Python

Python Decorators

Enhancing Functions with Elegant Metaprogramming

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Source Code

1. Introduction to Python Decorators

Python decorators are a powerful feature that allow developers to modify or enhance functions and classes without changing their core implementation. In essence, decorators are a design pattern that lets you "wrap" one function with another function to extend its behavior.

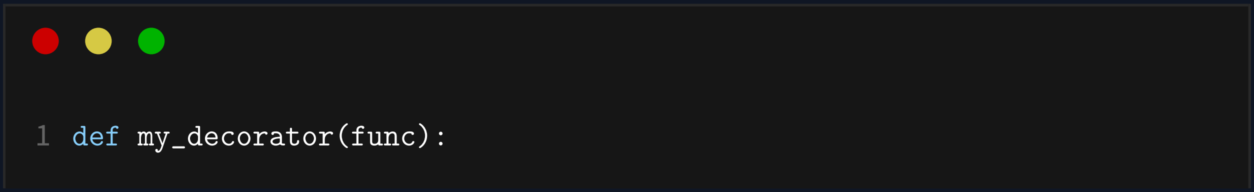
1.1. What Are Decorators?

At their core, decorators are a form of metaprogramming – code that manipulates other code. They provide a clean syntax to modify the behavior of functions or classes using the **@** symbol.

- **Higher-Order Functions:** Functions that take another function as an argument
- **Syntactic Sugar:** The **@decorator** syntax is equivalent to **function = decorator(function)**
- **Non-Invasive:** Add functionality without modifying the original code
- **Reusability:** Apply the same behavior across multiple functions

2. Basic Decorator Pattern

The fundamental decorator pattern consists of a function that takes another function as input and returns a new function with enhanced behavior:



```python
def my_decorator(func):
```

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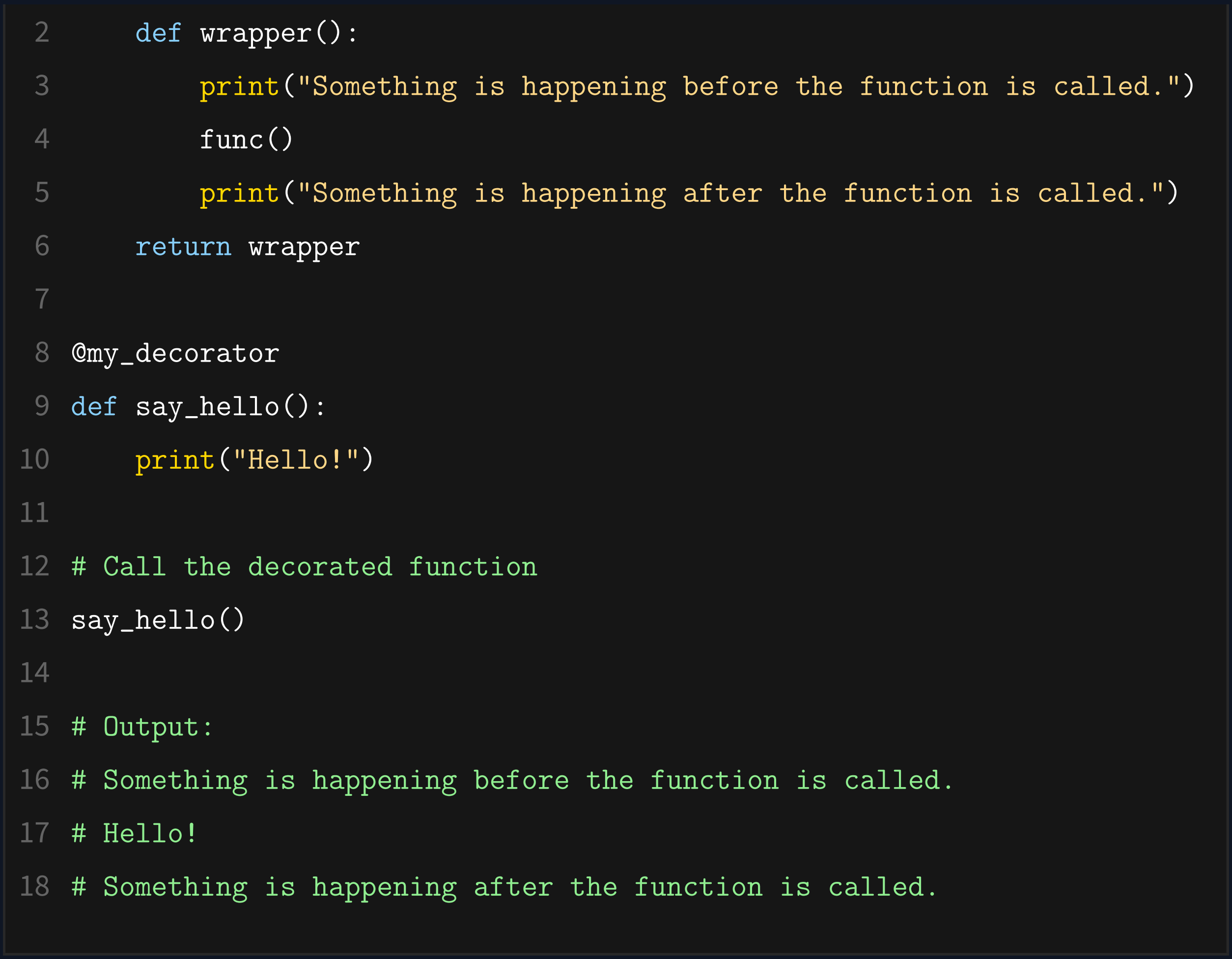


