
互動程式設計III
Interactive Programming Design Integration

Introduction to Multitasking

- Introduction to Multitasking in Unity
  - Definition: Multitasking in Unity refers to the ability to perform multiple tasks concurrently, improving the efficiency and responsiveness of your game or application.
  - Key Techniques:
    - Coroutines: Execute tasks over multiple frames without blocking the main thread.
    - Async/Await: Perform asynchronous operations such as I/O tasks without freezing the game.
    - Threads: Use separate threads for CPU-intensive tasks to keep the main thread responsive.
- Learning Objectives
  - Understand the basics of multitasking in Unity.
  - Learn how to use Coroutines for frame-based multitasking.
  - Implement asynchronous operations using Async/Await.
  - Explore threading for handling CPU-bound tasks.
  - Identify scenarios where each multitasking technique is most appropriate.
- Why This Chapter is Important
  - Performance: Enhances game performance by ensuring tasks do not block the main game loop.
  - Responsiveness: Improves user experience by keeping the game responsive even during complex operations.
  - Efficiency: Allows for better utilization of system resources by distributing tasks appropriately.
  - Scalability: Prepares your game or application to handle more complex and resource-intensive features seamlessly.
  - Practical Skills: Equips you with essential techniques for modern game development, ensuring your projects meet industry standards.

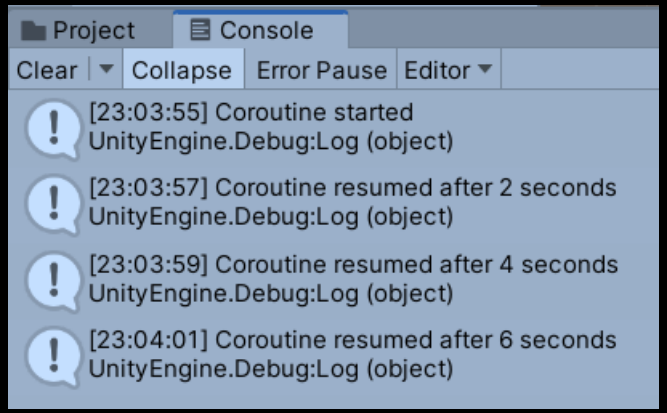

互動程式設計III
Interactive Programming Design Integration
• Multitasking
• Coroutine
• Async/Await
• Process/Thread/Task
• File I/O
• HTTP
• Appendix

What is Coroutine

- Definition and Usage
  - Definition: Coroutines are methods that can pause execution and return control to Unity but then continue where they left off on subsequent frames. A coroutine simulates a multi-threaded task in Unity.
  - Use Case: Ideal for tasks that need to be spread out over several frames, such as animations, waiting for conditions, and timed sequences.
- Benefits and Considerations
  - Benefits:
    - Non-Blocking: Allows lengthy operations (e.g., loading assets, waiting for user input) to run without freezing the game.
    - Simple Syntax: Easy to implement and read, compared to managing complex state machines.
    - Flexibility: Can be used for a variety of tasks like animations, timed events, and asynchronous operations.
    - Efficient: Allows better frame management and timing control.
  - Considerations:
    - Memory Overhead: Each coroutine adds overhead; excessive use can impact performance.
    - Lifecycle Management: Coroutines tied to MonoBehaviour can stop unexpectedly if the object is destroyed.
    - Error Handling: Exceptions in coroutines can be harder to debug and manage.
    - Scope: Ensure coroutines are managed properly to avoid unintended side effects, such as memory leaks or unexpected behavior.

EX: Create a Coroutine

- To create a coroutine:
  - The return type must be IEnumerator.
  - At least one yield return should be placed in coroutine body.
  - Use StartCoroutine to start a coroutine.




```
1  using System.Collections;
2  using UnityEngine;
3
4  public class EX_Coroutine_01 : MonoBehaviour
5  {
6      void Start()
7      {
8          StartCoroutine(MyCoroutine());
9      }
10
11     private IEnumerator MyCoroutine()
12     {
13         Debug.Log("Coroutine started");
14         yield return new WaitForSeconds(2);
15         Debug.Log("Coroutine resumed after 2 seconds");
16         yield return new WaitForSeconds(2);
17         Debug.Log("Coroutine resumed after 4 seconds");
18         yield return new WaitForSeconds(2);
19         Debug.Log("Coroutine resumed after 6 seconds");
20         yield return null;
21     }
22 }
```

EX: Create a Coroutine

- To create a coroutine:
  - The return type must be IEnumerator.
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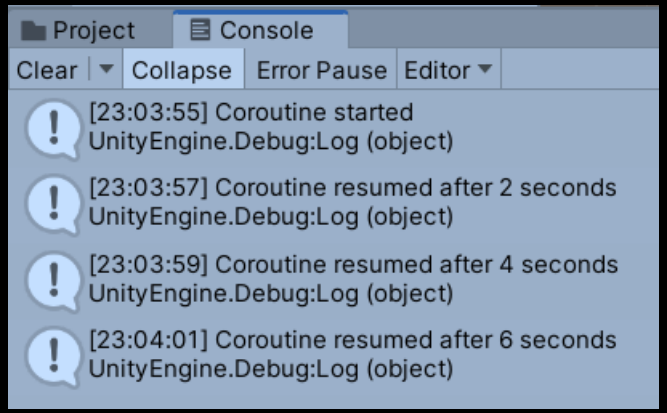



```
1  using System.Collections;
2  using UnityEngine;
3
4  public class EX_Coroutine_01 : MonoBehaviour
5  {
6      void Start()
7      {
8          StartCoroutine(MyCoroutine());
9      }
10
11     private IEnumerator MyCoroutine()
12     {
13         Debug.Log("Coroutine started");
14         yield return new WaitForSeconds(2);
15         Debug.Log("Coroutine resumed after 2 seconds");
16         yield return new WaitForSeconds(2);
17         Debug.Log("Coroutine resumed after 4 seconds");
18         yield return new WaitForSeconds(2);
19         Debug.Log("Coroutine resumed after 6 seconds");
20         yield return null;
21     }
22 }
```

EX: What Coroutine Does...

