This document describes the current stable version of Celery (4.2). For development docs, go here.

Canvas: Designing Work-flows

Signatures

New in version 2.0.

You just learned how to call a task using the tasks `delay` method in the calling guide, and this is often all you need, but sometimes you may want to pass the signature of a task invocation to another process or as an argument to another function.

A **`signature()`** wraps the arguments, keyword arguments, and execution options of a single task invocation in a way such that it can be passed to functions or even serialized and sent across the wire.

- You can create a signature for the `add` task using its name like this:

  ```
  >>> from celery import signature
  >>> signature('tasks.add', args=(2, 2), countdown=10)
  tasks.add(2, 2)
  ```

  This task has a signature of arity 2 (two arguments): `(2, 2)`, and sets the countdown execution option to 10.

- or you can create one using the task's `signature` method:

  ```
  >>> add.signature((2, 2), countdown=10)
  tasks.add(2, 2)
  ```

- There's also a shortcut using star arguments:

  ```
  >>> add.s(2, 2)
  tasks.add(2, 2)
  ```

- Keyword arguments are also supported:

  ```
  >>> add.s(2, 2, debug=True)
  tasks.add(2, 2, debug=True)
  ```

- From any signature instance you can inspect the different fields:

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```
>>> s = add.signature((2, 2), {'debug': True}, countdown=10)
>>> s.args
(2, 2)
>>> s.kwargs
{'debug': True}
>>> s.options
{'countdown': 10}
```

- It supports the "Calling API" of `delay`, `apply_async`, etc., including being called directly (`__call__`).

  Calling the signature will execute the task inline in the current process:

  ```
  >>> add(2, 2)
  4
  >>> add.s(2, 2)()
  4
  ```

  `delay` is our beloved shortcut to `apply_async` taking star-arguments:

  ```
  >>> result = add.delay(2, 2)
  >>> result.get()
  4
  ```

  `apply_async` takes the same arguments as the `app.Task.apply_async()` method:

  ```
  >>> add.apply_async(args, kwargs, **options)
  >>> add.signature(args, kwargs, **options).apply_async()

  >>> add.apply_async((2, 2), countdown=1)
  >>> add.signature((2, 2), countdown=1).apply_async()
  ```

- You can't define options with `s()`, but a chaining `set` call takes care of that:

  ```
  >>> add.s(2, 2).set(countdown=1)
  proj.tasks.add(2, 2)
  ```

Partials

With a signature, you can execute the task in a worker:

```
>>> add.s(2, 2).delay()
>>> add.s(2, 2).apply_async(countdown=1)
```

Or you can call it directly in the current process:

```
>>> add.s(2, 2)()
4
```

Specifying additional args, kwargs, or options to `apply_async`/`delay` creates partials:

- Any arguments added will be prepended to the args in the signature:

  ```
  >>> partial = add.s(2)          # incomplete signature
  >>> partial.delay(4)            # 4 + 2
  >>> partial.apply_async((4,))  # same
  ```

- Any keyword arguments added will be merged with the kwargs in the signature, with the new keyword arguments taking precedence:

```
>>> s = add.s(2, 2)
>>> s.delay(debug=True)                    # -> add(2, 2, debug=Tr
>>> s.apply_async(kwargs={'debug': True})  # same
```

- Any options added will be merged with the options in the signature, with the new options taking precedence:

```
>>> s = add.signature((2, 2), countdown=10)
>>> s.apply_async(countdown=1)  # countdown is now 1
```

You can also clone signatures to create derivatives:

```
>>> s = add.s(2)
proj.tasks.add(2)

>>> s.clone(args=(4,), kwargs={'debug': True})
proj.tasks.add(4, 2, debug=True)
```

Immutability

New in version 3.0.

Partials are meant to be used with callbacks, any tasks linked, or chord callbacks will be applied with the result of the parent task. Sometimes you want to specify a callback that doesn't take additional arguments, and in that case you can set the signature to be immutable:

```
>>> add.apply_async((2, 2), link=reset_buffers.signature(immutable=True)
```

The `.si()` shortcut can also be used to create immutable signatures:

```
>>> add.apply_async((2, 2), link=reset_buffers.si())
```

Only the execution options can be set when a signature is immutable, so it's not possible to call the signature with partial args/kwargs.

> **Note:**
>
> In this tutorial I sometimes use the prefix operator `~` to signatures. You probably shouldn't use it in your production code, but it's a handy shortcut when experimenting in the Python shell:
>
> ```
> >>> ~sig
>
> >>> # is the same as
> >>> sig.delay().get()
> ```

Callbacks

New in version 3.0.

Callbacks can be added to any task using the `link` argument to `apply_async`:

```
add.apply_async((2, 2), link=other_task.s())
```

The callback will only be applied if the task exited successfully, and it will be applied with the return value of the parent task as argument.

As I mentioned earlier, any arguments you add to a signature, will be prepended to the arguments specified by the signature itself!

If you have the signature:

```
>>> sig = add.s(10)
```

then *sig.delay(result)* becomes:

```
>>> add.apply_async(args=(result, 10))
```

…

Now let's call our `add` task with a callback using partial arguments:

```
>>> add.apply_async((2, 2), link=add.s(8))
```

As expected this will first launch one task calculating $2 + 2$, then another task calculating $4 + 8$.

The Primitives

New in version 3.0.

Overview

- `group`

  The group primitive is a signature that takes a list of tasks that should be applied in parallel.

- `chain`

  The chain primitive lets us link together signatures so that one is called after the other, essentially forming a *chain* of callbacks.

- `chord`

  A chord is just like a group but with a callback. A chord consists of a header group and a body, where the body is a task that should execute after all of the tasks in the header are complete.

- `map`

  The map primitive works like the built-in `map` function, but creates a temporary task where a list of arguments is applied to the task. For example, `task.map([1, 2])` – results in a single task being called, applying the arguments in order to the task function so that the result is:

  ```
  res = [task(1), task(2)]
  ```

- `starmap`

  Works exactly like map except the arguments are applied as `*args`. For example `add.starmap([(2, 2), (4, 4)])` results in a single task calling:

  ```
  res = [add(2, 2), add(4, 4)]
  ```

- `chunks`

Chunking splits a long list of arguments into parts, for example the operation:

```
>>> items = zip(xrange(1000), xrange(1000))  # 1000 items
>>> add.chunks(items, 10)
```

will split the list of items into chunks of 10, resulting in 100 tasks (each processing 10 items in sequence).

The primitives are also signature objects themselves, so that they can be combined in any number of ways to compose complex work-flows.

Here's some examples:

- Simple chain

  Here's a simple chain, the first task executes passing its return value to the next task in the chain, and so on.

  ```
  >>> from celery import chain

  >>> # 2 + 2 + 4 + 8
  >>> res = chain(add.s(2, 2), add.s(4), add.s(8))()
  >>> res.get()
  16
  ```

  This can also be written using pipes:

  ```
  >>> (add.s(2, 2) | add.s(4) | add.s(8))().get()
  16
  ```

- Immutable signatures

  Signatures can be partial so arguments can be added to the existing arguments, but you may not always want that, for example if you don't want the result of the previous task in a chain.

  In that case you can mark the signature as immutable, so that the arguments cannot be changed:

  ```
  >>> add.signature((2, 2), immutable=True)
  ```

  There's also a `.si()` shortcut for this, and this is the preffered way of creating signatures:

  ```
  >>> add.si(2, 2)
  ```

  Now you can create a chain of independent tasks instead:

  ```
  >>> res = (add.si(2, 2) | add.si(4, 4) | add.si(8, 8))()
  >>> res.get()
  16

  >>> res.parent.get()
  8

  >>> res.parent.parent.get()
  4
  ```

- Simple group

  You can easily create a group of tasks to execute in parallel:

```
>>> from celery import group
>>> res = group(add.s(i, i) for i in xrange(10))()
>>> res.get(timeout=1)
[0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
```

- Simple chord

  The chord primitive enables us to add a callback to be called when all of the tasks in a group have finished executing. This is often required for algorithms that aren't *embarrassingly parallel*:

  ```
  >>> from celery import chord
  >>> res = chord((add.s(i, i) for i in xrange(10)), xsum.s())()
  >>> res.get()
  90
  ```

  The above example creates 10 task that all start in parallel, and when all of them are complete the return values are combined into a list and sent to the `xsum` task.

  The body of a chord can also be immutable, so that the return value of the group isn't passed on to the callback:

  ```
  >>> chord((import_contact.s(c) for c in contacts),
  ...       notify_complete.si(import_id)).apply_async()
  ```

  Note the use of `.si` above; this creates an immutable signature, meaning any new arguments passed (including to return value of the previous task) will be ignored.

- Blow your mind by combining

  Chains can be partial too:

  ```
  >>> c1 = (add.s(4) | mul.s(8))

  # (16 + 4) * 8
  >>> res = c1(16)
  >>> res.get()
  160
  ```

  this means that you can combine chains:

  ```
  # ((4 + 16) * 2 + 4) * 8
  >>> c2 = (add.s(4, 16) | mul.s(2) | (add.s(4) | mul.s(8)))

  >>> res = c2()
  >>> res.get()
  352
  ```

  Chaining a group together with another task will automatically upgrade it to be a chord:

  ```
  >>> c3 = (group(add.s(i, i) for i in xrange(10)) | xsum.s())
  >>> res = c3()
  >>> res.get()
  90
  ```

  Groups and chords accepts partial arguments too, so in a chain the return value of the previous task is forwarded to all tasks in the group:

```
>>> new_user_workflow = (create_user.s() | group(
...                      import_contacts.s(),
...                      send_welcome_email.s()))
... new_user_workflow.delay(username='artv',
...                         first='Art',
...                         last='Vandelay',
...                         email='art@vandelay.com')
```

If you don't want to forward arguments to the group then you can make the signatures in the group immutable:

```
>>> res = (add.s(4, 4) | group(add.si(i, i) for i in xrange(10)))
>>> res.get()
<GroupResult: de44df8c-821d-4c84-9a6a-44769c738f98 [
    bc01831b-9486-4e51-b046-480d7c9b78de,
    2650a1b8-32bf-4771-a645-b0a35dcc791b,
    dcbee2a5-e92d-4b03-b6eb-7aec60fd30cf,
    59f92e0a-23ea-41ce-9fad-8645a0e7759c,
    26e1e707-eccf-4bf4-bbd8-1e1729c3cce3,
    2d10a5f4-37f0-41b2-96ac-a973b1df024d,
    e13d3bdb-7ae3-4101-81a4-6f17ee21df2d,
    104b2be0-7b75-44eb-ac8e-f9220bdfa140,
    c5c551a5-0386-4973-aa37-b65cbeb2624b,
    83f72d71-4b71-428e-b604-6f16599a9f37]>

>>> res.parent.get()
8
```

Chains

New in version 3.0.

Tasks can be linked together: the linked task is called when the task returns successfully:

```
>>> res = add.apply_async((2, 2), link=mul.s(16))
>>> res.get()
64
```

The linked task will be applied with the result of its parent task as the first argument. In the above case where the result was 64, this will result in `mul(4, 16)`.

The results will keep track of any subtasks called by the original task, and this can be accessed from the result instance:

```
>>> res.children
[<AsyncResult: 8c350acf-519d-4553-8a53-4ad3a5c5aeb4>]

>>> res.children[0].get()
64
```

The result instance also has a **`collect()`** method that treats the result as a graph, enabling you to iterate over the results:

```
>>> list(res.collect())
[(<AsyncResult: 7b720856-dc5f-4415-9134-5c89def5664e>, 4),
 (<AsyncResult: 8c350acf-519d-4553-8a53-4ad3a5c5aeb4>, 64)]
```

By default **`collect()`** will raise an **`IncompleteStream`** exception if the graph isn't fully formed (one of the tasks hasn't completed yet), but you can get an intermediate representation of the graph too:

```
>>> for result, value in res.collect(intermediate=True)):
....
```

You can link together as many tasks as you like, and signatures can be linked too:

```
>>> s = add.s(2, 2)
>>> s.link(mul.s(4))
>>> s.link(log_result.s())
```

You can also add *error callbacks* using the *on_error* method:

```
>>> add.s(2, 2).on_error(log_error.s()).delay()
```

This will result in the following `.apply_async` call when the signature is applied:

```
>>> add.apply_async((2, 2), link_error=log_error.s())
```

The worker won't actually call the errback as a task, but will instead call the errback function directly so that the raw request, exception and traceback objects can be passed to it.

Here's an example errback:

```
from __future__ import print_function

import os

from proj.celery import app

@app.task
def log_error(request, exc, traceback):
    with open(os.path.join('/var/errors', request.id), 'a') as fh:
        print('--\n\n{0} {1} {2}'.format(
            task_id, exc, traceback), file=fh)
```

To make it even easier to link tasks together there's a special signature called **`chain`** that lets you chain tasks together:

```
>>> from celery import chain
>>> from proj.tasks import add, mul

>>> # (4 + 4) * 8 * 10
>>> res = chain(add.s(4, 4), mul.s(8), mul.s(10))
proj.tasks.add(4, 4) | proj.tasks.mul(8) | proj.tasks.mul(10)
```

Calling the chain will call the tasks in the current process and return the result of the last task in the chain:

```
>>> res = chain(add.s(4, 4), mul.s(8), mul.s(10))()
>>> res.get()
640
```

It also sets `parent` attributes so that you can work your way up the chain to get intermediate results:

```
>>> res.parent.get()
64

>>> res.parent.parent.get()
8

>>> res.parent.parent
<AsyncResult: eeaad925-6778-4ad1-88c8-b2a63d017933>
```

Chains can also be made using the `|` (pipe) operator:

```
>>> (add.s(2, 2) | mul.s(8) | mul.s(10)).apply_async()
```

Graphs

In addition you can work with the result graph as a **DependencyGraph**:

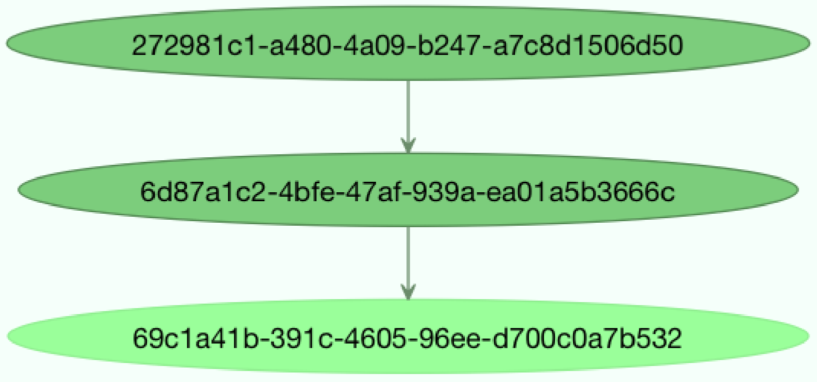
```
>>> res = chain(add.s(4, 4), mul.s(8), mul.s(10))()

>>> res.parent.parent.graph
285fa253-fcf8-42ef-8b95-0078897e83e6(1)
    463afec2-5ed4-4036-b22d-ba067ec64f52(0)
872c3995-6fa0-46ca-98c2-5a19155afcf0(2)
    285fa253-fcf8-42ef-8b95-0078897e83e6(1)
        463afec2-5ed4-4036-b22d-ba067ec64f52(0)
```

You can even convert these graphs to *dot* format:

```
>>> with open('graph.dot', 'w') as fh:
...     res.parent.parent.graph.to_dot(fh)
```

and create images:

```
$ dot -Tpng graph.dot -o graph.png
```



Groups

New in version 3.0.

A group can be used to execute several tasks in parallel.

The **group** function takes a list of signatures:

```
>>> from celery import group
>>> from proj.tasks import add

>>> group(add.s(2, 2), add.s(4, 4))
(proj.tasks.add(2, 2), proj.tasks.add(4, 4))
```

If you **call** the group, the tasks will be applied one after another in the current process, and a **GroupResult** instance is returned that can be used to keep track of the results, or tell how many tasks are ready and so on:

```
>>> g = group(add.s(2, 2), add.s(4, 4))
>>> res = g()
>>> res.get()
[4, 8]
```

Group also supports iterators:

```
>>> group(add.s(i, i) for i in xrange(100))()
```

A group is a signature object, so it can be used in combination with other signatures.

Group Results

The group task returns a special result too, this result works just like normal task results, except that it works on the group as a whole:

```
>>> from celery import group
>>> from tasks import add

>>> job = group([
...             add.s(2, 2),
...             add.s(4, 4),
...             add.s(8, 8),
...             add.s(16, 16),
...             add.s(32, 32),
... ])