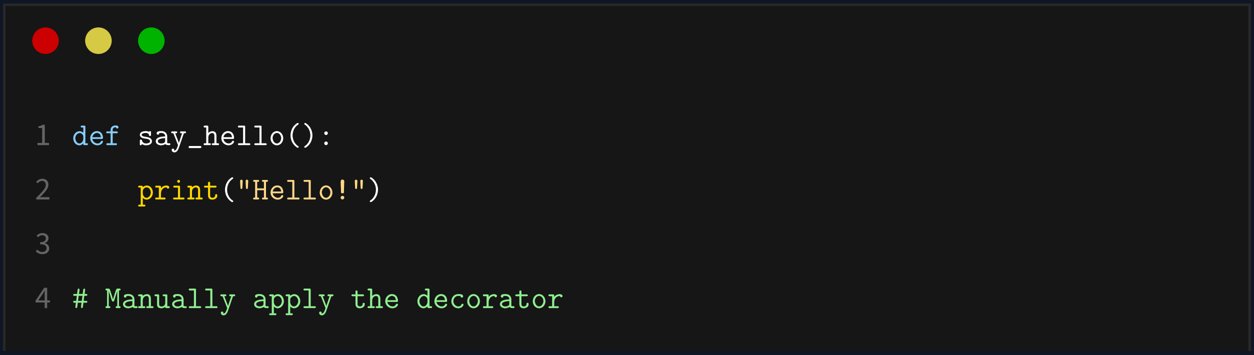
```python
    def wrapper():
        print("Something is happening before the function is called.")
        func()
        print("Something is happening after the function is called.")
    return wrapper

@my_decorator
def say_hello():
    print("Hello!")

# Call the decorated function
say_hello()

# Output:
# Something is happening before the function is called.
# Hello!
# Something is happening after the function is called.
```

The **@my_decorator** syntax is equivalent to:



```python
def say_hello():
    print("Hello!")

# Manually apply the decorator
```

```python
say_hello = my_decorator(say_hello)
```

3. Decorating Functions with Arguments

Real-world functions often have arguments. Decorators need to handle these arguments correctly:

```python
import functools

def decorator_with_args(func):
    @functools.wraps(func)  # Preserves the original function’s metadata
    def wrapper(*args, **kwargs):
        print(f"Calling {func.__name__} with arguments: {args}, {kwargs}")
        result = func(*args, **kwargs)
        print(f"Function {func.__name__} returned: {result}")
        return result
    return wrapper

@decorator_with_args
def add(a, b):
    """Add two numbers."""
```

```python
    return a + b

# Call the decorated function
result = add(3, 5)
print(f"Result: {result}")

# Output:
# Calling add with arguments: (3, 5), {}
# Function add returned: 8
# Result: 8

# Check that metadata is preserved
print(add.__name__)  # ’add’ (not ’wrapper’)
print(add.__doc__)   # ’Add two numbers.’
```

4. Decorators with Parameters

Sometimes we need to create decorators that accept their own parameters:

```python
def repeat(times=2):
    """A decorator that runs a function multiple times"""
    def decorator(func):
        @functools.wraps(func)
        def wrapper(*args, **kwargs):
            result = None
            for _ in range(times):
                result = func(*args, **kwargs)
            return result
        return wrapper
    return decorator

@repeat(times=3)
def greet(name):
    print(f"Hello, {name}!")
    return name

# Call the decorated function
greet("World")

# Output:
# Hello, World!
# Hello, World!
# Hello, World!
```

Note the triple-level nesting required for parameterized decorators:

- **Level 1: repeat()** - handles decorator parameters
- **Level 2: decorator()** - accepts the function being decorated
- **Level 3: wrapper()** - handles the function’s arguments

