Python

Context Managers

Efficient Resource Management in Python

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Source Code

1. What Are Context Managers?

Context managers in Python provide an elegant way to manage resources automatically. Using the **with** statement, they handle setup and cleanup operations, ensuring resources are properly acquired and released, even when errors occur.

- **Resource Safety:** Automatic cleanup even during exceptions
- **Code Simplicity:** Eliminates boilerplate try/finally blocks
- **Error Handling:** Built-in mechanism for exception management

1.1. The «with» Statement

Compare traditional resource management with context managers:

```python
# Without context manager
file = open('data.txt', 'r')
try:
    content = file.read()
finally:
    file.close()

# With context manager
with open('data.txt', 'r') as file:
    content = file.read()
# File is automatically closed
```

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2. Creating Context Managers

2.1. Class-Based Implementation

To implement a context manager as a class, you need to define the **__enter__** and **__exit__** methods:

- **__enter__**: Called when entering the **with** block - handles setup
- **__exit__**: Called when exiting the **with** block - handles cleanup

```python
class SimpleTimer:
    """A simple context manager that measures execution time."""

    def __init__(self, name):
        self.name = name
        self.start_time = None

    def __enter__(self):
        """
        Called when entering the -with- block.
        Sets up the timer by recording the start time.
        """
        import time
        print(f"Starting timer: {self.name}")
        self.start_time = time.time()
```

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```
        return self  # This object will be assigned to the variable after -as-

    def __exit__(self, exc_type, exc_value, traceback):
        """
        Called when exiting the -with- block (whether normally or due to exception).
        Calculates and displays the elapsed time.

        Parameters:
        - exc_type: Type of exception that occurred (or None if no exception)
        - exc_value: The exception object (or None)
        - traceback: The traceback object (or None)
        """
        import time
        elapsed = time.time() - self.start_time

        if exc_type is None:
            # No exception occurred
            print(f"Timer {self.name} finished: {elapsed:.4f} seconds")
        else:
            # An exception occurred
            print(f"Timer {self.name} aborted: {elapsed:.4f} seconds")
```

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```
            print(f"Exception: {exc_type.__name__}: {exc_value}")

        # Return False to let exceptions propagate
        # Return True would suppress the exception
        return False

# Using our custom context manager
with SimpleTimer("calculation") as timer:
    print("Performing calculation...")
    # Simulate some work
    total = sum(i**2 for i in range(1000000))
    print(f"Result: {total}")

# The __exit__ method is called automatically when leaving the with block
print("After the with block")
```

2.2. Function-Based Implementation

Using the **@contextmanager** decorator for a simpler approach:

```
from contextlib import contextmanager

@contextmanager
```

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```python
def file_manager(filename, mode):
    try:
        # Setup code
        f = open(filename, mode)
        yield f  # Yield the resource
    finally:
        # Cleanup code
        f.close()

# Usage
with file_manager('example.txt', 'r') as f:
    content = f.read()
```

3. Practical Applications

3.1. Database Transactions

A database context manager handles connections and transactions safely. This example explains how it works without requiring database expertise:

```python
import sqlite3

class DatabaseConnection:
    """
```

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```
    A context manager for database connections.
    - Automatically opens and closes database connections
    - Handles transactions (commit on success, rollback on error)
    """
    def __init__(self, db_name):
        # Store the database name for later use
        self.db_name = db_name
        self.conn = None

    def __enter__(self):
        """
        Called when entering the 'with' block.
        This method:
        1. Opens the database connection
        2. Returns the connection object for use in the 'with' block
        """
        print(f"Opening database connection to {self.db_name}")
        # sqlite3.connect creates a connection to the database
        self.conn = sqlite3.connect(self.db_name)
        return self.conn

    def __exit__(self, exc_type, exc_val, exc_tb):
        """
        Called when exiting the 'with' block (in any case).
        This method:
```

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```
        1. Checks if there was an exception (error)
        2. Rolls back changes if there was an error
        3. Commits changes if everything was successful
        4. Always closes the connection

        Parameters:
        - exc_type: The type of exception that occurred (or None if no exception)
        - exc_val: The exception object (or None)
        - exc_tb: The traceback object (or None)
        """
        if self.conn:
            if exc_type:  # If an exception/error occurred in the 'with' block
                print("Error occurred! Rolling back changes...")
                # rollback() undoes all changes made in the current transaction
                self.conn.rollback()
            else:  # If everything went well (no exceptions)
                print("Operations successful! Saving changes...")
                # commit() saves all changes made in the current transaction
                self.conn.commit()

            print("Closing database connection")
```

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```
            # Always close the connection to free up resources
            self.conn.close()

        # Return False to let exceptions propagate (be raised)
        # Return True would suppress the exception
        return False

# Simple usage example with an in-memory database (no file needed)
with DatabaseConnection(':memory:') as conn:
    # Create a cursor object to execute SQL commands
    cursor = conn.cursor()

    print("Creating a table...")
    # Create a simple table to store people
    cursor.execute('''
    CREATE TABLE people (
        id INTEGER PRIMARY KEY,
        name TEXT,
        age INTEGER
    )''')

    print("Adding a person to the database...")
    # Insert a person into the table
    cursor.execute('INSERT INTO people (name, age) VALUES (?, ?)',
                   ('John', 25))
```

