and the Graphical User Interface written using the Qt6 framework, contained in `melongui`. Both of these are published as a package `melon-scheduler`, available [on PyPi](#). It may be installed using

`$ pip install melon-scheduler` for just the scheduler, without the GUI,

`$ pip install melon-scheduler[gui]` with the GUI or optionally,

`$ pip install melon-scheduler[gui,plots,numba]` with all extras.

The package is capable of downloading and synchronising tasks from a calendar server supporting the industry-standard CalDAV protocol, displaying and editing them in the GUI and finally scheduling them into a calendar (cf. Figure 2). The scheduling mechanism we implemented is an MCMC method.



**Figure 2:** The scheduled tasks, as displayed in *Gnome Calendar* (the default duration for each task is one hour). Potentially existent events could be taken into account for task scheduling as well, just as well as breaks.

## 1.1 Idea of the Algorithm

We work with the following assumption on the state: the entire scheduling output, given the set of tasks, is solely determined by the order in which the tasks are scheduled. That is, for a given order of tasks, the full schedule can be created using the supplied input data. With this assumption, finding the absolute optimum is tedious, especially for a large number of tasks  $N \gg 1$ , as there are  $N!$  possible ways to order the tasks.

The idea of the Monte-Carlo method implemented here is to minimise a penalty function (borrowing the term *energy* from physics) over the discrete state space of size  $\mathcal{O}(N!)$  using a stochastic approach, as sketched in Section 2. The four key properties we aim to optimise for are:

- spending a minimal amount of time to complete all tasks,
- scheduling high priority tasks first,
- a low number of commutes between locations and
- having all tasks completed on time.

Due to this choice of state representation, the problem broadly mimics a Traveling Salesman Problem.

## 2 Primer on the Underlying Theory

Many complex problems cannot be solved using analytical methods due to, for instance, their discrete nature. MCMC methods with transition probabilities allow us to explore a huge state space regardless and minimise a function (energy  $E$ ) therein. There are many use cases in physics, such as for the simulation of the Ising model, where the term *energy* originates from.

The idea of the iterative procedure below, due to [Metropolis et al. 1953](#) and [Hastings 1970](#) is to start from an initial state  $\mathbf{x}^{01}$ , permute it slightly and then accept that new proposal with a probability proportional to the exponential of their energy difference. If the proposal's energy is better (lower) than the current state's energy, the acceptance probability is 1 and therefore automatically  $\mathbf{x}^{n+1} = \mathbf{x}^*$ . This allows us to explore state space, but not get stuck in local minima as there is always a non-zero chance for the iteration to escape the local minimum.

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<sup>1</sup>In our case, this could be a pre-ordering of tasks obtained by traditional sorting mechanisms, on a simpler metric such as the priority or due date.

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The Metropolis-Hastings sweep() sub-routine

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```

1  for  $N^2$  many times , repeat
2    sample a candidate  $\mathbf{x}^*$ .
3    set  $\mathbf{x}^{n+1} = \mathbf{x}^*$  with acceptance probability
4       $p_{\text{accept}} = \min\left(1, e^{-\beta(E^{n+1}-E^n)}\right)$ , with  $\beta \in \mathbb{R}^+$  a transition factor.
5    Otherwise , let  $\mathbf{x}^{n+1} = \mathbf{x}^n$ .

```

---

This algorithm is then employed as a subroutine to an outer iteration, a stochastic global optimisation technique called Simulated Annealing. In our specific case, we will minimise the function  $E(\mathbf{x})$  given in Equation (1) based on the four properties stated above, using the combination of Metropolis-Hastings and Simulated Annealing.

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Simulated Annealing

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```

1  let  $k = 1$ 
2  until convergence , repeat
3    set the temperature  $T = T_0 k^q$  and therefore  $\beta = \frac{1}{T}$ .
4    perform a sweep()
5    evaluate  $\langle E \rangle$  and  $\langle \Delta E^2 \rangle$  over the sweep.
6    set  $k = k + 1$ 

```

---

The key idea is to lower the temperature  $T$ , starting from an initial value  $T_0$ , over the course of the simulation to reduce the transition probability. For each temperature  $T$  we evaluate the average of the energy

$$\langle E \rangle \simeq \frac{1}{n} \sum_{\mathbf{x}} E(\mathbf{x}), \quad \text{and} \quad \langle E^2 \rangle \simeq \frac{1}{n} \sum_{\mathbf{x}} E^2(\mathbf{x})$$

with  $n$  the number of iterations for this temperature, hence the variance is given by

$$\langle \Delta E^2 \rangle := \langle E^2 \rangle - \langle E \rangle^2.$$

When the variance subceeds a certain threshold, this usually represents an indicator for us stop the iteration. In the present implementation however, we keep the number of sweeps constant at 15, across the four different implementations in order to make the runtimes comparable.

### 3 Package Design and Architecture

The CalDAV format, short for the Calendaring Extensions to Web Distributed Authoring and Versioning (WebDAV) as introduced in [Daboo, Dusseault and Desruisseaux 2007](#) defines three types of entities: VEVENTs, VTODOs and VJOURNALS. These entities are organised into calendars, for our purposes these could be thought of as different todo lists. *Melon* interacts with CalDAV servers and objects through Python's `caldav` package. A decent amount of the code in `melon` and `melongui` is concerned with the interaction from the package to these objects. Within the scope of this report, we will focus on a smaller version of these VTODO objects, created for a swift interface to the scheduler algorithm implementations.

This small object version, containing data relevant to the scheduling mechanism, looks like this:

```

1  import dataclasses
2  from datetime import datetime
3
4  @dataclasses.dataclass
5  class Task:
6      uid: str # unique identifier of the task
7      duration: float # estimated, in hours
8      priority: int # between 1 and 9
9      location: int # number indicating the location, 0 is "hybrid"
10     due: datetime | None # when the task is due

```

So each task has an associated UID, duration, priority, location and due date. UIDs are useful because they make value collisions very unlikely. This is not to say that these should not be checked, but if two separate calendar clients that each generated a set of UIDs, connected to a server, it is very unlikely to have to resolve potential conflicts.

As mentioned above, the energy we minimise over the state  $\mathbf{x}$  (to schedule the tasks) is a combination of four properties. To obtain our energy function, we propose numerical expressions for each of them (again, the lower, the better the state) and then perform

a weighted sum over all four. Roughly stated, the function we minimise is given by

$$\begin{aligned}
 E(\mathbf{x}) = & \text{slot end}_N - \text{slot start}_1 + \sum_{j=1}^N \mathbb{1}_{\text{slot end}_j > \text{due}_j} \cdot 100 \\
 & + \sum_{j=2}^n (1 - \mathbb{1}_{\text{location}_{j-1}, \text{location}_j}) \cdot 30 + \sum_{j=1}^N j \cdot \text{priority}_j,
 \end{aligned} \tag{1}$$

where the state variable  $\mathbf{x}$  can be computed to an ordered sequence of

$$(\text{slot start}_j, \text{slot end}_j, \text{priority}_j, \text{location}_j, \text{due}_j)_{j \in \{1, \dots, N\}}$$

ranging from  $j = 1$  the task scheduled into the first slot to  $j = N$  the last one. Results of the simulation may be found in Section 4.

### 3.1 Four Different Implementations

In order to compare runtimes, the same algorithm was implemented four times. Once in pure Python, once using the `numba` library and once in Rust and in C++. Numba uses Just-In-Time compilation to speed up subsequent calls of a subroutine. Rust and C++ are good choices for iterative procedures as they allow for low-level access to the implementation. Bindings are provided using `rust-cpython` and `pybind11`.