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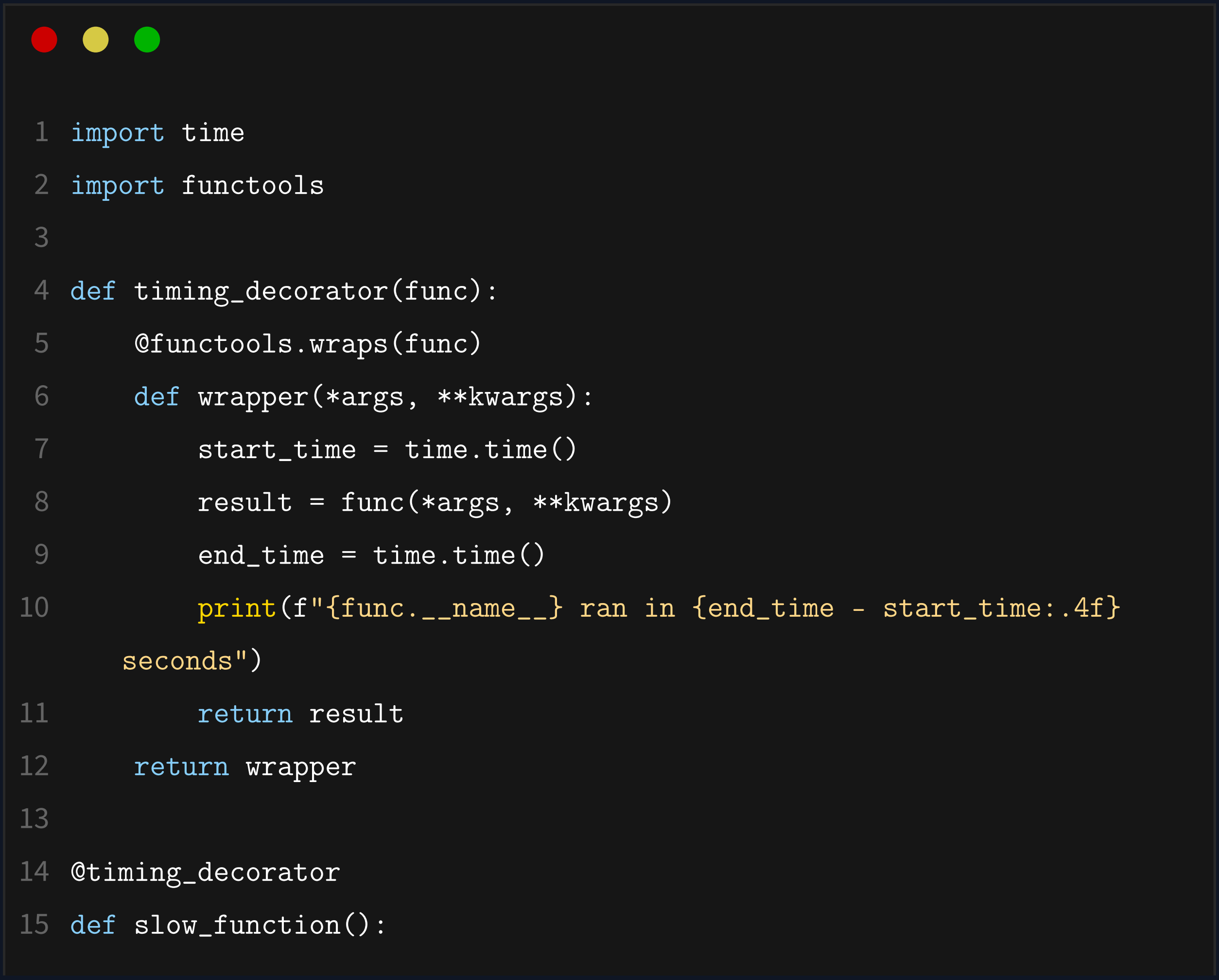
5. Practical Applications

Decorators shine in many real-world scenarios where they help separate cross-cutting concerns from business logic.

5.1. Timing Functions

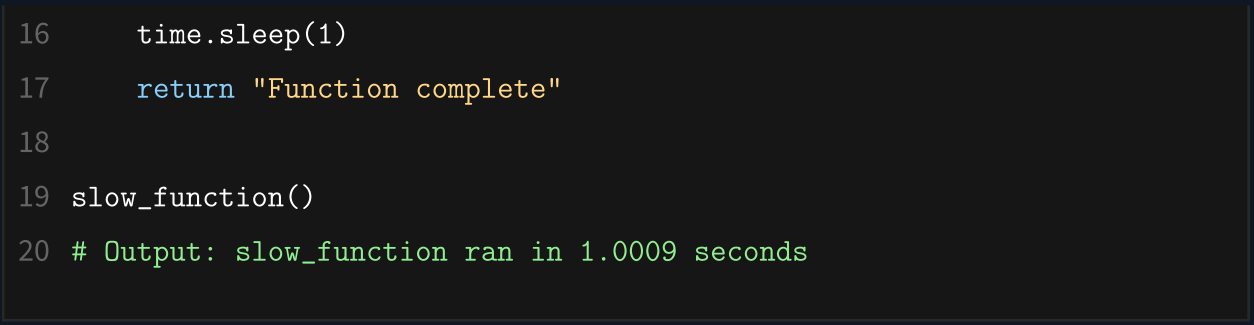
Measuring execution time without cluttering your functions:



```python
import time
import functools

def timing_decorator(func):
    @functools.wraps(func)
    def wrapper(*args, **kwargs):
        start_time = time.time()
        result = func(*args, **kwargs)
        end_time = time.time()
        print(f"{func.__name__} ran in {end_time - start_time:.4f} seconds")
        return result
    return wrapper

@timing_decorator
def slow_function():
```