- The Unity Coroutine just creates a state machine for us.
  - It uses a simple switch to control state processes.
- The Coroutine class implements IEnumerator ❶ interfaces.

```
1  using System;
2  using System.Collections;
3  using System.Collections.Generic;
4  using UnityEngine;
5
6  public class EX_Coroutine_02 : MonoBehaviour
7  {
8      private EX_Coroutine_02_Coroutine coroutine =
9          new EX_Coroutine_02_Coroutine();
10
11     void Update()
12     {
13         if (coroutine.MoveNext())
14         {
15             object nextObj = coroutine.Current;
16             print(nextObj);
17         }
18     }
19 }
20
```

```
20
21 public class EX_Coroutine_02_Coroutine : IEnumerator<object>
22 {
23     private int state;
24
25     public object Current {                                  ❷
26         get {
27             switch (state)
28             {
29                 case 1:
30                     return 1;
31                 case 2:
32                     return 2;
33                 case 3:
34                     return 3;
35                 default:
36                     throw new InvalidOperationException();
37             }
38         }
39     }
40
41     public void Dispose() { }
42
43     public bool MoveNext() {
44         state++;
45         return state <= 3;
46     }
47
48     public void Reset() {
49         state = 0;
50     }
51 }
```

EX: Yield Instructions

- In C#, the yield keyword is not exactly syntactic sugar, but it does simplify the process of creating iterators. Here's a detailed explanation of what yield does and how it compares to traditional iterator implementations:
  - Purpose: The yield keyword is used to return elements one at a time from an enumerator without the need to explicitly manage the state of the iteration.
  - Keywords:
    - yield return: Used to return each element one by one.
    - yield break: Used to end the iteration.
- When you use yield return in a method, the C# compiler generates a state machine behind the scenes. This state machine keeps track of the current position of the iteration and resumes execution from the point where yield return was last called.
  - This state machine is implemented as a class that implements the IEnumerable or IEnumerator interface.
- Key Differences
  - Complexity: Using yield greatly reduces the complexity of writing iterators. The manual implementation requires maintaining state and ensuring correct implementation of IEnumerable and IEnumerator interfaces.
  - Readability: Code using yield is more concise and easier to understand.
  - Maintainability: Less boilerplate code means fewer opportunities for errors and easier maintenance.
- Frequently used yield return instructions:
  - yield return null; (wait until next frame)
  - yield return new WaitForSeconds(seconds); (wait for a scaled duration)
  - yield return new WaitForEndOfFrame(); (wait until the end of the frame)
  - yield return new WaitForSecondsRealtime(seconds); (wait for a specified unscaled duration)

EX: Chaining Coroutines

-

```
1  using System.Collections;
2  using UnityEngine;
3
4  public class EX_Coroutine_03 : MonoBehaviour
5  {
6      void Start()
7      {
8          StartCoroutine(FirstCoroutine());
9      }
10
11     private IEnumerator FirstCoroutine()
12     {
13         Debug.Log("First Coroutine");
14         yield return new WaitForSeconds(1);
15         yield return StartCoroutine(SecondCoroutine());
16     }
17
18     private IEnumerator SecondCoroutine()
19     {
20         Debug.Log("Second Coroutine");
21         yield return null;
22     }
23 }
```

EX: Stopping Coroutines

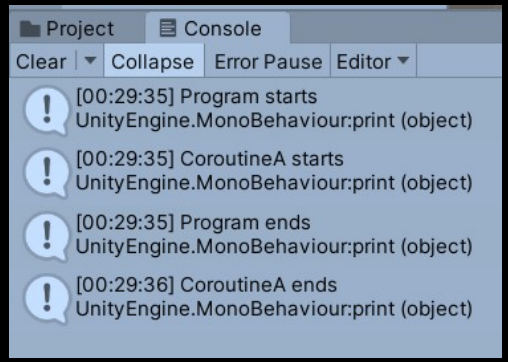
- Save the reference❶ of the coroutine enumerator in order to stop it.

```
1  using System.Collections;
2  using UnityEngine;
3
4  public class EX_Coroutine_04 : MonoBehaviour
5  {
6      private Coroutine myCoroutine;
7
8      private void Start()
9      {
10     ❶ myCoroutine = StartCoroutine(MyCoroutine());
11     }
12
13     private void Update()
14     {
15         if (Input.GetKeyDown("w"))
16         {
17             StopCoroutine(myCoroutine);
18         }
19     }
20
```

```
21     private IEnumerator MyCoroutine()
22     {
23         Debug.Log("Coroutine started");
24         yield return new WaitForSeconds(2);
25         Debug.Log("Coroutine resumed after 2 seconds");
26         yield return new WaitForSeconds(2);
27         Debug.Log("Coroutine resumed after 4 seconds");
28         yield return new WaitForSeconds(2);
29         Debug.Log("Coroutine resumed after 6 seconds");
30         yield return null;
31     }
32 }
```

EX: Problem of Execution Order

- Can you explain the console logs?



