

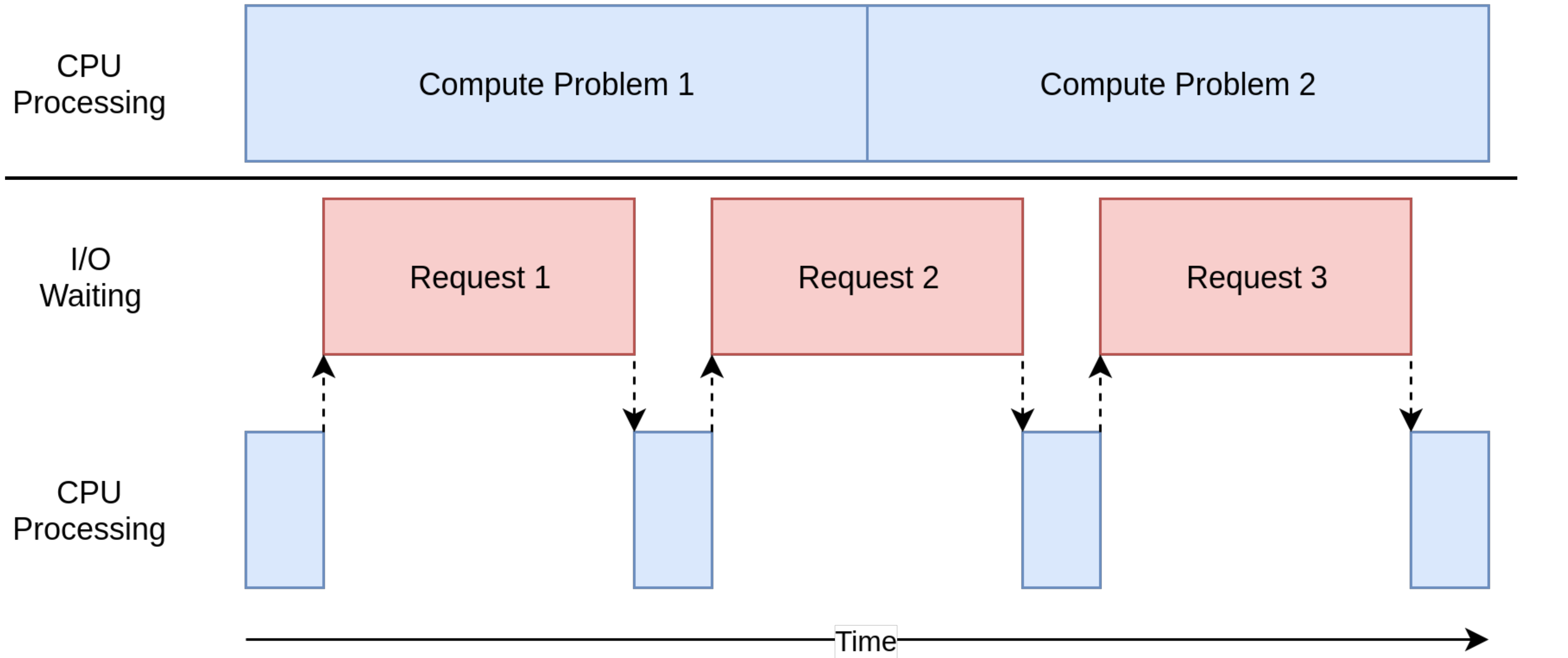
# Programming Principles in Python (CSCI 503/490)

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## Structural Pattern Matching