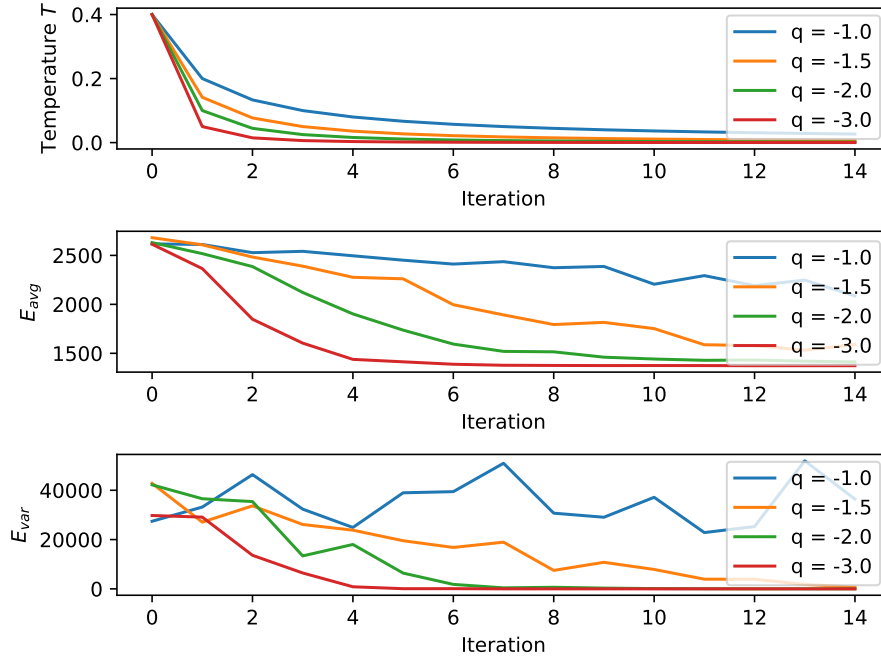
- MCMCScheduler: Pure Python implementation of the scheduling algorithm
- NumbaMCMCScheduler: Python with Numba Extension
- RustyMCMCScheduler: Rust implementation, with bindings via `rust-cpython`
- CppMCMCScheduler: C++ implementation, providing bindings with `pybind11`

## 4 Results

This section will present convergence and runtime results of the scheduling algorithm.

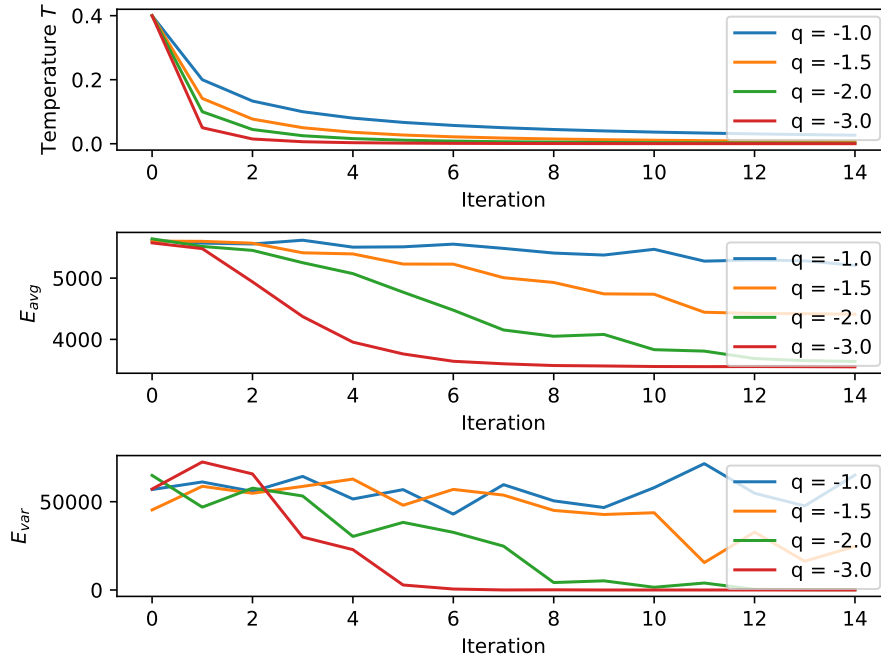
### 4.1 Energy Convergence

For the pure Python implementation of the MCMC scheduler, we recorded average energy and variance in between sweeps, which are documented in Figure 3 and Figure 4 for different lengths of day. Both figures compare different sweep exponents  $q$  from  $-1$  to  $-3$ , which governs how the temperature varies over the course of the simulation, and how that affects the convergence speed.



**Figure 3:** Temperature, average energy  $E_{avg} = \langle E \rangle$  and energy variance  $E_{var} = \langle \Delta E^2 \rangle$  for a 14-hour work day. Low variance can be used as a stopping criterion (cf. Section 2).

As we can see, the average energy  $\langle E \rangle$  generally decreases, and much faster so for higher values of  $|q|$ . The variance at the bottom stays high for the slowly-progressing run, indicating that convergence has not yet been achieved, but decays quicker for stronger temperature decreases (in red).



**Figure 4:** Temperature, average energy  $E_{avg} = \langle E \rangle$  and energy variance  $E_{var} = \langle \Delta E^2 \rangle$  for an 8-hour work day. The average energy here is higher than in Figure 3 because days are shorter and therefore long-duration task orderings matter a lot more, negatively impacting the optimality.

## 4.2 Runtime Performance

The following benchmarks were all accumulated on an x86\_64 Intel® i7-5600U CPU running at 2.6 GHz verified through 3 individual runs, keeping parameters consistent along them.

Table 2 contains profiling data of the pure Python implementation. Considering the high number of calls but low own time per function call, this suggests that there is little progress to be made using only Python, motivating the use of Numba and the low-level implementations in C++ and Rust to compare.

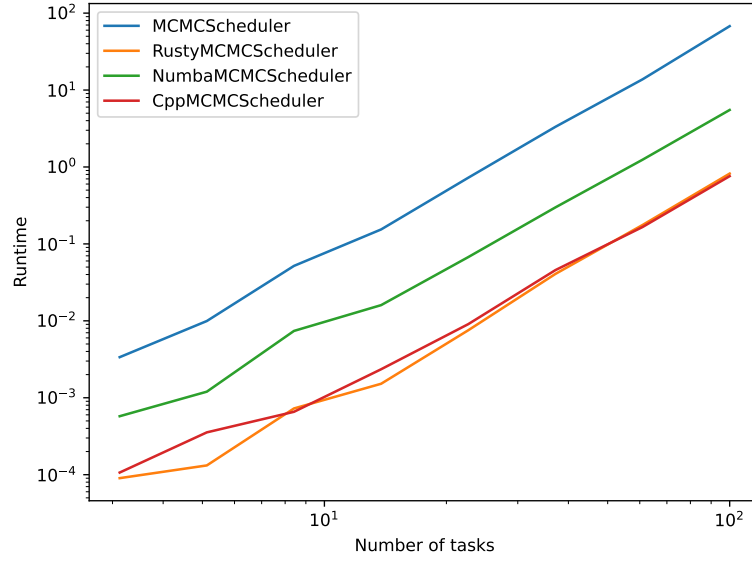


**Table 1:** Runtime Comparison of the different implementations run on the same scenarios with  $N = 80$  tasks. Each runtime is given as the average over three runs.

Implementation	Language	Runtime / seconds
MCMCScheduler	Python	31.3887
NumbaMCMCScheduler	Python	1.9335
RustyMCMCScheduler	Rust	0.4034
CppMCMCScheduler	C++	0.4062

And indeed, Table 1 shows us a 77-times speed up of the Rust and C++ implementations as compared to the pure Python implementation. Figure 5 reinforces this data for different input sizes, also revealing the complexity proportionality. As expected, Rust and C++, both compiled languages, perform very similarly in terms of their runtime. Memory usage analysis was not carried out as part of this project, but we suspect Rust and C++ to perform equivalently once again.

What is perhaps more surprising is that Numba is almost five times slower than the Rust and C++ implementations, which is rooted in the limitations of the just-in-time compilation of Python code. Nevertheless, Numba achieves an impressive speed-up, being 15 times faster than the pure Python implementation. One should also note that the Numba compilation time was approximately 3.2 seconds, taking place once for each Python process.



**Figure 5:** The runtimes of each implementation of the scheduler algorithm (Python, Rust, Python Numba, C++) for an increasing number of tasks.

Fitting a first-order polynomial on the logarithm of the runtime vs the logarithm of the number of tasks, so through the individual lines in Figure 5, we obtain the following slopes:

- MCMCScheduler: 2.874
- RustyMCMCScheduler: 2.728
- NumbaMCMCScheduler: 2.678
- CppMCMCScheduler: 2.570

So the empirical runtime complexity of the algorithm is between  $\mathcal{O}(2.5)$  and  $\mathcal{O}(2.9)$ .