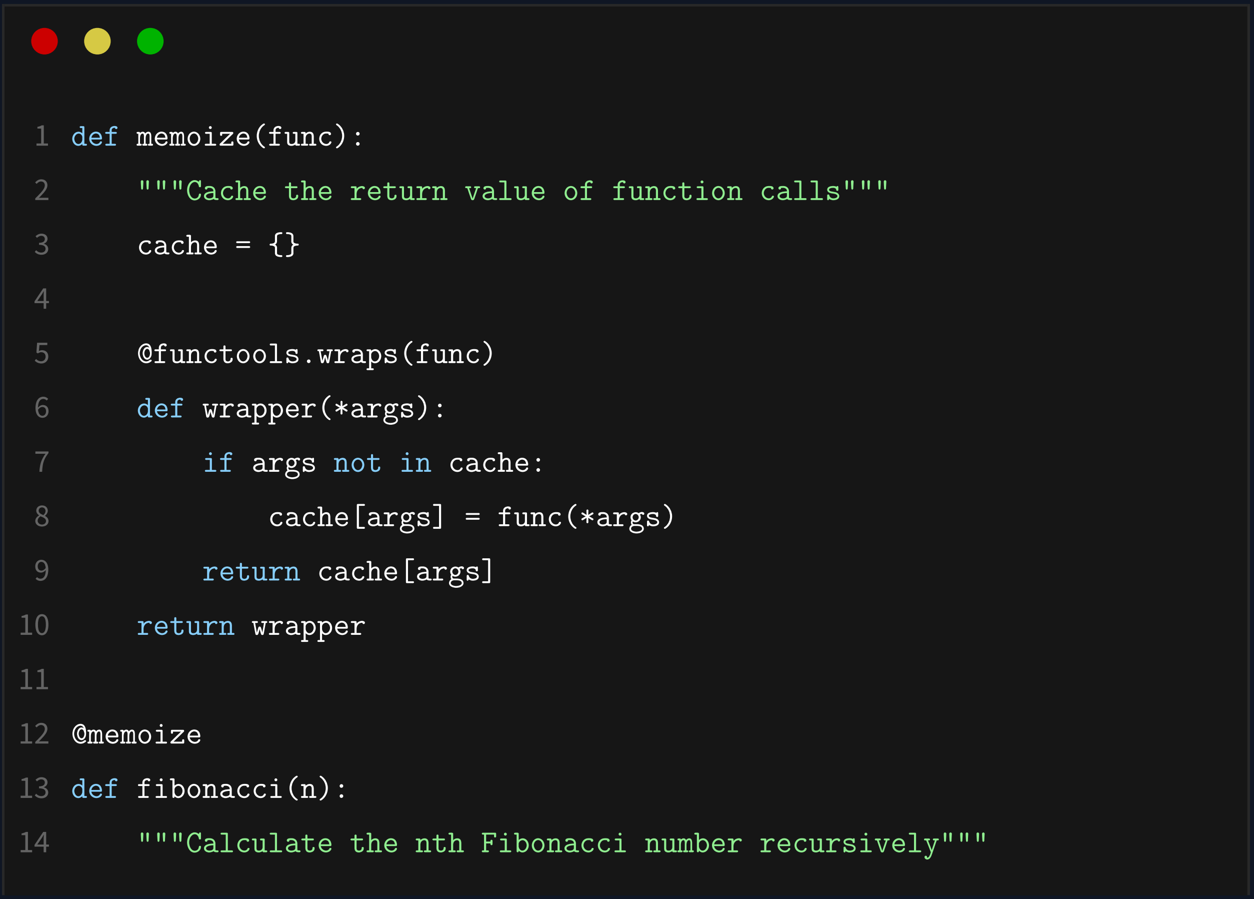


```python
    time.sleep(1)
    return "Function complete"

slow_function()
# Output: slow_function ran in 1.0009 seconds
```

5.2. Caching Results

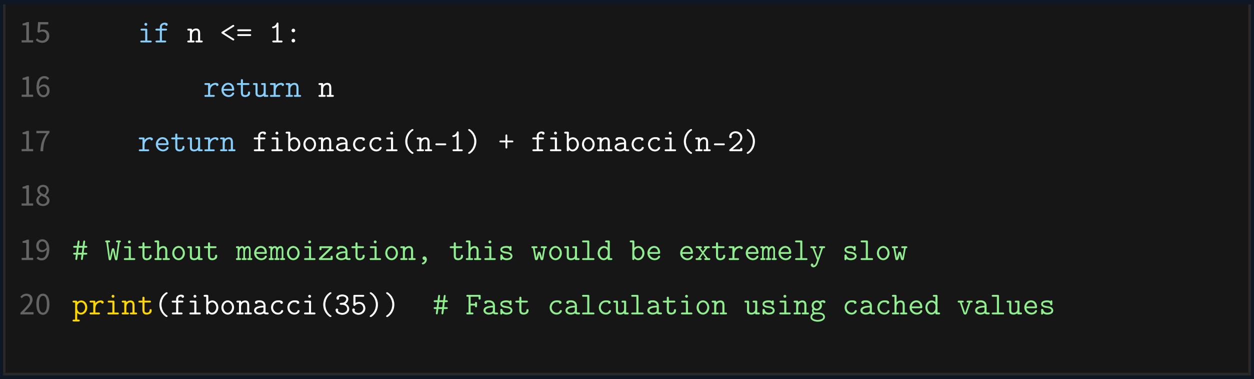
Improve performance by storing previously calculated results:



```python
def memoize(func):
    """Cache the return value of function calls"""
    cache = {}

    @functools.wraps(func)
    def wrapper(*args):
        if args not in cache:
            cache[args] = func(*args)
        return cache[args]
    return wrapper

@memoize
def fibonacci(n):
    """Calculate the nth Fibonacci number recursively"""
```