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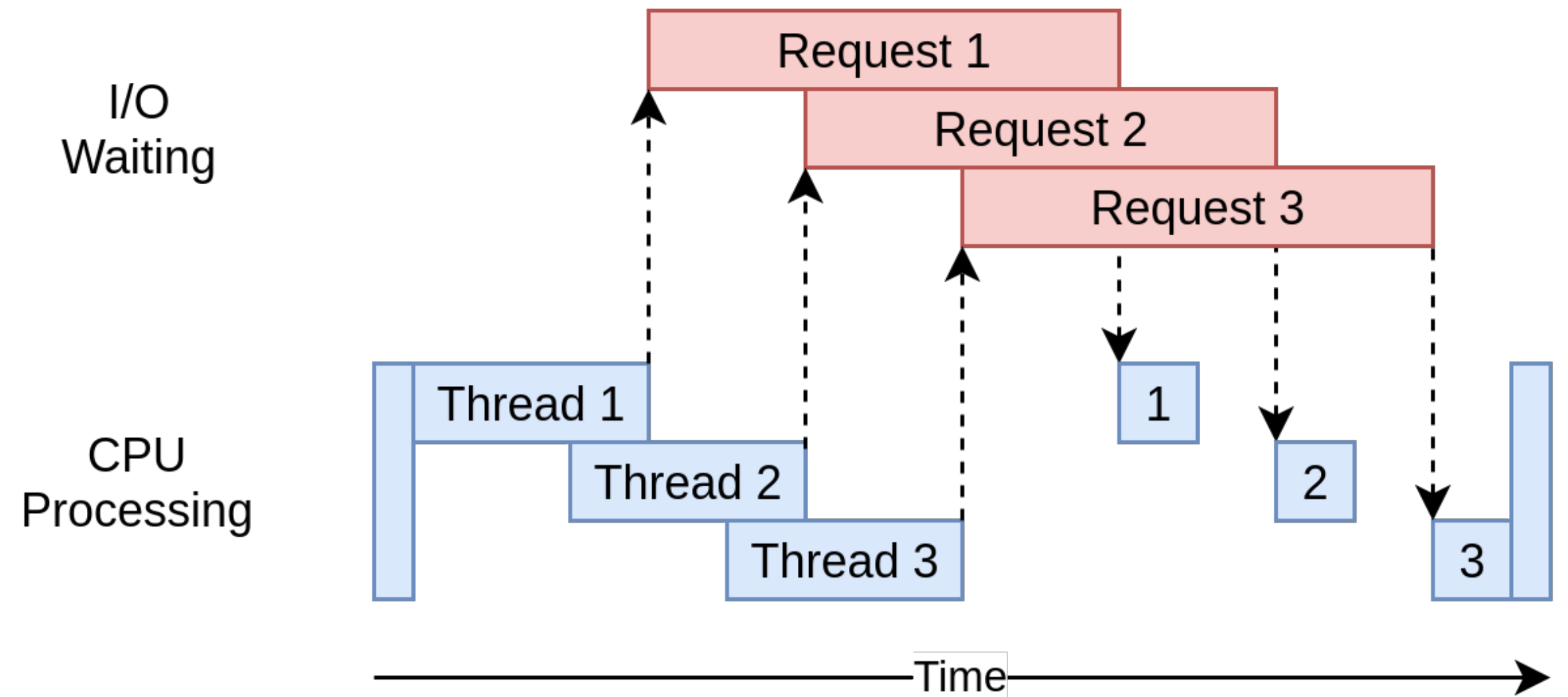
# CPU-Bound vs. I/O-Bound



[J. Anderson]

# Threading

- Threading address the I/O waits by letting separate pieces of a program run at the same time
- Threads run in the same process
- Threads share the same memory (and global variables)
- Operating system schedules threads; it can manage when each thread runs, e.g. round-robin scheduling
- When blocking for I/O, other threads can run



[J. Anderson]

# Python Threading Speed

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- If I/O bound, threads work great because time spent waiting can now be used by other threads
- Threads **do not** run simultaneously in standard Python, i.e. they cannot take advantage of multiple cores
- Use threads when code is **I/O bound**, otherwise no real speed-up plus some overhead for using threads

# Python and the GIL

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- Solution for reference counting (used for garbage collection)
- Could add locking to every value/data structure, but with multiple locks comes possible **deadlock**
- Python instead has a Global Interpreter Lock (GIL) that must be acquired to execute any Python code
- This effectively makes Python single-threaded (faster execution)
- Python requires threads to give up GIL after certain amount of time
- Python 3 improved allocation of GIL to threads by not allowing a single CPU-bound thread to hog it