**Table 2:** Profile obtained by running `$ inv profile-scheduler | grep purepython.py`.

Ncalls	Total	/ call	Cum.	/ call	Filename:line	Function
1	0.000	0.000	14.236	14.236	purepython:142	schedule
10	0.209	0.021	14.235	1.424	purepython:123	mcmcSweep
36010	1.144	0.000	13.784	0.000	purepython:97	computeEnergy
2196671	5.391	0.000	11.353	0.000	purepython:41	spreadTasks
1006332	1.389	0.000	1.842	0.000	purepython:27	generateNextSlot
2196610	0.798	0.000	0.972	0.000	purepython:108	<genexpr>
2196610	0.384	0.000	0.384	0.000	purepython:106	<genexpr>
36000	0.082	0.000	0.217	0.000	purepython:83	permuteState
36011	0.046	0.000	0.124	0.000	purepython:19	startingSlot

## 5 Installation and Usage

This project uses one of the latest versions of Python, 3.11.4.

### 5.1 Package Usage

After running `$ pip install melon-scheduler[gui]` and starting a Python console, the following code snippet should start the GUI:

```
1 from melongui.main import main
2 main() # to start the GUI
```

which launches a User Interface such as the one depicted in Figure 1.

Creation of and interaction with Todos in the calendar can be simple:

```
1 from melon.melon import Melon
2
3 melon = Melon() # loads the config and initialises
4 melon.autoInit() # initiates a network connection to the server
5 matches = list(melon.findTask("Submit report"))
6 matches[0].complete() # marks the todo as complete and syncs
7
8 calendar = melon.calendars["My Calendar"]
9 calendar.sync() # fetches updates from the server
10 todo = calendar.createTodo("New Todo")
11 todo.dueDate = datetime.date.today()
12 todo.save() # saves the todo to the server
```

To load todos from a remote calendar, as specified in the configuration file, and schedule them, use the following code snippet:

```
1 from melon.melon import Melon
2 from melon.scheduler.rust import RustyMCMCScheduler
3
4 melon = Melon()
5 melon.autoInit()
6 melon.scheduleAllAndExport("task-schedule.ics",
  ↪ Scheduler=RustyMCMCScheduler)
```

This will create an iCalendar file `task-schedule.ics` containing an event for each time slot allocated to the completion of a task in the todo list. These can be displayed in a regular calendar application and the output might look like according to Figure 2.

In order to run the scheduler on demonstration data, please run

```
1 from melon.scheduler.rust import RustyMCMCScheduler
2
3 tasks = generateManyDemoTasks(N=80)
4 scheduler = RustyMCMCScheduler(tasks)
5 result = scheduler.schedule()
```

There are many more usage examples available in the `tests`.

If not specified in the initialiser, Melon loads a configuration file located in the user's home configuration directory, so on Linux `~.config/melon/config.toml`. The file uses Tom's Obvious, Minimal Language (TOML) format and has the following contents:

```
1 [client]
2 url = "https://my-caldav-server.org:2023/dav/user/calendars/"
3 username = "user"
4 password = "password"
```

## 5.2 Full Project Usage

The ZIP file contains a number of configuration files at the top level, the two main code folders `melon` and `melongui`, `tests`, `docs` and the `report`. To install dependencies from the `pyproject.toml` file, please run

```
$ poetry install
```

which will automatically create a virtual environment.

There are two main entrypoints to running the code: `main.py` to run the GUI, as well as `tasks.py` which contains miscellaneous development and analysis scripts. *Melon* uses `invoke` to these common development tasks which are all callable by running

```
$ inv (name-of-the-task) (arguments) (--keyword-arguments)
```

**Table 3:** Running `$ inv -l` yields a selection of available `invoke` tasks.

<code>build-docs</code>	Builds documentation using Sphinx.
<code>compare-runtime</code>	Compares runtime of the different scheduling implementations.
<code>compile</code>	Assuming a full setup, compiles the low-level implementations of the scheduler algorithm in C++ and Rust.
<code>ipython-shell</code>	Starts an IPython shell with Melon initialised.
<code>plot-convergence</code>	Plots scheduler convergence to a file.
<code>plot-runtime-complexity</code>	Simulates with a varying number of tasks and plots runtime complexity.
<code>profile-scheduler</code>	Profile the pure Python MCMC Scheduler.
<code>schedule-and-export</code>	Run the MCMC scheduler and export the resulting events as an ICS file.
<code>start-mock-server</code>	Starts a Xandikos (CalDAV) server on port 8000.

**Low-Level Language Setup** In order to compile the C++ implementation of the scheduler algorithm, starting from the root folder of the project (containing `CMakeLists.txt` and `conanfile.txt`), please run

```
$ conan install . --output-folder=build --build=missing
$ cd build; cmake .. -DCMAKE_BUILD_TYPE=Release
$ make -j4
```

To compile the Rust implementation, simply

```
$ cargo build --release
```

again making sure that the current working directory is the root folder of the project (containing `Cargo.toml`).

This should have created two `.so` files in the respective folders. The import paths are already adjusted to be able to import these in `cpp.py` and `rust.py`, but they will also be copied to the correct `melon/scheduler` folder using `$ inv compile`.

We recommend usage with **xandikos**, a version-controlled DAV server, capable of syncing calendars (events, todos and journals) and contacts. Following the standard protocol, *Melon* is also compatible with commercial services such Google Calendar or Microsoft Office, as long as these offer an API endpoint with suitable authentication.

The code should mostly be platform-independent, for example due to the usage of `pathlib.Path`. Compiling the low-level language implementations might be more cumbersome however and is untested on platforms other than Linux.

## 6 Code Quality Measures

Writing good code is an art, but there are a few concepts, principles and tools to approach the problem using a standardised approach. Some of these are:

**Formatting** the *Melon* code is done by the `black` software package. Configuration thereof, as well as that for most other tools, can be found in the `pyproject.toml` file. To format all Python code, run `$ black .` which will recursively explore the entire folder. The C++ code is formatted using `clang-format` while the Rust code is formatted using `rustfmt`.

**Docstrings** help us document the code, *within* the code. Every class, method and function in the project, including `melon`, `melongui`, the `tasks` and the `tests`, has a docstring. These follow a specific format in order for Sphinx to be able to pick up arguments, exceptions raised and return values as well as their associated types. This coverage can be verified using `$ interrogate -vv`, cf. Table 4.

**Documentation** is important to make the purpose and usage of the code package clear. This project uses `sphinx` to generate documentation in PDF format which one may find at the end of this report. To generate it, run `$ inv build-docs`.

**Dependency Management** in this project is done using `poetry`, which not only manages install packages and manages virtual environments, but also keeps track of dependency groups. To install all direct dependencies, run `$ poetry install`.

**Type Checking** is done with `pyright` instead of `mypy` as it is much faster and analyses the entire project at once. This tool detects when, for instance, attempting to call a non-existent method on an object, or passing the wrong type to a function call, etc. The *Melon* code therefore contains numerous type hints. To verify all type hints, run `$ pyright .` in the root folder of the project.

**Using Appropriate Language Features** Tools such as `autoflake` and `pyupgrade` automatically correct unused imports or deprecated code usage. `ruff` is a highly performant linter written in Rust, that not only warns the programmer on common mistakes, but can also perform small fixes to the structure of the code such as import reordering. `nitpick` is a tool to synchronise linter configuration across projects.

**Table 4:** Output table of `$ interrogate -vv: Passed` (minimum: 80.0%, actual: 100.0%). Each file has a number of classes, functions and methods as displayed in **Total** and `interrogate` yields the proportion of those having a docstring.