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```
76
77      print("Checking if the person was added...")
78      # Verify the person was added
79      cursor.execute('SELECT * FROM people')
80      result = cursor.fetchone()  # Get the first row
81      print(f"Person in database: {result}")
82
83  # When this block ends:
84  # 1. The __exit__ method is called automatically
85  # 2. Changes are committed (saved) if no errors occurred
86  # 3. The connection is closed
87  print("Outside the with block - connection is already closed")
```

This example shows how context managers eliminate the need to manually open and close database connections, and handle transaction management (commit/rollback) automatically.

3.2. Temporary State Changes

Temporarily modify settings or environments:

```
1  import os
2  from contextlib import contextmanager
3
4  @contextmanager
```

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```python
def change_directory(path):
    """Temporarily change the working directory."""
    old_dir = os.getcwd()
    try:
        print(f"Changing directory to: {path}")
        os.chdir(path)
        yield  # Give control back to the with block
    finally:
        print(f"Changing back to: {old_dir}")
        os.chdir(old_dir)  # Always restore the original directory

# Code runs with /tmp as working directory
with change_directory("/tmp"):
    print(f"Current directory: {os.getcwd()}")
    # Do some work in the temporary directory

# Original directory is restored automatically
print("Back to the original directory")
print(f"Current directory: {os.getcwd()}")
```

4. Advanced Features

4.1. Exception Handling

Context managers can control whether exceptions are propagated or suppressed:

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```python
class ExceptionHandler:
    def __enter__(self):
        return self

    def __exit__(self, exc_type, exc_val, exc_tb):
        if exc_type is not None:
            print(f"Handled: {exc_type.__name__}: {exc_val}")
            return True  # Suppress the exception
        return False  # Propagate any exception

# Exception will be suppressed
with ExceptionHandler():
    result = 1 / 0
    print("This won't execute")
print("But this will")  # Execution continues
```

4.2. Useful Built-in Context Managers

Python provides several ready-to-use context managers:

```python
from contextlib import suppress, redirect_stdout
import io
```

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```
3
4 # Suppress specific exceptions
5 with suppress(FileNotFoundError):
6     # No exception if file doesn't exist
7     open('non_existent.txt').read()
8
9 # Redirect output
10 f = io.StringIO()
11 with redirect_stdout(f):
12     print("Hello, world!")
13 output = f.getvalue()  # Contains "Hello, world!"
14 print(output)
```

5. Performance Measurement

Create a simple timer context manager:

```
1 import time
2 from contextlib import contextmanager
3
4 @contextmanager
5 def timer(label):
6     """
```

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```
    A context manager that measures and prints the execution time
    of the code inside the 'with' block.

    Parameters:
    - label: A descriptive name for the operation being timed
    """
    # 1. Setup phase: Record the start time
    start = time.time()
    try:
        # 2. Yield control to the with-block
        #    Note: We don't yield a value here since we don't need
        #    to expose any object to the with-block
        yield
    finally:
        # 3. Cleanup phase: Calculate and display elapsed time
        #    This runs even if an exception occurs in the with-block
        end = time.time()
        elapsed = end - start
        print(f"{label}: {elapsed:.4f} seconds")

# Example 1: Basic usage
with timer("Processing data"):
    # Time-consuming operation
    time.sleep(0.5)  # Simulate work with a delay

```

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```python
# Example 2: Nested timers for profiling different parts of code
with timer("Complete operation"):
    # First subtask
    with timer("Data loading"):
        time.sleep(0.2)  # Simulate loading data

    # Second subtask
    with timer("Processing"):
        time.sleep(0.3)  # Simulate processing

    # Third subtask
    with timer("Saving results"):
        time.sleep(0.1)  # Simulate saving

# Output will show:
# Processing data: 0.5002 seconds
#  Data loading: 0.2001 seconds
#  Processing: 0.3002 seconds
#  Saving results: 0.1002 seconds
# Complete operation: 0.6009 seconds
```

6. Best Practices

- **Use for Resource Management:** Files, connections, locks
- **Keep Context Managers Focused:** Single responsibility

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- **Handle Exceptions Properly:** Decide when to propagate or suppress
- **Document Behavior:** Especially exception handling
- **Test Both Paths:** Success and exception scenarios

7. Conclusion

Context managers make Python code cleaner, safer, and more maintainable by automating resource management and error handling. Whether using the built-in managers or creating custom ones, they provide an elegant solution for handling resources properly in all circumstances.

- **Automation:** Eliminates manual resource management
- **Safety:** Ensures resources are properly released
- **Flexibility:** Implement via classes or decorators

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