Effective Programming Practices for Economists

Scientific Computing

Writing fast code with numpy

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Why numpy can be fast

- Numbers are stored efficiently in arrays

    - dtype of all numbers is known

    - it is fast to read numbers from memory into registers

- numpy functions are implemented very efficiently

    - in a low-level language like C

    - by experts who really know what they are doing

- Python overhead is incurred once per array, not once per number

Implications for writing fast code

- Vectorize everything!

- Use broadcasting where possible

- Prefer few large arrays over many small arrays

Why the example is slow

```python
def array_cobb_douglas(factors, weights, a):
    out = np.empty(len(factors))
    for i in range(len(factors)):
        out[i] = _cobb_douglas(factors[i], weights, a)
    return out

def _cobb_douglas(factors, weights, a):
    return a * np.prod(factors**weights)

# (inputs as before)

%timeit array_cobb_douglas(factors, weights, a)

25.1 ms ± 488 µs per loop
```

- This uses array operations (e.g. np.prod) inside a loop

- This is typically slow and full vectorization should be faster

- Even writing out everything as a loop might be faster than the mix!

Full vectorization

```python
def vectorized_array_cobb_douglas(factors, weights, a):
    return a * np.prod(factors**weights, axis=-1)
```

```
%timeit vectorized_array_cobb_douglas(factors, weights, a)

215 µs ± 1.63 µs per loop
```

- From ~25 milliseconds to ~215 microseconds

- Speedup of more than 110×

- Code is actually more readable

- Need to get good with `axis` argument!

Limits of performance with numpy

- Numpy is not a compiler, so it cannot

  - Fuse multiple operations into one (for more speed)

  - Eliminate intermediate results (for using less memory)

- Creating arrays is slower than creating list

  - Only relevant if you create many tiny arrays

- Calling array operations in a loop is typically slow but it is hard to detect this inefficiency in a profiler