Name	Total	Miss	Cover	Cover
main.py	2	0	2	100 %
tasks.py	8	0	8	100 %
docs/conf.py	1	0	1	100 %
melon/___init___py	1	0	1	100 %
melon/calendar.py	11	0	11	100 %
melon/config.py	1	0	1	100 %
melon/melon.py	19	0	19	100 %
melon/todo.py	20	0	20	100 %
melon/visualise.py	3	0	3	100 %
melon/scheduler/___init___py	1	0	1	100 %
melon/scheduler/base.py	10	0	10	100 %
melon/scheduler/cpp.py	3	0	3	100 %
melon/scheduler/numba.py	8	0	8	100 %
melon/scheduler/purepython.py	12	0	12	100 %
melon/scheduler/rust.py	3	0	3	100 %
melongui/___init___py	1	0	1	100 %
melongui/calendarlist.py	6	0	6	100 %
melongui/mainwindow.py	14	0	14	100 %
melongui/taskitemdelegate.py	12	0	12	100 %
melongui/tasklist.py	14	0	14	100 %
melongui/taskwidgets.py	8	0	8	100 %
tests/___init___py	1	0	1	100 %
tests/test_melon.py	7	0	7	100 %
tests/test_scheduler.py	9	0	9	100 %
<b>TOTAL</b>	175	0	175	100 %



## 6.1 Tests and Coverage

Software testing is a vital part of any programming endeavour to ensure high levels of overall code quality. This submission only contains tests for the `melon` package of the code, not for the GUI, which will be subject to future efforts. There are 34 tests provided along with the code.

In order to simulate the interaction with a Calendaring Extensions to WebDAV (CalDAV) server, we provide a tool to start a mock server using Docker, a containerisation engine that abstracts code execution to individual entities called containers. To start a the `xandikos` mock server, please run

```
$ inv start-mock-server
```

Once the server is running, the tests may be run simply by:

```
$ pytest
```

As we can see using `$ pytest --durations=0`,

```
===== slowest durations =====
3.53s call TestScheduler::test_length[NumbaMCMCScheduler]
0.19s call TestMelon::test_init_store_and_load
```

the slowest test is the first routine involving the Numba scheduler which takes some time to pre-compile the functions. So even when the runtime of the Numba scheduler itself is low (cf. Section 4.2), the test will always take some extra time.

The four different algorithm implementations are tested against each other and on different parameters in order to ensure they work correctly.

### 6.1.1 Code Coverage

One measure of the testing coverage, referring to the proportion of code that is actually being run as part of the tests, is to count the number of statements executed during a test run. In Python, this can be done using the `coverage` module, and integrated with the testing system using `pytest-cov`.

The coverage of the `melon` package is above 90% and documented in Table 5.

**Table 5:** Test coverage of the `melon` package: platform linux, python 3.11.4-final-0. Each file is analysed by the number of statements (lines) in the file executed as part of the tests. This table may be reproduced using `$ pytest --cov=melon`.

Name	Statements	Miss	Cover
melon/___init___.py	0	0	100 %
melon/calendar.py	57	5	91 %
melon/config.py	12	0	100 %
melon/melon.py	121	8	93 %
melon/scheduler/___init___.py	0	0	100 %
melon/scheduler/base.py	40	3	92 %
melon/scheduler/cpp.py	18	5	72 %
melon/scheduler/purepython.py	83	0	100 %
melon/scheduler/rust.py	18	5	72 %
melon/todo.py	101	17	83 %
melon/visualise.py	42	2	95 %
<b>TOTAL</b>	<b>492</b>	<b>45</b>	<b>91 %</b>

**Table 6:** Pre-Commit hooks run on all files of the repository using `$ pre-commit run --all-files`. Each hook can either pass, fail or modify existing code.

```

prettier.....Passed
fix end of files.....Passed
trim trailing whitespace.....Passed
black.....Passed
ruff.....Passed
check blanket noqa.....Passed
check for eval().....Passed
interrogate.....Passed
autoflake.....Passed
pyupgrade.....Passed
pyright.....Passed
pytest-check.....Passed
clang-format.....Passed
latex-format-all.....Passed

```

**Maintaining Code Quality** `pre-commit` is a tool that can install a git hook to the code repository, which automatically runs a set of checks before every commit, hence the name. For this project, various checks listed in Table 6 are employed, being run before each and every commit to keep code quality high throughout the entire development process.

A similar, more team-friendly option is to use GitHub Actions Continuous Integration (CI) / Continuous Delivery (CD), or simply CI/CD.

All the tools described above will be installed automatically using

```
$ poetry install --with=dev.
```

**Publishing to PyPi** As highlighted above, the project can be installed from [this PyPi repository](#). In order to build and publish the project, one can simply run

```
$ poetry publish --build
```

Although it would be possible to compile the C++ and Rust implementations on a CI service using a “platform matrix”, the published package only contains compilation targets for the x86\_64 platform and Python 3.11.

## 7 Conclusion

In this Special Topic, we implemented a task scheduling application, tested it thoroughly (code coverage over 90 %) and used it for the development of a Todo List Application. The optimisation is done using a MCMC method with Simulated Annealing. This algorithm was implemented four times, in Python, Rust and C++. Its key objective is to minimise a function (energy), the time development of which may be found in Figure 3 and Figure 4.

As expected, the low-level language implementations in Rust and C++ outperformed the high-level language implementation in Python by nearly two orders of magnitude. The just-in-time compilation optimisation using Numba also achieved a significant speed-up as compared to the pure Python implementation, but did not match that of Rust or C++. Specific runtime benchmarks can be found in Table 1. We also analysed the runtime complexity of the algorithm, which may be found in Figure 5.

### 7.1 Acknowledgements

The task check icon is the logo of the *Tasks.org* Free and Open Source Android App, the artwork may be found [here](#).

## References

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## Acronyms

CalDAV	Calendaring Extensions to WebDAV	1, 5, 17
CD	Continuous Delivery	19
CI	Continuous Integration	19
GUI	Graphical User Interface	1
MCMC	Markov chain Monte-Carlo	1
TOML	Tom’s Obvious, Minimal Language	12
WebDAV	Web Distributed Authoring and Versioning	5

## A Accessing VTODO properties

A profiler may be used to identify parts of the code that are slow. In the case of the GUI, the Item Delegate’s `paint()` method must be performant in order to provide a smooth user experience. This can be achieved when looking at different means of accessing the UID of a task, which as per Table 8 is a highly frequent action. Here is a comparison of different approaches:

```

1 In [1]: %timeit str(t.icalendar_component["uid"])
2         122 µs ± 1.06 µs per loop (7 runs, 10,000 loops each)
3 In [2]: %timeit t.vtodo.contents["uid"][0].value
4         355 ns ± 7.14 ns per loop (7 runs, 1,000,000 loops each)
5 In [3]: %timeit
6         ↪ t.vobject_instance.contents["vtodo"][0].contents["uid"][0].value
           296 ns ± 7.06 ns per loop (7 runs, 1,000,000 loops each)

```

```

7 In [4]: %timeit
      ↪ t._vobject_instance.contents["vtodo"][0].contents["uid"][0].value
8 208 ns ± 23.7 ns per loop (7 runs, 10,000,000 loops each)

```

As we can see, the last option is the fastest which has therefore been implemented in `todo.py`.

**Table 8:** Profile obtained by running `$ ./main.py --profile | grep todo.py`.

ncalls	tottime	percall	cumtime	percall	filename:lineno	function
16958	0.008	0.000	0.939	0.000	todo.py:36	vtodo
32475	0.047	0.000	0.705	0.000	todo.py:96	uid
856	0.003	0.000	0.579	0.001	todo.py:26	upgrade
117	0.000	0.000	0.489	0.004	todo.py:111	priority
417	0.001	0.000	0.461	0.001	todo.py:121	isIncomplete
5512	0.003	0.000	0.278	0.000	todo.py:45	summary
856	0.002	0.000	0.112	0.000	todo.py:21	__init__
1363	0.006	0.000	0.024	0.000	todo.py:164	__lt__
7844	0.004	0.000	0.009	0.000	todo.py:61	dueDate
2605	0.001	0.000	0.003	0.000	todo.py:85	dueTime

## B Sphinx Documentation

As mentioned above, this report also contains the documentation generated from the docstrings. It starts on the next page.

## MELON

Index file of the *melon* library, a task scheduling software package.