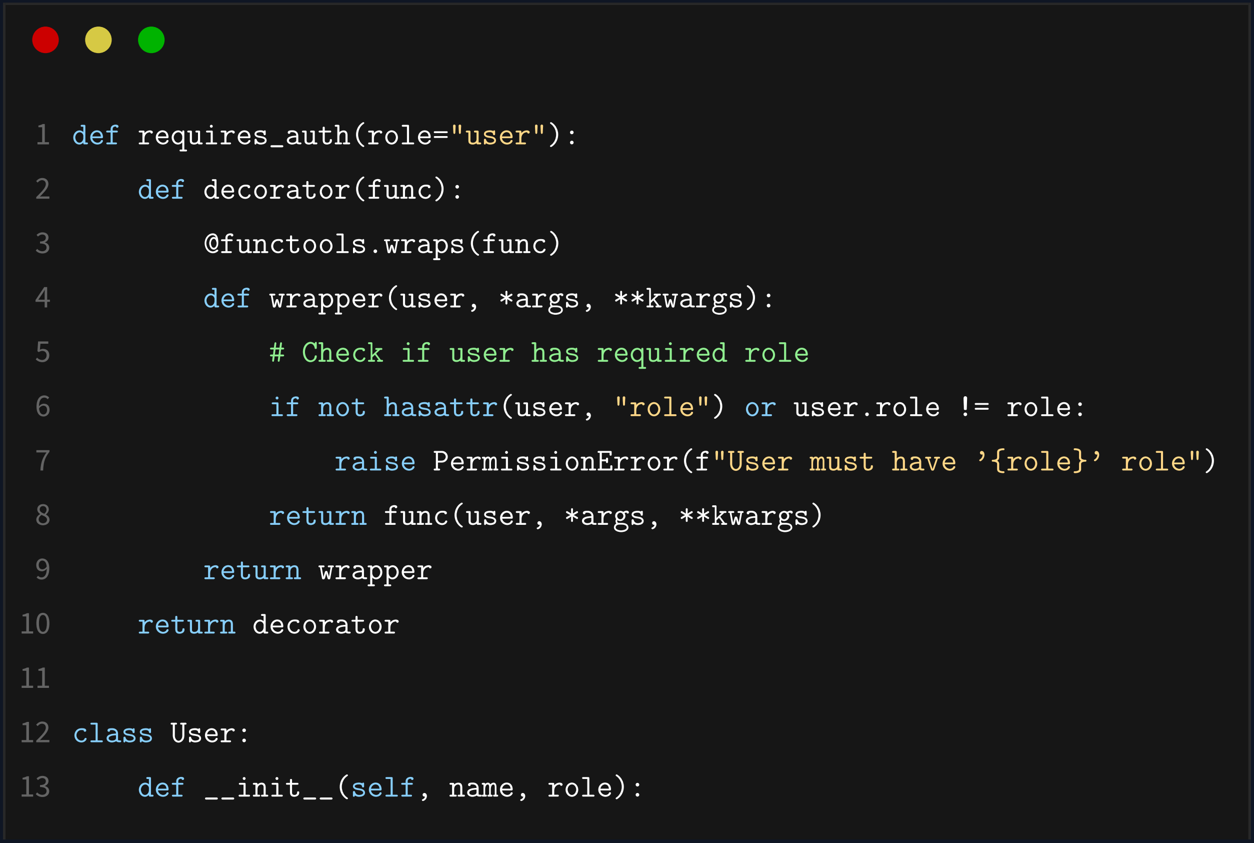


```python
    if n <= 1:
        return n
    return fibonacci(n-1) + fibonacci(n-2)

# Without memoization, this would be extremely slow
print(fibonacci(35))  # Fast calculation using cached values
```

5.3. Authentication and Authorization

Control access to functions based on user roles:



```python
def requires_auth(role="user"):
    def decorator(func):
        @functools.wraps(func)
        def wrapper(user, *args, **kwargs):
            # Check if user has required role
            if not hasattr(user, "role") or user.role != role:
                raise PermissionError(f"User must have '{role}' role")
            return func(user, *args, **kwargs)
        return wrapper
    return decorator

class User:
    def __init__(self, name, role):
```

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```python
        self.name = name
        self.role = role

@requires_auth(role="admin")
def delete_item(user, item_id):
    print(f"User {user.name} deleted item {item_id}")