What we expected

Program starts
CoroutineA starts
<Wait for 2 seconds>
CoroutineA ends
Program ends

What we get

Program starts
CoroutineA starts
Program ends
<Wait for 2 seconds>
CoroutineA ends

```
1  using System.Collections;
2  using UnityEngine;
3
4  public class EX_Coroutine_05 : MonoBehaviour
5  {
6      void Start()
7      {
8          print("Program starts");
9
10         StartCoroutine(CoroutineA());
11
12         print("Program ends");
13     }
14
15     IEnumerator CoroutineA()
16     {
17         print("CoroutineA starts");
18
19         yield return new WaitForSeconds(1);
20
21         print("CoroutineA ends");
22     }
23 }
```

- Multitasking
  - Coroutine
  - Async/Await
  - Process/Thread/Task
  - File I/O
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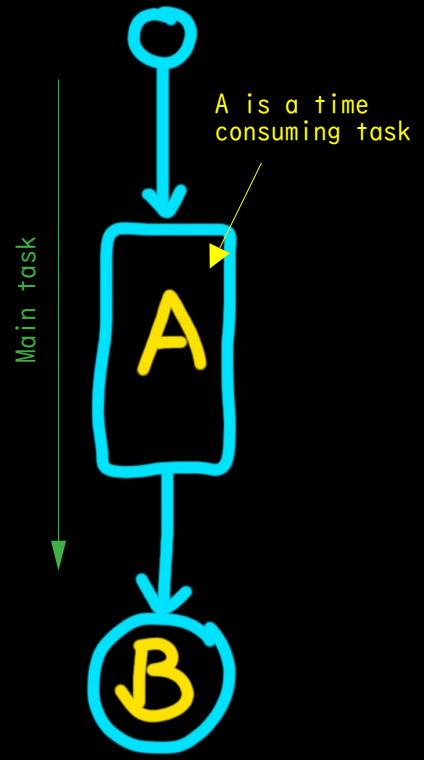
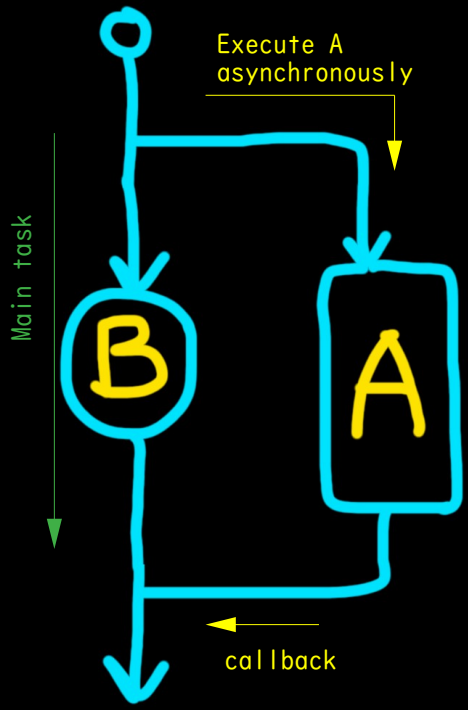
What is Async/Await

- - Introduction to asynchronous programming
  - Definition: Asynchronous programming allows for non-blocking operations, enabling tasks to run in the background while keeping the main thread responsive.
  - Benefits: Improved performance, Enhanced responsiveness, Better resource utilization
- - Task-based asynchronous patterns
  - Task: Represents an asynchronous operation. Will be introduced later.
  - Async/Await Keywords:
    - async: Marks a method as asynchronous and turn the method into a Task.
    - await: Pauses the execution of current Task and wait for the new Task to be completed.
- - You can use async with or without await.



blocking



non-blocking

Task-based Asynchronous Pattern (TAP)

- C# primarily uses the Task-based Asynchronous Pattern (TAP) to implement asynchronous operations. The Task and Task<T> types represent asynchronous operations. When you use the async keyword to define a method, and the await keyword to await a task, you're leveraging TAP.
- How async and await Work
  - Async Method:
    - The async keyword transforms the method into a state machine that can handle the asynchronous Task operation.
    - When you mark a method with the async keyword, it allows the method to use the await keyword within its body.
  - Await Keyword:
    - The await keyword is used to pause the execution of the Task until the awaited Task completes.
    - When await is encountered, the control is returned to the calling method, and the rest of the method is scheduled to continue after the awaited task completes.
  - Task Handling:
    - The Task type represents an asynchronous operation. The task can be completed, running, waiting to run, or canceled.
    - The Task is generally run on a thread pool, which is managed by the .NET runtime.

How await Works

- Suspending the Current Task:
  - When a Task encounters await, it suspends its execution and waits for the awaited Task to complete.
  - After suspension, control returns to the calling method, allowing other operations to continue.
- Scheduling Asynchronous Operations:
  - Asynchronous operations (like I/O operations) are scheduled and run, usually without consuming CPU time.
  - Code after await continues execution only after the awaited Task completes.
- Non-Blocking:
  - The await keyword allows the method to wait for a Task to complete without blocking the thread. This lets the thread handle other work.
- Summary
  - When using async/await, Tasks can call and wait for each other.
  - When a Task encounters await, it suspends and returns control to the calling method, allowing the calling method to continue other work.
  - A single thread does not execute multiple Tasks simultaneously but schedules and executes them in sequence.

Asynchronous Programming in C# (Under the Hood)

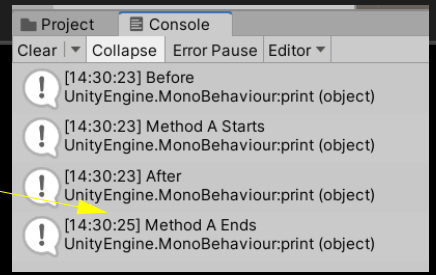
- State Machine:
  - The C# compiler translates async methods into state machines. This state machine keeps track of the method's state and knows how to resume the method once the awaited task completes.
  - The state machine allows the method to be paused and resumed without blocking the main thread.
- Thread Pool:
  - The .NET runtime uses a thread pool to manage and execute tasks. This pool is a collection of worker threads that can be reused to perform multiple tasks over their lifetime.
  - When an async method awaits a task, the task is often scheduled to run on a thread from the thread pool.
- Continuation:
  - When the awaited task completes, the state machine is resumed, and the continuation of the async method is executed.
  - The continuation may run on the same thread that completed the task or be scheduled to run on a different thread, depending on the synchronization context.