>>> result = job.apply_async()

>>> result.ready()  # have all subtasks completed?
True
>>> result.successful() # were all subtasks successful?
True
>>> result.get()
[4, 8, 16, 32, 64]
```

The `GroupResult` takes a list of `AsyncResult` instances and operates on them as if it was a single task.

It supports the following operations:

- **`successful()`**

  Return **`True`** if all of the subtasks finished successfully (e.g., didn't raise an exception).

- **`failed()`**

  Return **`True`** if any of the subtasks failed.

- **`waiting()`**

  Return **`True`** if any of the subtasks isn't ready yet.

- **`ready()`**

  Return **`True`** if all of the subtasks are ready.

- **`completed_count()`**

  Return the number of completed subtasks.

- **`revoke()`**

  Revoke all of the subtasks.

- **`join()`**

  Gather the results of all subtasks and return them in the same order as they were called (as a list).

Chords

New in version 2.3.

Note:

Tasks used within a chord must *not* ignore their results. If the result backend is disabled for *any* task (header or body) in your chord you should read " Important Notes." Chords are not currently supported with the RPC result backend.

A chord is a task that only executes after all of the tasks in a group have finished executing.

Let's calculate the sum of the expression $1 + 1 + 2 + 2 + 3 + 3 ... n + n$ up to a hundred digits.

First you need two tasks, **`add()`** and **`tsum()`** (`sum()` is already a standard function):

```
@app.task
def add(x, y):
    return x + y

@app.task
def tsum(numbers):
    return sum(numbers)
```

Now you can use a chord to calculate each addition step in parallel, and then get the sum of the resulting numbers:

```
>>> from celery import chord
>>> from tasks import add, tsum

>>> chord(add.s(i, i)
...       for i in xrange(100))(tsum.s()).get()
9900
```

This is obviously a very contrived example, the overhead of messaging and synchronization makes this a lot slower than its Python counterpart:

```
>>> sum(i + i for i in xrange(100))
```

The synchronization step is costly, so you should avoid using chords as much as possible. Still, the chord is a powerful primitive to have in your toolbox as synchronization is a required step for many parallel algorithms.

Let's break the chord expression down:

```
>>> callback = tsum.s()
>>> header = [add.s(i, i) for i in range(100)]
>>> result = chord(header)(callback)
>>> result.get()
9900
```

Remember, the callback can only be executed after all of the tasks in the header have returned. Each step in the header is executed as a task, in parallel, possibly on different nodes. The callback is then applied with the return value of each task in the header. The task id returned by **`chord()`** is the id of the callback, so you can wait for it to complete and get the final return value (but remember to never have a task wait for other tasks)

Error handling

So what happens if one of the tasks raises an exception?

The chord callback result will transition to the failure state, and the error is set to the **`ChordError`** exception:

```
>>> c = chord([add.s(4, 4), raising_task.s(), add.s(8, 8)])
>>> result = c()
>>> result.get()
```

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "*/celery/result.py", line 120, in get
    interval=interval)
  File "*/celery/backends/amqp.py", line 150, in wait_for
    raise meta['result']
celery.exceptions.ChordError: Dependency 97de6f3f-ea67-4517-a21c-d867c61
    raised ValueError('something something',)
```

While the traceback may be different depending on the result backend used, you can see that the error description includes the id of the task that failed and a string representation of the original exception. You can also find the original traceback in `result.traceback`.

Note that the rest of the tasks will still execute, so the third task (`add.s(8, 8)`) is still executed even though the middle task failed. Also the **`ChordError`** only shows the task that failed first (in time): it doesn't respect the ordering of the header group.

To perform an action when a chord fails you can therefore attach an errback to the chord callback:

```
@app.task
def on_chord_error(request, exc, traceback):
    print('Task {0!r} raised error: {1!r}'.format(request.id, exc))
```

```
>>> c = (group(add.s(i, i) for i in range(10)) |
...      xsum.s().on_error(on_chord_error.s()))).delay()
```

Important Notes

Tasks used within a chord must *not* ignore their results. In practice this means that you must enable a **`result_backend`** in order to use chords. Additionally, if **`task_ignore_result`** is set to **`True`** in your configuration, be sure that the individual tasks to be used within the chord are defined with **`ignore_result=False`**. This applies to both Task subclasses and decorated tasks.

