



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.



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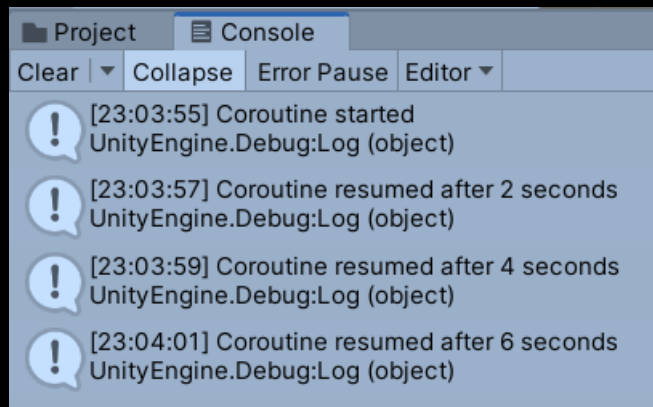
- **Multitasking**
 - **Coroutine**
 - Async/Await
 - Process/Thread/Task
 - File I/O
 - HTTP
 - Appendix

What is Coroutine

- Definition:
 - A coroutine is a lightweight form of virtual multitasking that simulates multithreading on a single thread. A coroutine can pause its execution and return control to the Unity game loop to perform a specified asynchronous task, then resume from the pause point when that task first yields or completes.
- Advantages:
 - Non-blocking: By using yield return, coroutines hand control back to the Unity game loop rather than freezing it.
 - Simple syntax: Compared to other multitasking approaches, coroutines are more straightforward to implement and read.
 - Seamless integration with Unity: They can be used for various Unity tasks—such as delayed events, animation sequences, and other asynchronous operations.
 - Minimal overhead: Unity coroutines are implemented as IEnumerator objects and are scheduled each frame by the engine. A single coroutine only occupies a small state-machine structure, so under normal use it is not a major performance bottleneck.
- Considerations:
 - Lifecycle management: Coroutines bound to a MonoBehaviour will stop unexpectedly if the associated GameObject is destroyed.
 - Error handling: Exceptions thrown inside a coroutine can be harder to debug, so you should explicitly catch and handle errors within coroutines.
 - Scope control: Coroutines still run on the main thread—they simply spread their execution across multiple frames, rather than running in parallel threads.

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: What Coroutine Does...

- C# compiler creates a **state machine** for Unity Coroutine. In this example we are trying to mimic the state machine by custom codes.
- There is a **switch condition** which controls state processes ❶.
- The Coroutine class should implement **IEnumerator** interface ❷.

```
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     ❶ public object Current {
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     ❷ 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

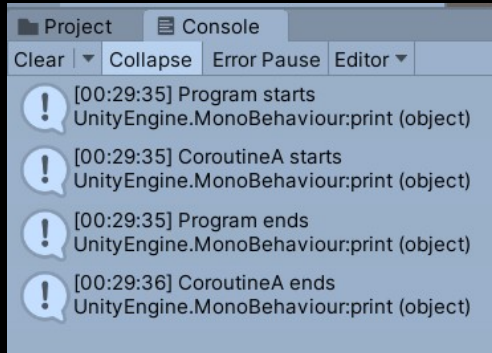
- Save the reference ❶ of the coroutine enumerator in order to stop it.

```
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?