EX: Use Async/Await to replace Coroutine

- Use Async/Await to replace Coroutine
  - By marking MethodA as async, we indicates that MethodA contains asynchronous operations❷.
    - But we call MethodA like an normal method call (without await)❶. This means we are not going to ”wait” for the whole methodA to be finished. But since MethodA is a async method, it will run asynchronously.
    - When an await method is called inside methodA❸, the program will fork to another new Task to execute the await call.
    - When await is encountered❸, the control returns to the calling method (Start in this case), and the remaining code in Start continues executing❹.
    - After the await is complete, the execution of MethodA resumes from where it was paused❺.

```
1  using System.Threading.Tasks;
2  using UnityEngine;
3
4  public class EX_AsyncAwait_01 : MonoBehaviour
5  {
6      void Start()
7      {
8          print("Before");
9
10         ❶ MethodA();
11
12         ❹ print("After");
13     }
14
15     ❷ async Task MethodA()
16     {
17         print("Method A Starts");
18
19         ❸ await Task.Delay(2000); // Wait for 2 seconds.
20
21         ❺ print("Method A Ends");
22     }
23 }
```

<Wait for 2 seconds here>



EX: Use Async/Await to replace Coroutine

- This time let's we call MethodA with await.
  - In order to use await in Start(), we have to set Start() as async❶.
  - We call MethodA with await❷, this will pause the Start() and wait for await to be completed.
- Inside MethodA,
  - The await Task.Delay forks the

```
1  using System.Threading.Tasks;
2  using UnityEngine;
3
4  public class EX_AsyncAwait_02 : MonoBehaviour
5  {
6      ❶ async void Start()
7      {
8          print("Before");
9
10         ❷ await MethodA();
11
12         print("After");
13     }
14
15     async Task MethodA()
16     {
17         print("Method A Starts");
18
19         await Task.Delay(2000); // Wait for 2 seconds.
20
21         print("Method A Ends");
22     }
23 }
```

<Wait for 2 seconds here>

```
[16:08:32] Before
UnityEngine.MonoBehaviour:print (object)
[16:08:32] Method A Starts
UnityEngine.MonoBehaviour:print (object)
[16:08:34] Method A Ends
UnityEngine.MonoBehaviour:print (object)
[16:08:34] After
UnityEngine.MonoBehaviour:print (object)
```

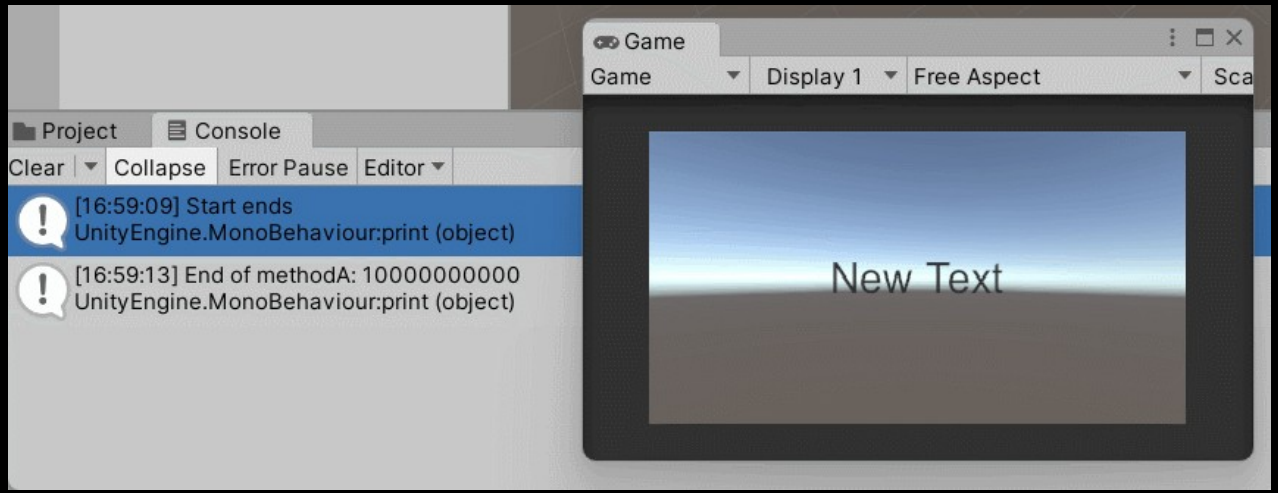
EX: Overloading in Start(1)

- Now let's intentionally overload the Start().
  - Put a super large for loop in MethodA❶, and invoke methodA in Start().
  - The "start ends" will be delayed.
  - The Update is blocked since the only Unity main thread is overloaded by Start().
- When this Unity procedure is halt, we are still able to open a Chrome or edit a Word file. This is because of the Multi-process behaviour.


```
1  using UnityEngine;
2  using UnityEngine.UI;
3
4  public class EX_AsyncAwait_04 : MonoBehaviour
5  {
6      public Text text;
7
8      void Start() {
9          MethodA();
10         print("Start ends");
11     }
12
13     void Update() {
14         if (Input.GetKey("w")) {
15             text.text = "W is pressed.";
16         }
17         else {
18             text.text = "";
19         }
20     }
21
22     void MethodA() {
23         long a = 0;
24         ❶ for (long i = 0; i < 30000000000; i++) {
25             a++;
26         }
27         print("end of MethodA: " + a);
28     }
29 }
```

EX: Overloading in Start(2)

