Python support for the Linux perf profiler

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The Linux perf profiler is a very powerful tool that allows you to profile and obtain information about the performance of your application. `perf` also has a very vibrant ecosystem of tools that aid with the analysis of the data that it produces.

The main problem with using the `perf` profiler with Python applications is that `perf` only gets information about native symbols, that is, the names of functions and procedures written in C. This means that the names and file names of Python functions in your code will not appear in the output of `perf`.

Since Python 3.12, the interpreter can run in a special mode that allows Python functions to appear in the output of the `perf` profiler. When this mode is enabled, the interpreter will interpose a small piece of code compiled on the fly before the execution of every Python function and it will teach `perf` the relationship between this piece of code and the associated Python function using perf map files.

Note: Support for the `perf` profiler is currently only available for Linux on select architectures. Check the output of the `configure` build step or check the output of `python -m sysconfig | grep HAVE_PERF_TRAMPOLINE` to see if your system is supported.

For example, consider the following script:

```
def foo(n):
    result = 0
    for _ in range(n):
        result += 1
    return result
```

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```python
def bar(n):
    foo(n)

def baz(n):
    bar(n)

if __name__ == "__main__":
    baz(1000000)
```

We can run `perf` to sample CPU stack traces at 9999 hertz:

```
$ perf record -F 9999 -g -o perf.data python my_script.py
```

Then we can use `perf report` to analyze the data:

```
$ perf report --stdio -n -g

# Children      Self       Samples  Command     Shared Object        Symbol
# ........  ........  ............  ..........  ..................  ...............
↪...........................
#
    91.08%     0.00%             0  python.exe  python.exe          [.] _start
            |
            ---_start
            |
                --90.71%--__libc_start_main
                        Py_BytesMain
                        |
                        |--56.88%--pymain_run_python.constprop.0
                        |          |
                        |          |--56.13%--_PyRun_AnyFileObject
                        |          |          _PyRun_SimpleFileObject
                        |          |          |
                        |          |          |--55.02%--run_mod
                        |          |          |          |
                        |          |          |          --54.65%--PyEval_EvalCode
                        |          |          |                    _PyEval_
↪EvalFrameDefault
                        |          |          |                    PyObject_
↪Vectorcall
                        |          |          |                    _PyEval_Vector
                        |          |          |                    _PyEval_
↪EvalFrameDefault
                        |          |          |                    PyObject_
↪Vectorcall
                        |          |          |                    _PyEval_Vector
                        |          |          |                    _PyEval_
↪EvalFrameDefault
                        |          |          |                    PyObject_
↪Vectorcall
                        |          |          |                    _PyEval_Vector
                        |          |          |                    |
                        |          |          |                    |--51.67%--_
↪PyEval_EvalFrameDefault
                        |          |          |                    |          |
                        |          |          |                    |          |--
↪11.52%--_PyLong_Add
                        |          |          |                    |          |  ␣
↪       |
                        |          |          |                    |          |  ␣
↪       |--2.97%--_PyObject_Malloc
```

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```
...
```

As you can see, the Python functions are not shown in the output, only `_PyEval_EvalFrameDefault` (the function that evaluates the Python bytecode) shows up. Unfortunately that's not very useful because all Python functions use the same C function to evaluate bytecode so we cannot know which Python function corresponds to which bytecode-evaluating function.

Instead, if we run the same experiment with `perf` support enabled we get:

```
$ perf report --stdio -n -g

# Children      Self       Samples  Command     Shared Object       Symbol
# ........  ........  ............  ..........  ..................  ...............
↪......................................................
#
    90.58%     0.36%             1  python.exe  python.exe          [.] _start
            |
            ---_start
            |
                --89.86%--__libc_start_main
                        Py_BytesMain
                        |
                        |--55.43%--pymain_run_python.constprop.0
                        |          |
                        |          |--54.71%--_PyRun_AnyFileObject
                        |          |          _PyRun_SimpleFileObject
                        |          |          |
                        |          |          |--53.62%--run_mod
                        |          |          |          |
                        |          |          |           --53.26%--PyEval_EvalCode
                        |          |          |                     py::<module>:/
↪src/script.py
                        |          |          |                     _PyEval_
↪EvalFrameDefault
                        |          |          |                     PyObject_
↪Vectorcall
                        |          |          |                     _PyEval_Vector
                        |          |          |                     py::baz:/src/
↪script.py
                        |          |          |                     _PyEval_
↪EvalFrameDefault
                        |          |          |                     PyObject_
↪Vectorcall
                        |          |          |                     _PyEval_Vector
                        |          |          |                     py::bar:/src/
↪script.py
                        |          |          |                     _PyEval_
↪EvalFrameDefault
                        |          |          |                     PyObject_
↪Vectorcall
                        |          |          |                     _PyEval_Vector
                        |          |          |                     py::foo:/src/
↪script.py
                        |          |          |                     |
                        |          |          |                     |--51.81%--_
↪PyEval_EvalFrameDefault
                        |          |          |                     |          |
                        |          |          |                     |          |--
↪13.77%--_PyLong_Add
                        |          |          |                     |          |  ␣
↪       |
```

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```
                        |          |          |                     |          |  ␣
↪       |--3.26%--_PyObject_Malloc
```

1 How to enable `perf` profiling support

`perf` profiling support can be enabled either from the start using the environment variable `PYTHONPERFSUPPORT` or the `-X perf` option, or dynamically using `sys.activate_stack_trampoline()` and `sys.deactivate_stack_trampoline()`.

The `sys` functions take precedence over the `-X` option, the `-X` option takes precedence over the environment variable.

Example, using the environment variable:

```
$ PYTHONPERFSUPPORT=1 python script.py
$ perf report -g -i perf.data
```

Example, using the `-X` option:

```
$ python -X perf script.py
$ perf report -g -i perf.data
```

Example, using the `sys` APIs in file `example.py`:

```
import sys

sys.activate_stack_trampoline("perf")
do_profiled_stuff()
sys.deactivate_stack_trampoline()

non_profiled_stuff()
```

…then:

```
$ python ./example.py
$ perf report -g -i perf.data
```

2 How to obtain the best results

For best results, Python should be compiled with `CFLAGS="-fno-omit-frame-pointer -mno-omit-leaf-frame-pointer"` as this allows profilers to unwind using only the frame pointer and not on DWARF debug information. This is because as the code that is interposed to allow `perf` support is dynamically generated it doesn't have any DWARF debugging information available.

You can check if your system has been compiled with this flag by running:

```
$ python -m sysconfig | grep 'no-omit-frame-pointer'
```

If you don't see any output it means that your interpreter has not been compiled with frame pointers and therefore it may not be able to show Python functions in the output of `perf`.

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