### Modules

<i>melon.calendar</i>	This module contains the Calendar class.
<i>melon.config</i>	This submodule only does one thing: loading configuration from the right place.
<i>melon.melon</i>	This file is the main entry point of the melon package, containing the Melon class, the main point of contact for users of this package.
<i>melon.scheduler</i>	Melon.Scheduler library housing different implementations of an MCMC task scheduler.
<i>melon.todo</i>	This module contains the Todo class.
<i>melon.visualise</i>	A collection of (quality measure) visualisation helpers.

## 1.1 melon.calendar

This module contains the Calendar class.

### Classes

<i>Calendar</i> (calendar)	Class representing a calendar (or todo list, if you want to call it that, this name is given by CalDAV).
<i>Syncable</i> (calendar, objects, sync_token)	The synchronisable collection of CalDAV objects, handling efficient syncs between server and client.

### 1.1.1 melon.calendar.Calendar

**class** `melon.calendar.Calendar(calendar: Calendar)`

Class representing a calendar (or todo list, if you want to call it that, this name is given by CalDAV). A calendar is a collection of objects that can be synced to a CalDAV server. In this implementation, the objects are stored within the *syncable* subclass.

**\_\_init\_\_**(calendar: Calendar) → None

A copy constructor

**Args:**

calendar (caldav.Calendar): Argument

#### Methods

<code>__init__(calendar)</code>	A copy constructor
<code>add_event([ical, no_overwrite, no_create])</code>	Add a new event to the calendar, with the given ical.
<code>add_journal([ical, no_overwrite, no_create])</code>	Add a new journal entry to the calendar, with the given ical.
<code>add_todo([ical, no_overwrite, no_create])</code>	Add a new task to the calendar, with the given ical.
<code>build_date_search_query(start[, end, ...])</code>	WARNING: DEPRECATED
<code>build_search_xml_query([comp_class, todo, ...])</code>	This method will produce a caldav search query as an etree object.
<code>calendar_multiget(event_urls)</code>	get multiple events' data @author <a href="mailto:mtor-ange@gmail.com">mtor-ange@gmail.com</a> @type events list of Event
<code>children([type])</code>	List children, using a propfind (resourcetype) on the parent object, at depth = 1.
<code>createTodo([summary])</code>	Args:
<code>date_search(start[, end, compfilter, ...])</code>	Deprecated.
<code>delete()</code>	Delete the object.
<code>event(uid)</code>	
<code>event_by_uid(uid)</code>	
<code>event_by_url(href[, data])</code>	Returns the event with the given URL
<code>events()</code>	List all events from the calendar.
<code>freebusy_request(start, end)</code>	Search the calendar, but return only the free/busy information.
<code>get_display_name()</code>	Get calendar display name
<code>get_properties([props, depth, ...])</code>	Get properties (PROPFIND) for this object.
<code>get_property(prop[, use_cached])</code>	
<code>get_supported_components()</code>	returns a list of component types supported by the calendar, in string format (typically ['VJOURNAL', 'VTODO', 'VEVENT'])
<code>journal_by_uid(uid)</code>	
<code>journals()</code>	List all journals from the calendar.
<code>loadFromFile(client, principal, name, ...)</code>	Args:
<code>object_by_uid(uid[, comp_filter, comp_class])</code>	Get one event from the calendar.
<code>objects([sync_token, load_objects])</code>	objects_by_sync_token aka objects

continues on next page



Table 1 – continued from previous page

<code>objects_by_sync_token([sync_token, load_objects])</code>	<code>objects_by_sync_token</code> aka <code>objects</code>
<code>save()</code>	The save method for a calendar is only used to create it, for now.
<code>save_event([ical, no_overwrite, no_create])</code>	Add a new event to the calendar, with the given ical.
<code>save_journal([ical, no_overwrite, no_create])</code>	Add a new journal entry to the calendar, with the given ical.
<code>save_todo([ical, no_overwrite, no_create])</code>	Add a new task to the calendar, with the given ical.
<code>save_with_invites(ical, attendees, ...)</code>	sends a schedule request to the server.
<code>search([xml, comp_class, todo, ...])</code>	Creates an XML query, does a REPORT request towards the server and returns objects found, eventually sorting them before delivery.
<code>set_properties([props])</code>	Set properties (PROPPATCH) for this object.
<code>storageObject()</code>	Returns:
<code>storeToFile()</code>	Save the calendar objects to a local file on disk, in iCal format.
<code>sync()</code>	Synchronise me
<code>todo_by_uid(uid)</code>	
<code>todos([sort_keys, include_completed, sort_key])</code>	fetches a list of todo events (refactored to a wrapper around search)

## Attributes

<code>canonical_url</code>
<code>client</code>
<code>id</code>
<code>name</code>
<code>parent</code>
<code>url</code>

**createTodo**(*summary: str = 'An exciting new task!'*)

**Args:**

`summary (str): Argument`

**static loadFromFile**(*client: DAVClient, principal: Principal, name: str, sync\_token: str, url: str*)

**Args:**

`client (caldav.DAVClient): Argument` `principal (caldav.Principal): Argument` `name (str): Argument` `sync_token (str): Argument` `url (str): Argument`

**storageObject**() → dict

**Returns:**

(dict):

### **storeToFile()**

Save the calendar objects to a local file on disk, in iCal format.

### **sync()**

Synchronise me

## 1.1.2 melon.calendar.Syncable

**class** `melon.calendar.Syncable(calendar, objects, sync_token)`

The synchronisable collection of CalDAV objects, handling efficient syncs between server and client.

**\_\_init\_\_**(calendar, objects, sync\_token)

### Methods

<code>__init__(calendar, objects, sync_token)</code>	
<code>objects_by_url()</code>	returns a dict of the contents of the SynchronizableCalendarObjectCollection, URLs -> objects.
<code>sync()</code>	This method will contact the caldav server, request all changes from it, and sync up the collection
<code>upgrade(synchronisable, calendarName)</code>	Upgrades the third-party caldav.SynchronizableCalendarObjectCollection to a Syncable
<code>upgradeObjects(calendarName)</code>	Converts all objects in self.objects to Todos.

### Attributes

<code>calendar</code>
<code>objects</code>
<code>sync_token</code>

**static upgrade**(*synchronisable: SynchronizableCalendarObjectCollection, calendarName: str*) → *Syncable*

Upgrades the third-party caldav.SynchronizableCalendarObjectCollection to a Syncable

#### **Args:**

*synchronisable* (caldav.SynchronizableCalendarObjectCollection): the original instance

#### **Returns:**

(Syncable): the syncable

**upgradeObjects**(*calendarName: str*)

Converts all objects in self.objects to Todos.

## 1.2 melon.config

This submodule only does one thing: loading configuration from the right place.

### Functions

<code>load_config()</code>	Loads, or re-loads, the configuration file.
----------------------------	---

### 1.2.1 melon.config.load\_config

`melon.config.load_config()`

Loads, or re-loads, the configuration file.

## 1.3 melon.melon

This file is the main entry point of the melon package, containing the Melon class, the main point of contact for users of this package. It can be initialised like this:

```
melon = Melon() melon.autoInit()
```

### Classes

<code>Melon([url, username, password, maxCalendars])</code>	The Melon class, wrapping a caldav client and principal, loading specifics from the config.
---	---

### 1.3.1 melon.melon.Melon

```
class melon.melon.Melon(url='http://localhost:8000/dav/user/calendars/', username=None, password=None,
                        maxCalendars: int | None = None)
```

The Melon class, wrapping a caldav client and principal, loading specifics from the config. Through me, users have access to calendars and todos. I also handle load, sync and store functionality.

```
__init__(url='http://localhost:8000/dav/user/calendars/', username=None, password=None, maxCalendars:
          int | None = None) → None
```

Initialises the Melon client

#### Args:

url (str, optional): URL to the CalDAV server. Defaults to CONFIG["client"]["url"]. username (str, optional): Username. Defaults to CONFIG["client"]["username"]. password (str, optional): Password. Defaults to CONFIG["client"]["password"]. maxCalendars (int, optional): the highest number of calendars to load. Useful for testing.