- We can create a new thread for methodA in order not to block the Unity main thread.
  - Use Task() constructor to wrap the method into a task❶.
  - Use Task.Start() to create a new thread and run the task❶.
- Run the project and you'll see that the MethodA will not block the execution of Start() and Update() anymore.




```
1  using System.Threading.Tasks;
2  using UnityEngine;
3  using UnityEngine.UI;
4
5  public class EX_AsyncAwait_04 : MonoBehaviour
6  {
7      public Text text;
8
9      void Start()
10     {
11         Task task = new Task(MethodA);
12         task.Start();
13         print("Start ends");
14     }
15
16     void Update()
17     {
18         if (Input.GetKey("w"))
19         {
20             text.text = "W is pressed.";
21         }
22         else
23         {
24             text.text = "";
25         }
26     }
27
28     void MethodA()
29     {
30         long a = 0;
31         for (long i = 0; i < 50000000000; i++)
32         {
33             a++;
34         }
35         print("End of methodA: " + a);
36     }
37 }
```

EX: Async to Yield from Overloading

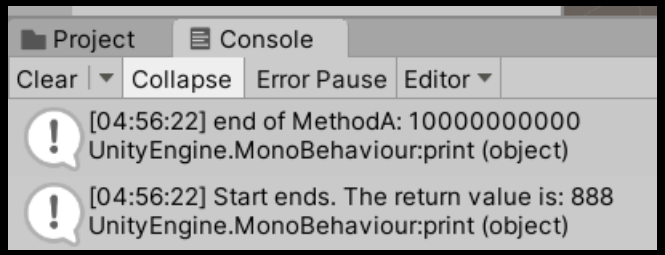
- Let's put all the heavy loading codes in a lambda method, and send it to a Task.Run(…)❶. This enables the codes to be invoke as an await task.
- Since we use await in MethodA, so it should be modified as an async method with a Task type return❷.
- Task.Run() will get a new thread from C# CLR thread pool and offload the for loop to that thread.

Question: The "Start ends" message is supposed to be shown after the for loop is finished. How to fix this problem?

```
using System.Threading.Tasks;
using UnityEngine;
using UnityEngine.UI;

public class EX_AsyncAwait_05 : MonoBehaviour
{
    public Text text;

    void Start() {
        MethodA();
        print("Start ends");
    }

    void Update() {
        if (Input.GetKey("w")) {
            text.text = "W is pressed.";
        }
        else {
            text.text = "";
        }
    }

    async Task MethodA() {
        await Task.Run(() => {
            long a = 0;
            for (long i = 0; i < 10000000000; i++) {
                a++;
            }
            print("end of MethodA: " + a);
        });
    }
}
```

EX: Return from an Async Task(2)

- In order to return some value from async Task, we have to make some changes:
  - Set the return type as a generic type T in Task<T>❶.
  - Set the return value in MethodA❷.
  - Get the return value in Start() by making the invocation of MethodA as an await Task❸.
  - Since we placed an await in Start(), we have to make it an async Task with Task type return❹.




```
1  using System.Threading.Tasks;
2  using UnityEngine;
3  using UnityEngine.UI;
4
5  public class EX_AsyncAwait_05 : MonoBehaviour
6  {
7      public Text text;
8
9      async Task Start() {
10         int x = await MethodA();
11         print("Start ends. The return value is: " + x);
12     }
13
14     void Update() {
15         if (Input.GetKey("w")) {
16             text.text = "W is pressed.";
17         }
18         else {
19             text.text = "";
20         }
21     }
22
23     async Task<int> MethodA() {
24         await Task.Run(() => {
25             long a = 0;
26             for (long i = 0; i < 10000000000; i++) {
27                 a++;
28             }
29             print("end of MethodA: " + a);
30         });
31         return 888;
32     }
33 }
```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What is Thread

- Process
  - A process is an instance of a program running in a computer. It has its own memory space and system resources.
    - Isolation: Each process runs independently and is isolated from others.
    - Resource Management: Managed by the operating system; each process has its own memory and system resources.
    - Heavyweight: Creating and managing processes is resource-intensive.
    - Need some IPC mechanism to communicated with other process.
- Thread
  - A Thread is the smallest unit of a process that can be scheduled by the operating system.
  - It represents an independent path of execution.
    - Shared Memory: Threads within the same process share memory and resources.
    - Lightweight: Less overhead compared to processes; faster to create and manage.
    - Concurrency: Enables parallelism within a single process, improving performance for CPU-bound tasks.
    - Can communicate easily with other threads within the same process.
- Task
  - A Task represents an asynchronous operation and provides a higher-level abstraction over threads.
  - It is part of the Task Parallel Library (TPL) and is used for concurrent programming.
    - Asynchronous Programming: Simplifies writing concurrent and asynchronous code.
    - Task-based Asynchronous Pattern (TAP): Utilizes async and await keywords for asynchronous operations.
    - Flexible: Can represent various types of work, such as computations or I/O operations.
    - Built on top of the thread pool

Comparison

- Key Points
  - Processes are isolated and resource-intensive, suitable for running separate applications.
  - Threads share memory within a process, enabling concurrency with lower overhead than processes.
  - Tasks provide a higher-level abstraction for asynchronous programming, leveraging the TPL for efficient task management.

Feature	Process	Thread	Task
Isolation	Yes	No	No
Creation Overhead	High	Low	Low
Communication	Inter-process communication (IPC)	Shared memory	Easier with async/await syntax
Use Case	Running separate applications	Concurrent execution within app	Asynchronous programming, TAP