# Admin user can delete items
admin = User("Alice", "admin")
delete_item(admin, 42)

# Regular user will get an error
regular_user = User("Bob", "user")
try:
    delete_item(regular_user, 42)
except PermissionError as e:
    print(e)  # Output: User must have ’admin’ role
```

5.4. Validation and Type Checking

Ensure function inputs meet requirements:

```python
def validate_types(**param_types):
    def decorator(func):
        @functools.wraps(func)
        def wrapper(*args, **kwargs):
            # Get function parameter names
            import inspect
            sig = inspect.signature(func)
            bound_args = sig.bind(*args, **kwargs)

            # Check each parameter type
            for param_name, param_type in param_types.items():
                if param_name in bound_args.arguments:
                    value = bound_args.arguments[param_name]
                    if not isinstance(value, param_type):
                        raise TypeError(
                            f"Parameter ’{param_name}’ must be {param_type.__name__}"
                        )
            return func(*args, **kwargs)
        return wrapper
    return decorator

@validate_types(name=str, age=int)
def create_user(name, age):
    return f"User {name}, age {age} created"

print(create_user("Alice", 30))  # Works
```

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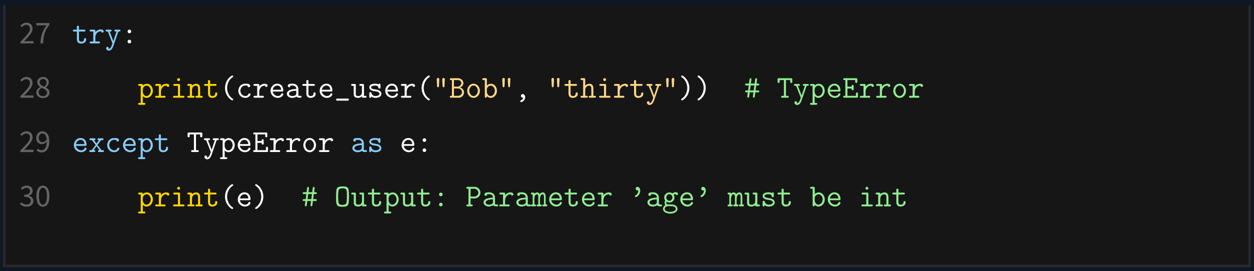


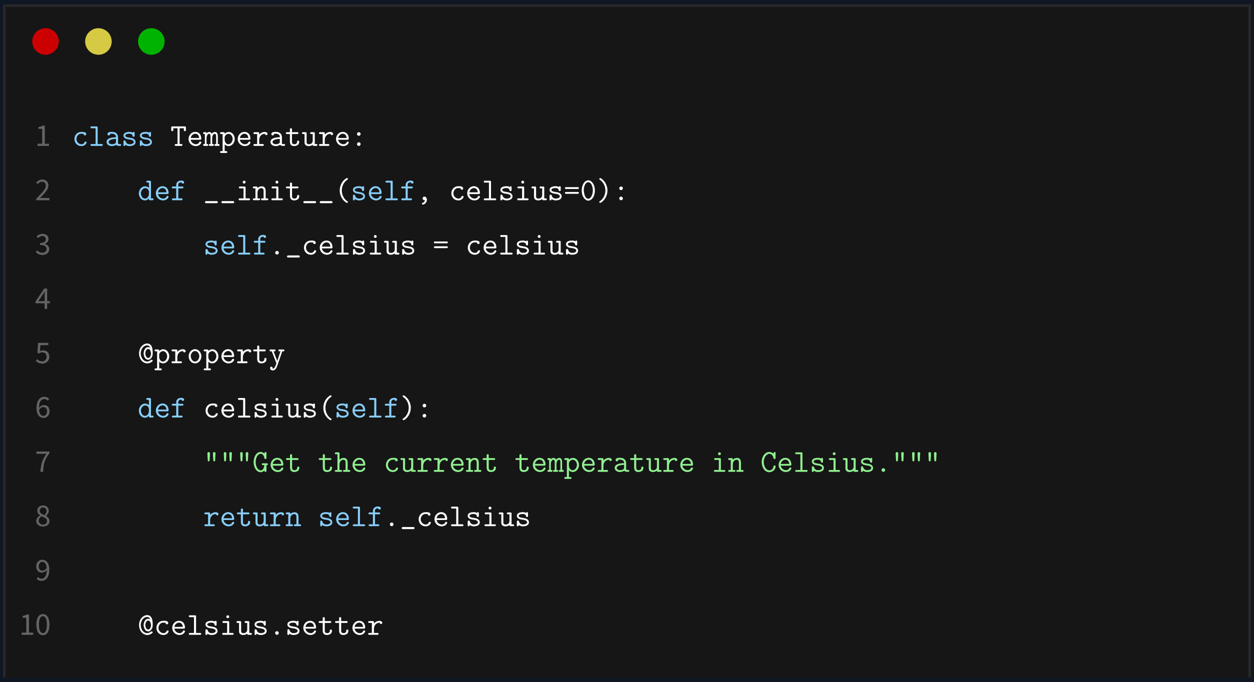
```python
try:
    print(create_user("Bob", "thirty"))  # TypeError
except TypeError as e:
    print(e)  # Output: Parameter ’age’ must be int
```

6. Built-in Decorators

Python includes several built-in decorators that demonstrate the power of this pattern.

6.1. Property Decorator

The **@property** decorator transforms methods into attribute-like accessors:



```python
class Temperature:
    def __init__(self, celsius=0):
        self._celsius = celsius

    @property
    def celsius(self):
        """Get the current temperature in Celsius."""
        return self._celsius

    @celsius.setter
    def celsius(self, value):
        if value < -273.15:
            raise ValueError("Temperature below absolute zero!")
        self._celsius = value

    @property
    def fahrenheit(self):
        """Get the current temperature in Fahrenheit."""
        return self._celsius * 9/5 + 32

    @fahrenheit.setter
    def fahrenheit(self, value):
        self.celsius = (value - 32) * 5/9

# Using the properties
temp = Temperature()
temp.celsius = 25
print(f"{temp.celsius} C is {temp.fahrenheit} F")

# Setting in Fahrenheit automatically updates Celsius
temp.fahrenheit = 68
print(f"{temp.fahrenheit} F is {temp.celsius} C")
```

6.2. Class and Static Method Decorators

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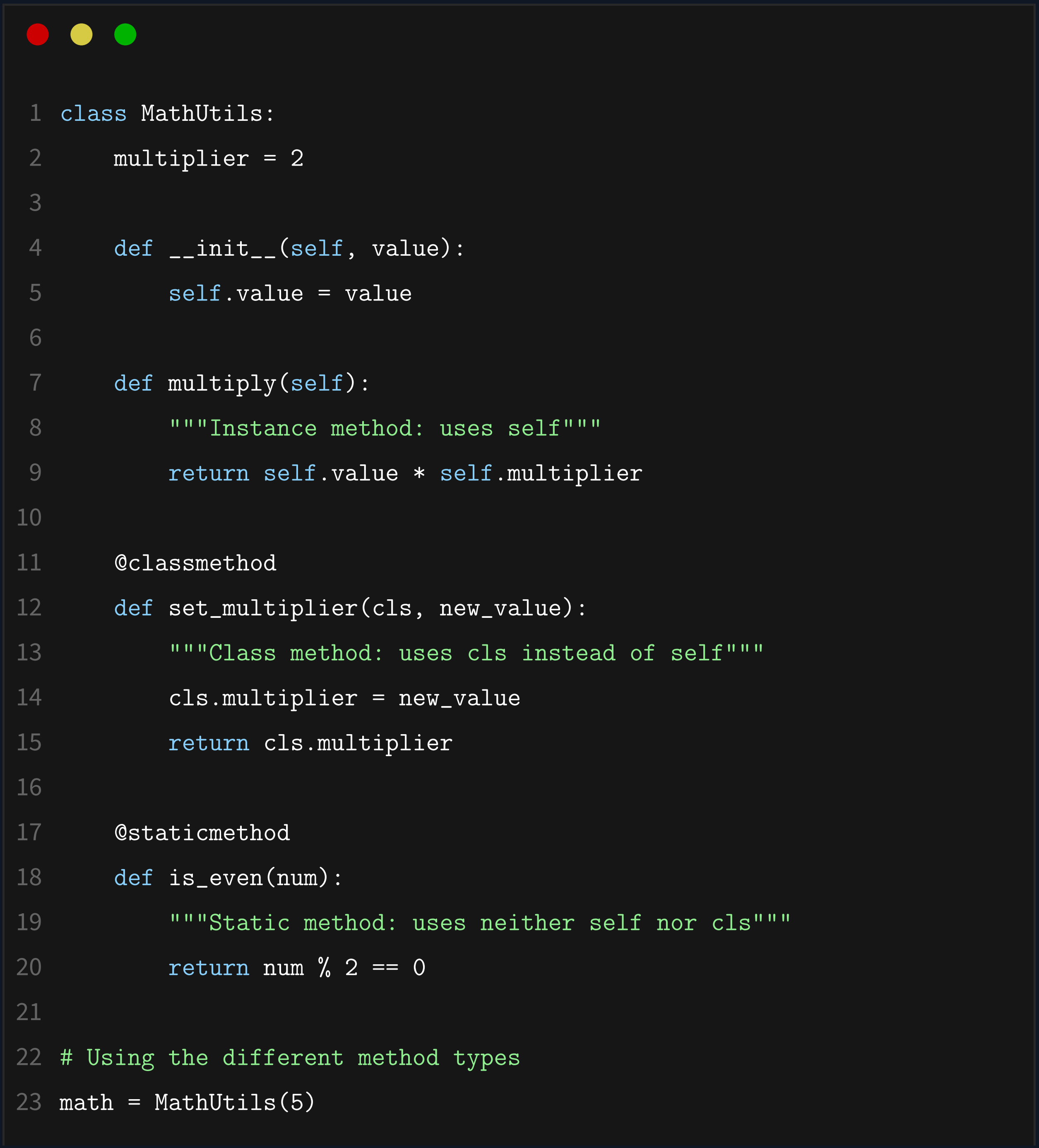