## Methods

<code>__init__</code> ([url, username, password, maxCalendars])	Initialises the Melon client
<code>addOrUpdateTask</code> (todo)	Args:
<code>allIncompleteTasks</code> ()	Returns all incomplete todos
<code>allTasks</code> ()	Returns an iterable of all tasks in all calendars as a single list
<code>autoInit</code> ()	Args:
<code>connect</code> ()	Args:
<code>exportScheduleAsCalendar</code> (scheduling)	A read-only ICS calendar containing scheduled tasks.
<code>fetch</code> ()	Args:
<code>findTask</code> (string)	Finds a task given a search query
<code>getTask</code> (uid)	Returns task with given UID
<code>load</code> ()	Args:
<code>scheduleAllAndExport</code> (file[, Scheduler])	Runs the scheduler on all tasks and exports as an ICS file.
<code>store</code> ()	Args:
<code>syncAll</code> ()	Args:
<code>syncCalendar</code> (calendar)	Args:
<code>tasksToSchedule</code> ()	Returns all incomplete tasks as scheduler.Task objects

## Attributes

HIDDEN\_CALENDARS

**addOrUpdateTask**(*todo*: [Todo](#))

**Args:**  
todo ([Todo](#)): Argument

**allIncompleteTasks**() → Iterable[[Todo](#)]

Returns all incomplete todos

**Yields:**  
Iterator[Iterable[[Todo](#)]]: incomplete todos

**allTasks**() → Iterable[[Todo](#)]

Returns an iterable of all tasks in all calendars as a single list

**Yields:**  
Iterator[Iterable[[Todo](#)]]: iterator of all tasks

**autoInit**()

Args:

**connect**()

Args:

**exportScheduleAsCalendar**(*scheduling*: Mapping[str, TimeSlot]) → Calendar

A read-only ICS calendar containing scheduled tasks. Can be stored to disk using `schedule.to_ical()`.

**Args:**

`scheduling` (Mapping[str, TimeSlot]): Mapping of task UID to TimeSlot

**Returns:**

`icalendar.Calendar`: the calendar containing events (time slots) proposed for the completion of tasks

**fetch()**

Args:

**findTask**(*string*: str) → Iterable[*Todo*]

Finds a task given a search query

**Args:**

`string` (str): the search query.

**Yields:**

Iterator[Iterable[*Todo*]]: the generated search results.

**getTask**(*uid*: str) → *Todo*

Returns task with given UID

**Args:**

`uid` (str): the Unique Identifier

**Raises:**

`ValueError`: when the task could not be found

**Returns:**

*Todo*: the *Todo* with given uid

**load()**

Args:

**scheduleAllAndExport**(*file*: str, *Scheduler*: type[melon.scheduler.base.AbstractScheduler] = <class 'melon.scheduler.purepython.MCMCScheduler'>)

Runs the scheduler on all tasks and exports as an ICS file.

**Args:**

`file` (str): filesystem path that the ics file should be exported to

**store()**

Args:

**syncAll()**

Args:

**syncCalendar**(*calendar*: Calendar)

**Args:**

`calendar`: Argument

**tasksToSchedule**() → list[melon.scheduler.base.Task]

Returns all incomplete tasks as scheduler.Task objects

**Returns:**

list[Task]: `_description_`

## 1.4 melon.scheduler

Melon.Scheduler library housing different implementations of an MCMC task scheduler.

### Modules

<code>melon.scheduler.base</code>	The scheduler algorithm
<code>melon.scheduler.cpp</code>	The scheduler algorithm
<code>melon.scheduler.libcppscheduler</code>	Schedule tasks
<code>melon.scheduler.libscheduler</code>	This module is implemented in Rust.
<code>melon.scheduler.numba</code>	Numba implementation of the scheduler algorithm.
<code>melon.scheduler.purepython</code>	The scheduler algorithm
<code>melon.scheduler.rust</code>	The scheduler algorithm

### 1.4.1 melon.scheduler.base

The scheduler algorithm

### Functions

<code>generateDemoTasks()</code>	Generates a fixed set of demo tasks.
<code>generateManyDemoTasks(N[, proportionOfDueDates])</code>	Generates a larger set of randomly generated demo tasks.

#### melon.scheduler.base.generateDemoTasks

`melon.scheduler.base.generateDemoTasks()` → list[*melon.scheduler.base.Task*]

Generates a fixed set of demo tasks.

**Returns:**

list[Task]: the generated list of tasks

#### melon.scheduler.base.generateManyDemoTasks

`melon.scheduler.base.generateManyDemoTasks(N: int, proportionOfDueDates: float = 0.5)` → list[*melon.scheduler.base.Task*]

Generates a larger set of randomly generated demo tasks.

**Args:**

N (int): Number of tasks to be generated  
proportionOfDueDates (float, optional): what percentage (from 0 to 1) of tasks should have a due date.

Defaults to 0.5.

**Returns:**

list[Task]: the list of tasks

## Classes

<code>AbstractScheduler</code> (tasks)	Abstract Base Class (ABC) for schedulers.
<code>Task</code> (uid, duration, priority, location, due)	Slim struct representing a task
<code>TimeSlot</code> (timestamp, duration)	Slim struct representing a time slot, so an event consisting of a start and end date.

### melon.scheduler.base.AbstractScheduler

**class** melon.scheduler.base.**AbstractScheduler**(tasks: list[melon.scheduler.base.Task])

Abstract Base Class (ABC) for schedulers.

**\_\_init\_\_**(tasks: list[melon.scheduler.base.Task]) → None

Initialises the scheduler, working on a set of pre-defined tasks.

**Args:**

tasks (list[Task]): the tasks to be scheduled

### Methods

<b>__init__</b> (tasks)	Initialises the scheduler, working on a set of pre-defined tasks.
<code>schedule</code> ()	Schedules the tasks using an MCMC procedure.
<code>uidTaskMap</code> ()	Generates a dictionary for task lookup by UID.

**schedule**() → Mapping[str, TimeSlot]

Schedules the tasks using an MCMC procedure.

**Returns:**

Mapping[str, TimeSlot]: the resulting map of Tasks to TimeSlots

**uidTaskMap**() → Mapping[str, Task]

Generates a dictionary for task lookup by UID.

**Returns:**

Mapping[str, Task]: the dictionary keyed by UID of each task.

### melon.scheduler.base.Task

**class** melon.scheduler.base.**Task**(uid: str, duration: float, priority: int, location: int, due: datetime | None)

Slim struct representing a task

**\_\_init\_\_**(uid: str, duration: float, priority: int, location: int, due: datetime | None) → None

### Methods

<code>__init__(uid, duration, priority, location, due)</code>	
<code>asTuple(start)</code>	Returns a low-level representation of this instance.

### Attributes

<code>uid</code>
<code>duration</code>
<code>priority</code>
<code>location</code>
<code>due</code>

**asTuple**(*start: datetime*) → tuple[str, float, int, int, float]

Returns a low-level representation of this instance.

**Args:**

start (datetime): Start time reference for the due date

**Returns:**

**tuple[str, float, int, int, float]:** low-level representation (uid, duration, priority, location, due).  
due is 0 if there is no due date.

### melon.scheduler.base.TimeSlot

**class** melon.scheduler.base.**TimeSlot**(*timestamp: datetime, duration: float*)

Slim struct representing a time slot, so an event consisting of a start and end date.

`__init__(timestamp: datetime, duration: float)` → None

### Methods

<code>__init__(timestamp, duration)</code>
--



## Attributes

<code>end</code>	Returns:
<code>timedelta</code>	Returns:
<code>timestamp</code>	
<code>duration</code>	

**property end:** `datetime`

**Returns:**

`datetime`: the end timestamp of this time slot

**property timedelta:** `timedelta`

**Returns:**

`timedelta`: the duration as a `datetime.timedelta` instance

## 1.4.2 melon.scheduler.cpp

The scheduler algorithm

## Classes

<code>CppMCMCScheduler</code> (tasks)	Markov Chain Monte-Carlo Task Scheduler, implemented in Rust.
---------------------------------------	---

### melon.scheduler.cpp.CppMCMCScheduler

**class** `melon.scheduler.cpp.CppMCMCScheduler`(tasks: list[`melon.scheduler.base.Task`])

Markov Chain Monte-Carlo Task Scheduler, implemented in Rust.

**\_\_init\_\_**(tasks: list[`melon.scheduler.base.Task`]) → None

Initialises the scheduler, working on a set of pre-defined tasks.