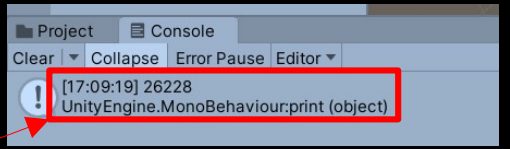
Comparison

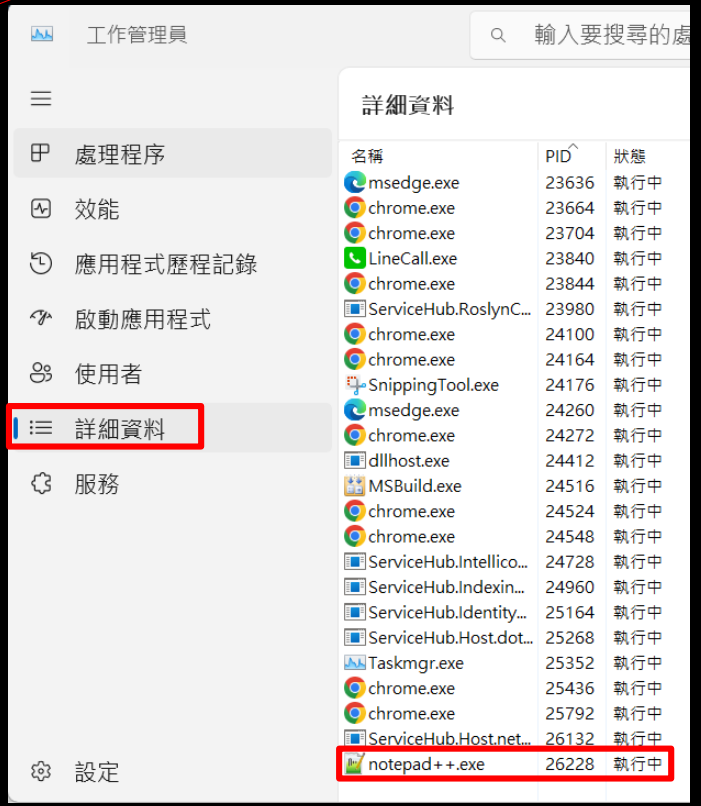
- Process:
  - Benefits:
    - Each process runs independently, preventing issues in one process from affecting others.
    - Crashes in one process do not affect others.
  - Considerations:
    - High overhead for creation and management.
    - Needs IPC for communication. More complex than thread communication.
- Threads:
  - Benefits:
    - Direct control over thread lifecycle.
    - Suitable for long-running background tasks.
  - Considerations:
    - More complex synchronization and resource management.
    - Higher resource consumption due to direct management.
- Tasks:
  - Benefits:
    - Simplified syntax for asynchronous operations.
    - Integrated with the async/await keywords for easier concurrency management.
    - More efficient resource management.
  - Considerations:
    - Overhead of task creation and context switching.
    - Not suitable for very fine-grained parallelism.

EX: Create a Process in Unity3D

- Use Process.Start() to initiate a new process.
- Use Process.CloseMainWindow() or Process.Kill() to close the process.
- You can find the process id with Task manager(Ctrl + Shift + Esc).

```
1  using System.Diagnostics;
2  using UnityEngine;
3
4  public class EX_Thread_01 : MonoBehaviour
5  {
6      Process process;
7
8      void Start()
9      {
10         process = Process.Start("C:\\Program Files\\Notepad++\\notepad++.exe");
11         print(process.Id);
12     }
13
14     void Update()
15     {
16         if (Input.GetKeyDown("w"))
17         {
18             process.CloseMainWindow();
19             //process.Kill();      // Enforce OS to terminate the process.
20         }
21     }
22 }
```





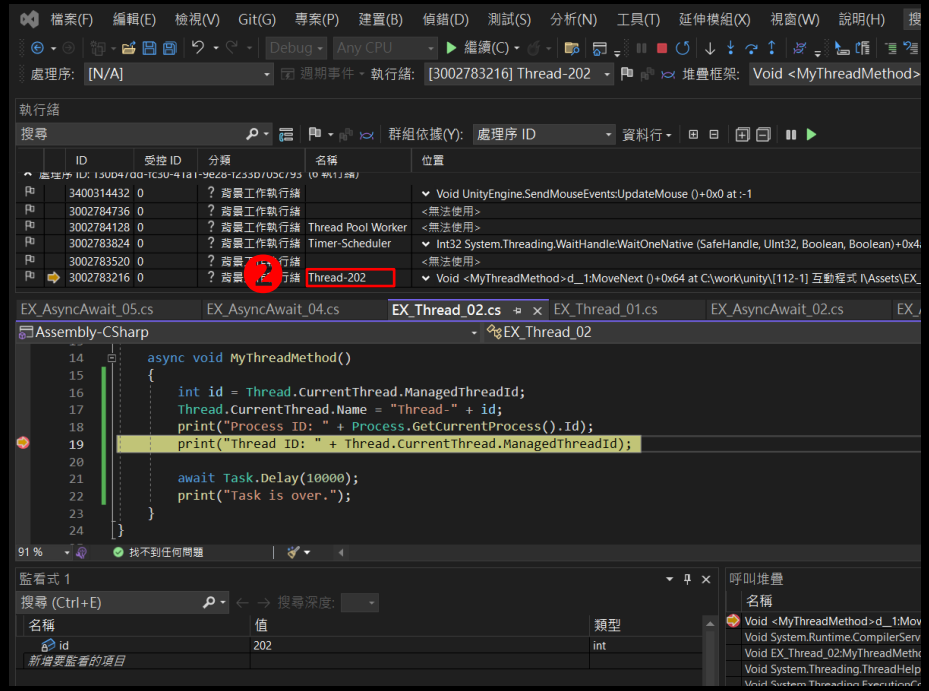
EX: Create a Thread in Unity3D

- The Thread constructor needs an delegate to specify the signature for the Thread method. There are two acceptable delegates for a Thread constructor[*]:
  - If the method has no arguments, you pass a ThreadStart delegate to the constructor.
  - If the method has an argument, you pass a ParameterizedThreadStart delegate to the constructor. The type of the only argument should be object.
- We can place a breakpoint❶ in VS studio to check the Thread id. But there are some bugs in the VS thread browser to display a managed thread id[*],so we can put the thread id into its name and check for the name in thread browser❷.