```python
class MathUtils:
    multiplier = 2

    def __init__(self, value):
        self.value = value

    def multiply(self):
        """Instance method: uses self"""
        return self.value * self.multiplier

    @classmethod
    def set_multiplier(cls, new_value):
        """Class method: uses cls instead of self"""
        cls.multiplier = new_value
        return cls.multiplier

    @staticmethod
    def is_even(num):
        """Static method: uses neither self nor cls"""
        return num % 2 == 0

# Using the different method types
math = MathUtils(5)
```

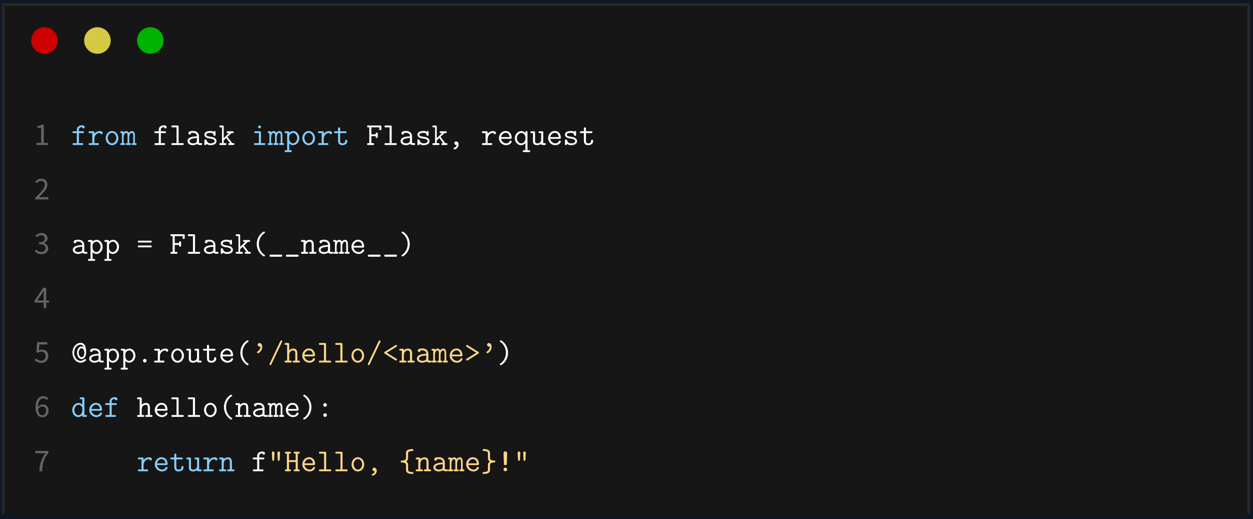
```python
print(math.multiply())  # 10 (5 * 2)

# Class method affects all instances
MathUtils.set_multiplier(3)
print(math.multiply())  # 15 (5 * 3)

# Static method is independent
print(MathUtils.is_even(4))  # True
```

7. Decorators in the Wild

Decorators are widely used in popular Python frameworks and libraries.

7.1. Flask Web Framework

Flask uses decorators for route definitions:



```python
from flask import Flask, request

app = Flask(__name__)

@app.route(’/hello/<name>’)
def hello(name):
    return f"Hello, {name}!"
```

```python

@app.route('/login', methods=['POST'])
def login():
    username = request.form['username']
    password = request.form['password']
    # Authentication logic here
    return f"Welcome back, {username}!"
```

7.2. Django Framework

Django uses decorators for views and authentication:

```python
from django.shortcuts import render
from django.contrib.auth.decorators import login_required
from django.views.decorators.http import require_POST

@login_required
def profile(request):
    # Only accessible to logged-in users
    return render(request, 'profile.html')

@require_POST
def update_profile(request):
    # Only accepts POST requests
```

```
    # Update profile logic
    return render(request, ’profile_updated.html’)
```

8. Best Practices

Follow these guidelines to create effective and maintainable decorators:

- **Use functools.wraps:** Always preserve the original function’s metadata
- **Handle all arguments:** Use ***args, **kwargs** to support any function signature
- **Keep decorators focused:** Each decorator should do one thing well
- **Document decorators:** Clearly explain what your decorator does
- **Consider performance:** Decorators add overhead to function calls
- **Test decorated functions:** Ensure decorators don’t change expected behavior

9. Conclusion

Python decorators embody elegant metaprogramming by providing a clean syntax for extending function and class behavior. They allow developers to apply consistent patterns across their codebase, separate concerns, and write more maintainable software.
By mastering decorators, you can:

- Add cross-cutting functionality without cluttering core business logic
- Create reusable code patterns that can be applied consistently

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- Solve common programming challenges with clean, readable solutions
- Better understand Python's powerful metaprogramming capabilities

Decorators shine brightest when they handle aspects like logging, timing, caching, authentication, and validation—allowing your core code to focus solely on its primary responsibility.

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Decorators: Transform Your Code

How will you leverage decorators in your next project?