**Args:**

tasks (list[Task]): the tasks to be scheduled

## Methods

<code>__init__</code> (tasks)	Initialises the scheduler, working on a set of pre-defined tasks.
<code>schedule</code> ()	Runs the Rust implementation of the scheduler.
<code>uidTaskMap</code> ()	Generates a dictionary for task lookup by UID.

**schedule()**  $\rightarrow$  Mapping[str, *TimeSlot*]

Runs the Rust implementation of the scheduler.

**Returns:**

Mapping[str, TimeSlot]: the resulting schedule

### 1.4.3 melon.scheduler.libcppscheduler

Schedule tasks

#### Functions

<i>schedule</i> (arg0)	Schedule tasks
------------------------	----------------

#### melon.scheduler.libcppscheduler.schedule

melon.scheduler.libcppscheduler.**schedule**(arg0: list)  $\rightarrow$  list

Schedule tasks

### 1.4.4 melon.scheduler.libscheduler

This module is implemented in Rust.

### 1.4.5 melon.scheduler.numba

Numba implementation of the scheduler algorithm.

#### Functions

<i>computeEnergy</i> (tasks, state)	For the given state, compute an MCMC energy (the lower, the better)
<i>mcmcSweep</i> (tasks, initialState, temperature)	Performs a full MCMC sweep
<i>permuteState</i> (state)	Proposes a new state to use instead of the old state.
<i>schedule</i> (tasks)	Schedules the given tasks in low-level representation into calendar.
<i>spreadTasks</i> (tasks)	Spreads the given list of tasks across the available slots in the calendar, in order.

### melon.scheduler.numba.computeEnergy

`melon.scheduler.numba.computeEnergy(tasks: Sequence[tuple[str, float, int, int, float]], state: list[int]) → float`

For the given state, compute an MCMC energy (the lower, the better)

**Args:**

tasks (Sequence[tuple[str, float, int, int, float]]): list of tasks (uid, duration, priority, location, due) state (State): state of the MCMC algorithm

**Returns:**

float: the energy / penalty for this state

### melon.scheduler.numba.mcmcSweep

`melon.scheduler.numba.mcmcSweep(tasks: Sequence[tuple[str, float, int, int, float]], initialState: list[int], temperature: float) → list[int]`

Performs a full MCMC sweep

**Args:**

tasks (Sequence[tuple[str, float, int, int, float]]): list of tasks initialState (State): initial ordering temperature (float): temperature for Simulated Annealing

**Returns:**

State: new state

### melon.scheduler.numba.permuteState

`melon.scheduler.numba.permuteState(state: list[int]) → list[int]`

Proposes a new state to use instead of the old state.

**Returns:**

State: the new state, a list of indices within tasks representing traversal order

### melon.scheduler.numba.schedule

`melon.scheduler.numba.schedule(tasks: Sequence[tuple[str, float, int, int, float]]) → Sequence[tuple[str, float, float]]`

Schedules the given tasks in low-level representation into calendar.

**Args:**

tasks (Sequence[tuple[str, float, int, int, float]]): vector of tasks (uid, duration, priority, location, due)

**Returns:**

Sequence[tuple[str, float, float]]: vector of allocated timeslots (uid, timestamp, duration)

### melon.scheduler.numba.spreadTasks

`melon.scheduler.numba.spreadTasks(tasks: Sequence[tuple[str, float, int, int, float]]) → Sequence[tuple[str, float, float]]`

Spreads the given list of tasks across the available slots in the calendar, in order.

**Args:**

tasks (Sequence[Task]): list of tasks to schedule

**Yields:**

Iterator[tuple[str, TimeSlot]]: pairs of (UID, TimeSlot), returned in chronological order

### Classes

<code>NumbaMCMCScheduler(tasks)</code>	Markov Chain Monte-Carlo Task Scheduler, implemented in Python with numba speed-up.
--	---

### melon.scheduler.numba.NumbaMCMCScheduler

**class** `melon.scheduler.numba.NumbaMCMCScheduler(tasks: list[melon.scheduler.base.Task])`

Markov Chain Monte-Carlo Task Scheduler, implemented in Python with numba speed-up.

`__init__(tasks: list[melon.scheduler.base.Task]) → None`

Initialises the scheduler, working on a set of pre-defined tasks.

**Args:**

tasks (list[Task]): the tasks to be scheduled

### Methods

<code>__init__(tasks)</code>	Initialises the scheduler, working on a set of pre-defined tasks.
<code>schedule()</code>	Runs the Rust implementation of the scheduler.
<code>uidTaskMap()</code>	Generates a dictionary for task lookup by UID.

`schedule() → Mapping[str, TimeSlot]`

Runs the Rust implementation of the scheduler.

**Returns:**

Mapping[str, TimeSlot]: the resulting schedule

## 1.4.6 melon.scheduler.purepython

The scheduler algorithm

### Classes

<code>AvailabilityManager()</code>	This class manages the user's availability in a calendar.
<code>MCMCScheduler(tasks)</code>	MCMC class to schedule tasks to events in a calendar.

### melon.scheduler.purepython.AvailabilityManager

**class** `melon.scheduler.purepython.AvailabilityManager`

This class manages the user's availability in a calendar.

`__init__()` → None

Initialises the availability manager according to defaults.

### Methods

<code>__init__()</code>	Initialises the availability manager according to defaults.
<code>generateNextSlot(previous)</code>	Following a daily schedule, returns the next possible working slot
<code>spreadTasks(tasks)</code>	Spreads the given list of tasks across the available slots in the calendar, in order.
<code>startingSlot()</code>	Starting slot, starting at 10am today

**generateNextSlot**(*previous*: `TimeSlot`) → `TimeSlot`

Following a daily schedule, returns the next possible working slot

**Args:**

*previous* (`TimeSlot`): the previous working slot

**Returns:**

`TimeSlot`: the next working slot

**spreadTasks**(*tasks*: `Iterable[Task]`) → `Iterable[tuple[str, melon.scheduler.base.TimeSlot]]`

Spreads the given list of tasks across the available slots in the calendar, in order.

**Args:**

*tasks* (`Iterable[Task]`): list of tasks to schedule

**Yields:**

`Iterator[tuple[str, TimeSlot]]`: pairs of (UID, `TimeSlot`), returned in chronological order

**startingSlot**() → `TimeSlot`

Starting slot, starting at 10am today

**Returns:**

`TimeSlot`: the first working slot

## melon.scheduler.purepython.MCMCScheduler

**class** melon.scheduler.purepython.MCMCScheduler(*tasks: list[melon.scheduler.base.Task]*)

MCMC class to schedule tasks to events in a calendar.

**\_\_init\_\_**(*tasks: list[melon.scheduler.base.Task]*) → None

Initialises the MCMC scheduler, working on a set of pre-defined tasks.

**Args:**

tasks (list[Task]): the tasks to be scheduled

## Methods

<code>__init__(tasks)</code>	Initialises the MCMC scheduler, working on a set of pre-defined tasks.
<code>computeEnergy(state)</code>	For the given state, compute an MCMC energy (the lower, the better)
<code>mcmcSweep()</code>	Performs a full MCMC sweep
<code>permuteState()</code>	Proposes a new state to use instead of the old state.
<code>schedule()</code>	Schedules the tasks using an MCMC procedure.
<code>uidTaskMap()</code>	Generates a dictionary for task lookup by UID.

## Attributes

<code>State</code>	alias of tuple[int, ...]
--------------------	--------------------------

## State

alias of tuple[int, ...]

**computeEnergy**(*state: tuple[int, ...]*) → float

For the given state, compute an MCMC energy (the lower, the better)

**Args:**

state (State): state of the MCMC algorithm

**Returns:**

float: the energy / penalty for this state

**mcmcSweep()**

Performs a full MCMC sweep

**permuteState()** → tuple[int, ...]

Proposes a new state to use instead of the old state.

**Returns:**

State: the new state, a list of indices within self.tasks representing traversal order

**schedule()** → Mapping[str, TimeSlot]

Schedules the tasks using an MCMC procedure.