Assembly-CSharp — EX_Thread_02

```
1  using System.Diagnostics;
2  using System.Threading;
3  using System.Threading.Tasks;
4  using UnityEngine;
5
6  public class EX_Thread_02 : MonoBehaviour
7  {
8      void Start()
9      {
10         Thread thread = new Thread(new ThreadStart(MyThreadMethod));
11         thread.Start();
12     }
13
14     async void MyThreadMethod()
15     {
16         int id = Thread.CurrentThread.ManagedThreadId;
17         Thread.CurrentThread.Name = "Thread-" + id;
18         print("Process ID: " + Process.GetCurrentProcess().Id);
19         print("Thread ID: " + Thread.CurrentThread.ManagedThreadId);
20
21         await Task.Delay(10000);
22         print("Task is over.");
23     }
24 }
```

❶



❷

EX: Create a Task in Unity3D

- This had been introduced in last section.
  Here we have some examples.

```cs
using System.Threading.Tasks;
using UnityEngine;

public class EX_Thread_03 : MonoBehaviour
{
    void Start()
    {
        Task task = new Task(MyTaskMethod);
        task.Start();
    }

    void MyTaskMethod()
    {
        for (int i = 0; i < 10000; i++)
        {
            print(i);
        }
    }
}
```

A simple blocking task.
Just turn a method into a task and start it.

```cs
using System.Threading.Tasks;
using UnityEngine;

public class EX_Thread_04 : MonoBehaviour
{
    void Start()
    {
        MyTaskMethod();
        print("start finished.");
    }

    async Task MyTaskMethod()
    {
        await Task.Run(() => {
            for (int i = 0; i < 10000; i++)
            {
                //print(i);
            }
        });
        print("loop finished.");
    }
}
```

An async/await non-blocking task.

```cs
using System.Threading.Tasks;
using UnityEngine;

public class EX_Thread_04 : MonoBehaviour
{
    async void Start()
    {
        await MyTaskMethod();
        print("start finished.");
    }

    async Task MyTaskMethod()
    {
        await Task.Run(() => {
            for (int i = 0; i < 10000; i++)
            {
                //print(i);
            }
        });
        print("loop finished.");
    }
}
```

An async/await non-blocking task with await invocation.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What is Async File I/O

- Definition
  - Asynchronous file I/O operations allow reading from and writing to files without blocking the main thread. This ensures the application remains responsive, especially during long-running file operations.
- Benefits of Async File I/O
  - Non-Blocking: Prevents the main thread from being blocked, improving responsiveness in UI applications.
  - Scalability: Handles multiple file operations concurrently, making it suitable for applications dealing with a large number of files.
  - Performance: Efficiently utilizes system resources by leveraging asynchronous I/O operations.
- Considerations:
  - Error Handling: Always use try-catch blocks to handle potential exceptions during file I/O operations.
  - File Locks: Be aware of file locks that may occur when multiple operations access the same file concurrently.
  - Large Files: For very large files, consider using Stream methods like ReadAsync and WriteAsync for more granular control over the I/O process.

EX: Read a Text File

- Put your text file in <Project folder>/StreamingAssets
- Write some text in the file

```
using System;
using System.IO;
using System.Threading.Tasks;
using UnityEngine;

public class EX_FileIO_01 : MonoBehaviour
{
    async private void Start()
    {
        string path = Path.Combine(Application.streamingAssetsPath, "test.txt");
        string content = await ReadFileAsync(path);
        print(content);
    }

    public async Task<string> ReadFileAsync(string filePath)
    {
        string content = "";
        try
        {
            content = await File.ReadAllTextAsync(filePath);
        }
        catch (Exception ex)
        {
            print("Error reading file: " + ex.Message);
        }
        return content;
    }
}
```

EX: Write a Text File

- Put your text file in <Project folder>/StreamingAssets
- Write some sentences to the content variable.

```
1  using System;
2  using System.IO;
3  using System.Threading.Tasks;
4  using UnityEngine;
5
6  public class EX_FileIO_02 : MonoBehaviour
7  {
8      async private void Start()
9      {
10         string path = Path.Combine(Application.streamingAssetsPath, "test.txt");
11         string content = await WriteFileAsync(path);
12         print(content);
13     }
14
15     public async Task<string> WriteFileAsync(string filePath)
16     {
17         string content = "您好: 有什麼需要我為您服務的嗎?";
18         try
19         {
20             await File.WriteAllTextAsync(filePath, content);
21         }
22         catch (Exception ex)
23         {
24             print("Error reading file: " + ex.Message);
25         }
26         return content;
27     }
28 }
```

Difference Between File and Stream in C#

- File:
  - The File class in C# provides static methods for creating, copying, deleting, moving, and opening files. It also helps in reading from and writing to files in one go.
    - Static Methods: The File class consists of static methods, meaning you don't need to create an instance of the File class to use them.
    - Convenience: Provides high-level methods for common file operations like ReadAllText, WriteAllText, ReadAllBytes, WriteAllBytes, etc.
    - Use Cases: Ideal for simple file operations where the entire file is read or written at once.
- Stream:
  - A Stream is an abstract base class for working with sequences of bytes, such as file streams, memory streams, network streams, etc. Streams provide a way to read and write data in chunks.
    - Instance Methods: You need to create an instance of a stream class to use it (e.g., FileStream, MemoryStream).
    - Flexibility: Streams provide more control over how data is read and written, allowing for operations on parts of a file or handling continuous data streams.
    - Use Cases: Ideal for scenarios where you need to process large files, read or write data incrementally, or work with network data.
- Summary
  - File: Best for simple, high-level file operations where convenience and ease of use are important.
  - Stream: Best for scenarios requiring detailed control over data processing, large files, and continuous data streams.