# Multiprocessing using concurrent.futures

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- ```
import concurrent.futures
import multiprocessing as mp
import time

def dummy(num):
    time.sleep(5)
    return num ** 2

with concurrent.futures.ProcessPoolExecutor(max_workers=5,
   mp_context=mp.get_context('fork')) as executor:
    results = executor.map(dummy, range(10))
```
- `mp.get_context('fork')` changes from `'spawn'` used by default in MacOS, works in notebook

# asyncio

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- Single event loop that controls when each task is run
- Tasks can be ready or waiting
- Tasks are **not interrupted** like they are with threading
  - Task controls when control goes back to the main event loop
  - Either waiting or complete
- Event loop keeps track of whether tasks are ready or waiting
  - Re-checks to see if new tasks are now ready
  - Picks the task that has been waiting the longest

[J. Anderson]



# Concurrency Comparison

| Concurrency Type                     | Switching Decision                                                    | Number of Processors |
|--------------------------------------|-----------------------------------------------------------------------|----------------------|
| Pre-emptive multitasking (threading) | The operating system decides when to switch tasks external to Python. | 1                    |
| Cooperative multitasking (asyncio)   | The tasks decide when to give up control.                             | 1                    |
| Multiprocessing (multiprocessing)    | The processes all run at the same time on different processors.       | Many                 |

[J. Anderson]



# Assignment 7

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- Concurrency, System Integration, and Structural Pattern Matching
- Coming soon...

# Match Statement

# Conditional Logic

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- if/elif/else
- What about a switch statement?
- Exists in C++
- What are the advantages of a switch?

- C++ Example:

```
- switch (val) {  
    case 1:  
        cout << "1st" << endl;  
        break;  
    case 2:  
        cout << "2nd" << endl;  
        break;  
    default:  
        cout << "???" << endl;  
}
```

# Conditional Logic

---

- if/elif/else
- What about a switch statement?
- Exists in C++
- What are the advantages of a switch?
  - Cleaner and less redundant
  - More efficient than if/elif...

- C++ Example:

```
- switch (val) {  
    case 1:  
        cout << "1st" << endl;  
        break;  
    case 2:  
        cout << "2nd" << endl;  
        break;  
    default:  
        cout << "???" << endl;  
}
```

# Python

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- Python's if/elif structure is pretty similar structure-wise to a switch statement
- If you want the "jump" functionality, remember that dictionaries offer efficient lookup and can store functions!
- Example:
  - ```
ops = {  
    1: lambda: print('1st'),  
    2: lambda: print('2nd')  
}  
ops.get(val, lambda: print('???'))()
```
- ... so no great need for a standard switch statement

# Match Statement

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- But... Python 3.10 added a match statement that can be used like a switch statement
- ```
match val:  
    case 1:  
        print('1st')  
    case 2:  
        print('2nd')  
    case _:  
        print('???')
```
- Why?
  - It can do **more** than a switch statement

# Structural Pattern Matching

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- Besides literal cases, match statements can be used to
  - differentiate structure
  - assign values
  - differentiate class instances
- Example:
- `match sys.argv:`
  - `case [_, "commit"]:`
    - `print("Committing")`
  - `case [_, 'add', fname]:`
    - `print("Adding file", fname)`



# Evaluation

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- Works similar to if/elif/else logic
- Cases are processed **in order**
- Once the first case is matched, its body is executed and **no** other cases will be matched
- Name bindings (assignments) **can** be used **after** the match statement
  - Like standard conditional logic in Python
  - Differs from some other languages where if/then blocks are scoped...

# Simple Patterns

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- Literal patterns:
  - e.g. `2`, `"commit"`, but also `True`, `False`, `None`
- Simple capture pattern:
  - an identifier: `fname`
- Wildcard: matches anything: `_`

[PEP 636]

# Sequence Pattern

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- A sequence composed of other patterns: ["add", fname]
- Any identifiers are assigned when the structure is matched
- Can allow a match of multiple values using \* syntax

```
- match sys.argv:  
    case [_, "commit"]:  
        print("Committing")  
    case [_, 'add', *fnames]:  
        print("Adding files", fnames)
```

[PEP 636]

# Or Pattern

---

- May allow multiple patterns to be processed by a single block
- Uses the bar symbol `|` (**not** the word "or") to connect the patterns
- Example:

```
match command.split():
    ... # Other cases
    case ["north"] | ["go", "north"]:
        current_room = current_room.neighbor("north")
    case ["pick", "up", obj] | ["pick", obj, "up"]:
        ... # Code for picking up the given object
```

[PEP 636]

# Or Pattern

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- Problem: Suppose we want to restrict the set of values but don't know which pattern was selected...
- ```
match command.split():  
    case ["go", ("north" | "south" | "east" | "west")]:  
        current_room = current_room.neighbor(...)  
        # how do I know which direction to go?
```

[PEP 636]

# As Pattern

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- Similar to exceptions where we can assign the matched value to an identifier when the patterns are literals
- Can even do this in a more complex pattern:
- ```
match command.split():  
    case ["go", ("north" | "south" | "east" | "west") as d]:  
        current_room = current_room.neighbor(d)
```

[PEP 636]

# Guards

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- In some cases, we want to add additional logic to check the pattern before allowing the block to be executed
- If the guard is not True, **other cases continue to be checked**
- Example: Suppose certain directions are not allowed in a given room:
- ```
match command.split():  
    case ["go", dir] if dir in current_room.exits:  
        current_room = current_room.neighbor(dir)  
    case ["go", _]:  
        print("Sorry, you can't go that way")
```

[PEP 636]



# Matching Types

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- You can match a type in a similar manner, but must put parentheses after it
  - `case str() :`
- We can combine this with the `as` pattern to capture the value
  - `case str() as s :`
- There is also shorthand to do this (useful in more complex expressions)
  - `case str(s) :`

# Class Pattern

---

- We can also match objects...
- match event:

```
case Click() as c:  
    print("Click happened", c.x, c.y)
```
- but the type shortcut **does not work**
- match event:

```
case Click(c):  
    print("Click happened", c)
```

...
- `TypeError: Click() accepts 0 positional sub-patterns (1 given)`

# Class Pattern

---

- This hints at something different being allowed for classes
- We can match **instance attributes**!
- match event:

```
case Click(x=x, y=y) if x < y:  
    print("Lower-right click happened", x, y)
```

# Class Pattern

---

- This syntax is a bit clunky and requires keyword-style attributes
- We can use `__match_args__` to specify the order of attributes instead:

- ```
class Click:  
    __match_args__ = ('x', 'y')  
    ...
```

```
match event:  
    case Click(x, y) if x < y:  
        print("Lower-right click happened", x, y)
```

- Dataclasses automatically order attributes based on their position

# Matching Enumerated Values or Constants

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- Can use dotted notation to reference the value of an enumerated value or constant (`Button.LEFT`)
- Cannot use bare identifiers (e.g. referencing constants) because they are interpreted as part of the pattern...

# Mapping Pattern

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- Just like matching sequences, we can also match mappings (i.e. dictionaries)
- Any unmatched key-value pairs are ignored
  - You don't need to use the multiple match as with sequences
  - But you can use `**rest` if you want to use them
- Works similar to object destructuring in JavaScript, **doesn't exist** in Python **except** in the context of match statements
  - `{ 'a': val, 'c': val2 } = { 'a': 123, 'b': 456, 'c': 789 }`
  - In JavaScript, this would assign `val = 123, val2 = 789`
  - This is a `SyntaxError` in Python, but that syntax works in a **case**

# Mapping Pattern

---

```
• for action in actions:
    match action:
        case {"text": message, "color": c}:
            ui.set_text_color(c)
            ui.display(message)
        case {"sleep": duration}:
            ui.wait(duration)
        case {"sound": url, "format": "mp3"}:
            ui.play(url)
        case {"sound": _, "format": _}:
            warning("Unsupported audio format")
```

[PEP 636]



# Match Statement Guidance

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- Zen of Python: "There should be one-- and preferable only one --obvious way to do it."
  - Can use if/elif/else logic
  - Can use checks of sequence length, dictionary structure
- If you're emulating a switch statement, don't use a match statement
- If you're matching structure (sequence, mapping, object), a match statement may be a good idea

# Example

---

```
• def eval_expr(expr):  
    """Evaluate an expression and return the result."""  
    match expr:  
        case BinaryOp('+', left, right):  
            return eval_expr(left) + eval_expr(right)  
        case BinaryOp('-', left, right):  
            return eval_expr(left) - eval_expr(right)  
        case BinaryOp('*', left, right):  
            return eval_expr(left) * eval_expr(right)  
        case BinaryOp('/', left, right):  
            return eval_expr(left) / eval_expr(right)  
        case UnaryOp('+', arg):  
            return eval_expr(arg)  
        case UnaryOp('-', arg):  
            return -eval_expr(arg)  
        case VarExpr(name):  
            raise ValueError(f"Unknown value of: {name}")  
        case float() | int():  
            return expr  
        case _:  
            raise ValueError(f"Invalid expression value: {repr(expr)}")
```

[G. van Rossum]