**Returns:**

Mapping[str, TimeSlot]: the resulting map of Tasks to TimeSlots

### 1.4.7 melon.scheduler.rust

The scheduler algorithm

#### Classes

<code>RustyMCMCScheduler(tasks)</code>	Markov Chain Monte-Carlo Task Scheduler, implemented in Rust.
--	---

#### melon.scheduler.rust.RustyMCMCScheduler

**class** `melon.scheduler.rust.RustyMCMCScheduler`(*tasks*: *list*[`melon.scheduler.base.Task`])

Markov Chain Monte-Carlo Task Scheduler, implemented in Rust.

**\_\_init\_\_**(*tasks*: *list*[`melon.scheduler.base.Task`]) → None

Initialises the scheduler, working on a set of pre-defined tasks.

**Args:**

*tasks* (list[Task]): the tasks to be scheduled

#### Methods

<code>__init__</code> ( <i>tasks</i> )	Initialises the scheduler, working on a set of pre-defined tasks.
<code>schedule</code> ()	Runs the Rust implementation of the scheduler.
<code>uidTaskMap</code> ()	Generates a dictionary for task lookup by UID.

**schedule**() → Mapping[str, *TimeSlot*]

Runs the Rust implementation of the scheduler.

**Returns:**

Mapping[str, TimeSlot]: the resulting schedule

## 1.5 melon.todo

This module contains the Todo class.

#### Classes

<code>Todo(*args[, calendarName])</code>	A class representing todos (= tasks), subclassing the <code>calendar.Calendar</code> object which in turn stores VTOD data.
--	---

### 1.5.1 melon.todo.TODO

**class** `melon.todo.TODO(*args, calendarName: str | None = None, **kwargs)`

A class representing todos (= tasks), subclassing the caldav.TODO object which in turn stores VTODO data.

**\_\_init\_\_**(\*args, calendarName: str | None = None, \*\*kwargs)

Initialises the base class

#### Methods

<code>__init__(*args[, calendarName])</code>	Initialises the base class
<code>accept_invite([calendar])</code>	
<code>add_attendee(attendee[, no_default_parameters])</code> <code>add_organizer()</code>	For the current (event/todo/journal), add an attendee. goes via self.client, finds the principal, figures out the right attendee-format and adds an organizer line to the event
<code>change_attendee_status([attendee])</code>	
<code>children([type])</code>	List children, using a propfind (resourcetype) on the parent object, at depth = 1.
<code>complete([completion_timestamp, ...])</code> <code>copy([keep_uid, new_parent])</code>	Args: Events, todos etc can be copied within the same calendar, to another calendar or even to another caldav server
<code>decline_invite([calendar])</code>	
<code>delete()</code>	Delete the object.
<code>expand_rrule(start, end)</code>	This method will transform the calendar content of the event and expand the calendar data from a "master copy" with RRULE set and into a "recurrence set" with RECURRENCE-ID set and no RRULE set.
<code>generate_url()</code>	
<code>get_display_name()</code>	Get calendar display name
<code>get_due()</code>	A VTODO may have due or duration set.
<code>get_duration()</code>	According to the RFC, either DURATION or DUE should be set for a task, but never both - implicitly meaning that DURATION is the difference between DTSTART and DUE (personally I believe that's stupid.
<code>get_properties([props, depth, ...])</code> <code>get_property(prop[, use_cached])</code>	Get properties (PROPFIND) for this object.
<code>isComplete()</code>	Returns:
<code>isIncomplete()</code>	Returns:
<code>isTodo()</code>	Returns:
<code>is_invite_request()</code>	
<code>is_loaded()</code>	

continues on next page



Table 2 – continued from previous page

<code>load([only_if_unloaded])</code>	(Re)load the object from the caldav server.
<code>save([no_overwrite, no_create, obj_type, ...])</code>	Save the object, can be used for creation and update.
<code>set_due(due[, move_dtstart, check_dependent])</code>	The RFC specifies that a VTODO cannot have both due and duration, so when setting due, the duration field must be evicted
<code>set_duration(duration[, movable_attr])</code>	If DTSTART and DUE/DTEND is already set, one of them should be moved.
<code>set_properties([props])</code>	Set properties (PROPPATCH) for this object.
<code>set_relation(other[, reltype, set_reverse])</code>	Sets a relation between this object and another object (given by uid or object).
<code>split_expanded()</code>	
<code>tentatively_accept_invite([calendar])</code>	
<code>toTask()</code>	Converts this Todo into the scheduler-compatible Task struct.
<code>uncomplete()</code>	Undo completion - marks a completed task as not completed
<code>upgrade(todo, calendarName)</code>	A copy constructor constructing a melon.TODO from a caldav.TODO

## Attributes

<code>canonical_url</code>	
<code>client</code>	
<code>data</code>	vCal representation of the object as normal string
<code>dueDate</code>	Returns:
<code>dueDateTime</code>	Returns:
<code>dueTime</code>	Returns:
<code>icalendar_component</code>	icalendar component - should not be used with recurrence sets
<code>icalendar_instance</code>	icalendar instance of the object
<code>id</code>	
<code>instance</code>	vobject instance of the object
<code>name</code>	
<code>parent</code>	
<code>priority</code>	Returns:
<code>summary</code>	Returns:
<code>uid</code>	This method has to be fast, as it is accessed very frequently according to profiler output.
<code>url</code>	
<code>vobject_instance</code>	vobject instance of the object
<code>vtodo</code>	Returns the VTODO object stored within me.
<code>wire_data</code>	vCal representation of the object in wire format (UTF-8, CRLN)

**complete**(*completion\_timestamp: datetime | None = None, handle\_rrule: bool = True, rrule\_mode: Literal['safe', 'this\_and\_future'] = 'safe'*) → None

### Args:

**completion\_timestamp** (Union[datetime.datetime, None], optional): Argument (default is None)

**handle\_rrule** (bool, optional): Argument (default is True)

**rrule\_mode** (Literal['safe', 'this\_and\_future'], optional): Argument (default is 'safe')

**property dueDate:** date | None

**Returns:**  
(datetime.date | None):

**property dueDateTime:** datetime | None

**Returns:**  
(datetime.datetime | None):

**property dueTime:** `time | None`

**Returns:**  
(datetime.time | None):

**isComplete()** → bool

**Returns:**  
(bool):

**isIncomplete()** → bool

**Returns:**  
(bool):

**isTodo()** → bool

**Returns:**  
bool: whether this object is a VTODOD or not (i.e. an event or journal).

**property priority:** `int`

**Returns:**  
**int:** the priority of the task, an integer between 1 and 9,  
where 1 corresponds to the highest and 9 to the lowest priority

**property summary:** `str`

**Returns:**  
(str):

**toTask()** → *Task*

Converts this Todo into the scheduler-compatible Task struct.

**Returns:**  
Task: a melon.scheduler.Task

**property uid:** `str | None`

This method has to be fast, as it is accessed very frequently according to profiler output. Therefore we use do not use self.vtodo.

**Returns:**  
(Union[str, None]):

**static upgrade(todo: Todo, calendarName: str) → Todo**

A copy constructor constructing a melon.TODO from a caldav.TODO

**Args:**  
todo (caldav.TODO): Argument calendarName (str): Argument

**property vtodo:** `Component`

Returns the VTODOD object stored within me. This is faster than accessing the icalendar\_component.

**Returns:**  
(vobject.base.Component):

## 1.6 melon.visualise

A collection of (quality measure) visualisation helpers.

### Functions

<code>plotConvergence(data, labels[, filename])</code>	Plots convergence data to a file
<code>radarChart(values, title[, filename])</code>	Plots a helpful priority chart.

### 1.6.1 melon.visualise.plotConvergence

`melon.visualise.plotConvergence(data: ndarray, labels: Sequence, filename: str | None = None)`

Plots convergence data to a file

**Args:**

data (np.array): data of temp, E\_avg, E\_var filename (str): path to file

### 1.6.2 melon.visualise.radarChart

`melon.visualise.radarChart(values: tuple[float, float, float], title: str, filename: str | None = None)`

Plots a helpful priority chart.

Adapted from <https://gist.github.com/sausheong/3997c7ba8f42278866d2d15f9e63f7ad>.

**Args:**

data (tuple[float, float, float]): data title (str): titles of plots

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