EX: Read a Text File Stream

- Put your text file in <Project folder>/StreamingAssets
- Use FileStream to open file. Use StreamReader to read file.

```
using System.IO;
using System.Threading.Tasks;
using UnityEngine;

public class EX_StreamIO_01 : MonoBehaviour
{
    async void Start()
    {
        string path = Path.Combine(Application.streamingAssetsPath, "test.txt");
        await ReadFileAsync(path);
    }

    public async Task ReadFileAsync(string filePath)
    {
        using (FileStream fs = new FileStream(filePath, FileMode.Open, FileAccess.Read, FileShare.Read, 4096, true))
        using (StreamReader reader = new StreamReader(fs))
        {
            string line;
            while ((line = await reader.ReadLineAsync()) != null)
            {
                // Process one line of data.
                print(line);
            }
        }
    }
}
```

EX: Write a Text File Stream

- Put your text file in <Project folder>/StreamingAssets
- Use FileStream to open file. Use StreamWriter to write file.

```
1  using System.IO;
2  using System.Threading.Tasks;
3  using UnityEngine;
4
5  public class EX_StreamIO_02 : MonoBehaviour
6  {
7      async void Start()
8      {
9          string path = Path.Combine(Application.streamingAssetsPath, "test.txt");
10         string content = "您好：有什麼需要我為您服務的？";
11         await WriteFileAsync(path, content);
12     }
13
14     public async Task WriteFileAsync(string filePath, string content)
15     {
16         using (FileStream fs = new FileStream(filePath, FileMode.Create, FileAccess.Write, FileShare.None, 4096, true))
17         using (StreamWriter writer = new StreamWriter(fs))
18         {
19             await writer.WriteAsync(content);
20         }
21     }
22 }
```

Using using(...) Statement with Streams in C#

- Using()
  - The using statement in C# provides a convenient syntax for ensuring that IDisposable objects, such as streams, are properly disposed of when they are no longer needed. Ensures that resources are released in a timely manner, preventing resource leaks and improving application reliability.
  - Benefits of Using using Statement
    - Automatic Disposal: Automatically calls the Dispose method on the object when the block is exited, even if an exception occurs.
    - Resource Management: Ensures that resources such as file handles, network connections, and memory buffers are properly cleaned up.
    - Code Clarity: Simplifies the code by eliminating the need for explicit try-finally blocks for resource cleanup.


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Asynchronous HTTP Content Retrieval

- Definition:
  - Asynchronous HTTP content retrieval involves making non-blocking web requests to fetch data from web servers. This keeps the Unity game or application responsive while waiting for the server response.
- Common Use Cases:
  - Fetching data from REST APIs
  - Downloading assets or resources
  - Sending data to web servers
- Benefits of Asynchronous HTTP Requests
  - Non-Blocking: Prevents the main thread from being blocked, ensuring the game or application remains responsive.
  - Efficiency: Allows other operations to continue while waiting for the HTTP response.
  - Scalability: Handles multiple web requests concurrently, improving performance in network-intensive applications.

Asynchronous HTTP Content Retrieval

- Using UnityWebRequest API

```
using System.Collections;
using UnityEngine;
using UnityEngine.Networking;

public class EX_HTTP_01 : MonoBehaviour
{
    void Start()
    {
        // A correct website page.
        StartCoroutine(GetRequest("https://www.example.com"));

        // A non-existing page.
        //StartCoroutine(GetRequest("https://error.html"));
    }

    IEnumerator GetRequest(string uri)
    {
        using (UnityWebRequest webRequest = UnityWebRequest.Get(uri))
        {
            // Request and wait for the desired page.
            yield return webRequest.SendWebRequest();

            switch (webRequest.result)
            {
                case UnityWebRequest.Result.ConnectionError:
                case UnityWebRequest.Result.DataProcessingError:
                    Debug.LogError(uri + ": Error: " + webRequest.error);
                    break;
                case UnityWebRequest.Result.ProtocolError:
                    Debug.LogError(uri + ": HTTP Error: " + webRequest.error);
                    break;
                case UnityWebRequest.Result.Success:
                    Debug.Log(uri + ":\nReceived: " + webRequest.downloadHandler.text);
                    break;
            }
        }
    }
}
```

Asynchronous HTTP Content Retrieval

- Using System.Net.Http API

```
using System;
using System.Net.Http;
using System.IO;
using System.Threading.Tasks;
using UnityEngine;

public class EX_HTTP_02 : MonoBehaviour
{
    private static readonly HttpClient client = new HttpClient();

    async void Start()
    {
        string url = "https://example.com";
        await FetchAndProcessDataAsync(url);
    }

    private async Task FetchAndProcessDataAsync(string url)
    {
        try
        {
            using (HttpResponseMessage response =
                await client.GetAsync(url, HttpCompletionOption.ResponseHeadersRead))
            {
                // 下列代碼會檢查是否response.IsSuccessStatusCode==true，成立即拋出錯誤
                response.EnsureSuccessStatusCode();
                using (Stream stream = await response.Content.ReadAsStreamAsync())
                using (StreamReader reader = new StreamReader(stream))
                {
                    {
                        string content = await reader.ReadToEndAsync();
                        Debug.Log("Received content: " + content);
                    }
                }
            }
        }
        catch (Exception ex)
        {
            Debug.LogError("Error fetching data: " + ex.Message);
        }
    }
}
```


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Self Learning: Iterator Design Pattern

- Resources:
  - English:
    - Refactoring Guru:
      - https://refactoring.guru/design-patterns/iterator
    - Derek Banas
      - https://www.youtube.com/watch?v=VKIzUuMdmag
    - Gang of four: Design Pattern, 5 Behavioral Pattern - Iterator
      - https://github.com/media-lib/prog_lib/blob/master/general/Gang%20of%20Four%20-%20Design%20Patterns%20-%20Elements%20of%20Reusable%20Object-Oriented%20Software.pdf
  - Chinese:
    - 結城浩（數學少女作者）: DESIGN PATTERNS 於 JAVA 語言上的實習應用 Ch.01
      - https://www.drmaster.com.tw/bookinfo.asp?BookID=PG20214
    - 劉韜： 秒懂設計模式 Ch.15
      - https://www.tenlong.com.tw/products/9786263240261


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Q&A