Example Task subclass:

```
class MyTask(Task):
    ignore_result = False
```

Example decorated task:

```
@app.task(ignore_result=False)
def another_task(project):
    do_something()
```

By default the synchronization step is implemented by having a recurring task poll the completion of the group every second, calling the signature when ready.

Example implementation:

```python
from celery import maybe_signature

@app.task(bind=True)
def unlock_chord(self, group, callback, interval=1, max_retries=None):
    if group.ready():
        return maybe_signature(callback).delay(group.join())
    raise self.retry(countdown=interval, max_retries=max_retries)
```

This is used by all result backends except Redis and Memcached: they increment a counter after each task in the header, then applies the callback when the counter exceeds the number of tasks in the set.

The Redis and Memcached approach is a much better solution, but not easily implemented in other backends (suggestions welcome!).

> **Note:**
>
> Chords don't properly work with Redis before version 2.2; you'll need to upgrade to at least redis-server 2.2 to use them.

> **Note:**
>
> If you're using chords with the Redis result backend and also overriding the **`Task.after_return()`** method, you need to make sure to call the super method or else the chord callback won't be applied.
>
> ```python
> def after_return(self, *args, **kwargs):
>     do_something()
>     super(MyTask, self).after_return(*args, **kwargs)
> ```

Map & Starmap

`map` and **`starmap`** are built-in tasks that calls the task for every element in a sequence.

They differ from group in that

- only one task message is sent
- the operation is sequential.

For example using `map`:

```python
>>> from proj.tasks import add

>>> ~xsum.map([range(10), range(100)])
[45, 4950]
```

is the same as having a task doing:

```python
@app.task
def temp():
    return [xsum(range(10)), xsum(range(100))]
```

and using `starmap`:

```python
>>> ~add.starmap(zip(range(10), range(10)))
[0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
```

is the same as having a task doing:

```
@app.task
def temp():
    return [add(i, i) for i in range(10)]
```

Both `map` and `starmap` are signature objects, so they can be used as other signatures and combined in groups etc., for example to call the starmap after 10 seconds:

```
>>> add.starmap(zip(range(10), range(10))).apply_async(countdown=10)
```

Chunks

Chunking lets you divide an iterable of work into pieces, so that if you have one million objects, you can create 10 tasks with hundred thousand objects each.

Some may worry that chunking your tasks results in a degradation of parallelism, but this is rarely true for a busy cluster and in practice since you're avoiding the overhead of messaging it may considerably increase performance.

To create a chunks signature you can use **`app.Task.chunks()`**:

```
>>> add.chunks(zip(range(100), range(100)), 10)
```

As with **`group`** the act of sending the messages for the chunks will happen in the current process when called:

```
>>> from proj.tasks import add

>>> res = add.chunks(zip(range(100), range(100)), 10)()
>>> res.get()
[[0, 2, 4, 6, 8, 10, 12, 14, 16, 18],
 [20, 22, 24, 26, 28, 30, 32, 34, 36, 38],
 [40, 42, 44, 46, 48, 50, 52, 54, 56, 58],
 [60, 62, 64, 66, 68, 70, 72, 74, 76, 78],
 [80, 82, 84, 86, 88, 90, 92, 94, 96, 98],
 [100, 102, 104, 106, 108, 110, 112, 114, 116, 118],
 [120, 122, 124, 126, 128, 130, 132, 134, 136, 138],
 [140, 142, 144, 146, 148, 150, 152, 154, 156, 158],
 [160, 162, 164, 166, 168, 170, 172, 174, 176, 178],
 [180, 182, 184, 186, 188, 190, 192, 194, 196, 198]]
```

while calling `.apply_async` will create a dedicated task so that the individual tasks are applied in a worker instead:

```
>>> add.chunks(zip(range(100), range(100)), 10).apply_async()
```

You can also convert chunks to a group:

```
>>> group = add.chunks(zip(range(100), range(100)), 10).group()
```

and with the group skew the countdown of each task by increments of one:

```
>>> group.skew(start=1, stop=10)()
```

This means that the first task will have a countdown of one second, the second task a countdown of two seconds, and so on.