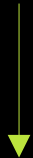


What we expected



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 }
```



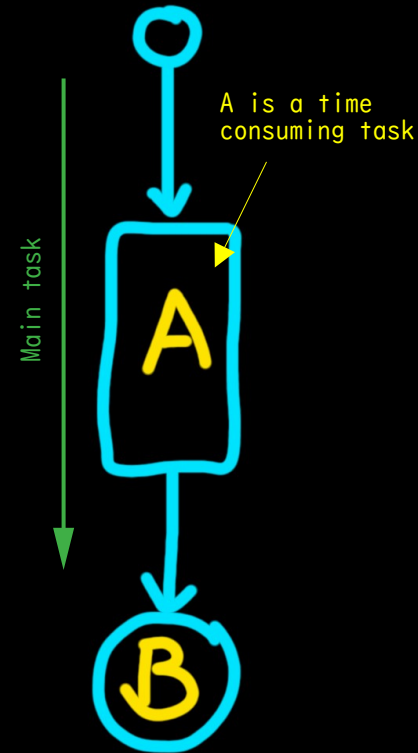
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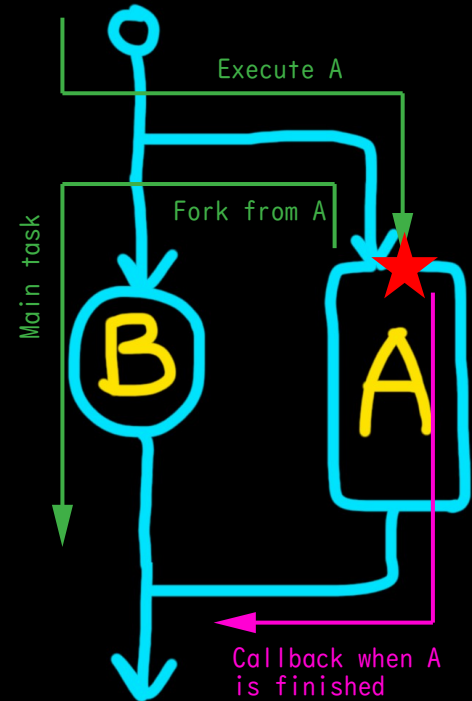
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What is Async/Await

- 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 indicate that MethodA contains asynchronous operations^②.
 - But we call MethodA like a normal method call (without await)^①. This means we are not going to "wait" for the whole MethodA to be finished. But since MethodA is an async method, it will run asynchronously.
 - When an **await** method is called inside MethodA^③, the program will fork to another new Task to execute the await call.
 - When **await** is encountered^③, the control returns to the calling method (Start in this case), and the remaining code in Start continues executing^④.
 - After the **await** is complete, the execution of MethodA resumes from where it was paused^⑤.

```
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         ① MethodA();
11
12         ④ print("After");
13     }
14
15     ② async Task MethodA()
16     {
17         print("Method A Starts");
18
19         ③ await Task.Delay(2000); // Wait for 2 seconds.
20
21         ⑤ print("Method A Ends");
22     }
23 }
```

Project Console

	Clear	Collapse	Error	Pause	Editor
!	[14:30:23] Before				UnityEngine.MonoBehaviour:print (object)
!	[14:30:23] Method A Starts				UnityEngine.MonoBehaviour:print (object)
!	[14:30:23] After				UnityEngine.MonoBehaviour:print (object)
!	[14:30:25] Method A Ends				UnityEngine.MonoBehaviour:print (object)

<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 async ❶.
 - We call MethodA with await ❷, this will pause the Start() and wait for await to be completed.
- Inside MethodA,
 - The await Task.Delay forks the

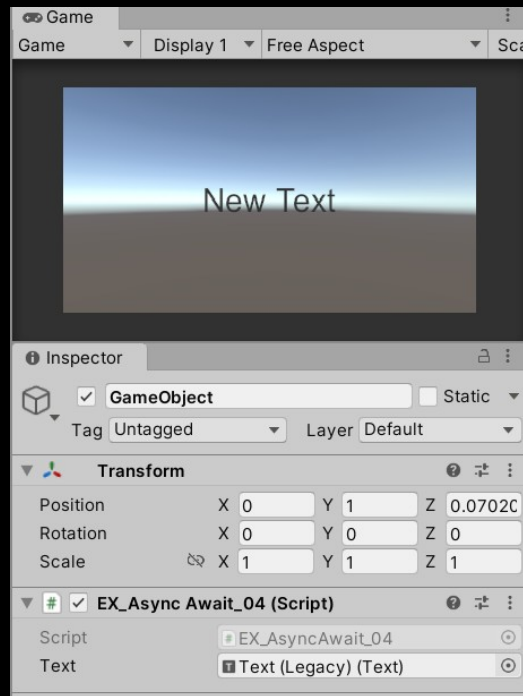
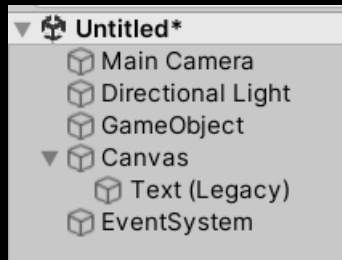
```
1 using System.Threading.Tasks;
2 using UnityEngine;
3
4 public class EX_AsyncAwait_02 : MonoBehaviour
5 {
6     ❶ async void Start()
7     {
8         print("Before");
9
10        ❷ await MethodA();
11
12        print("After");
13    }
14
15    async Task MethodA()
16    {
17        print("Method 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 MethodA** ①, 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        ① for (long i = 0; i < 3000000000; 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 task ❶.
 - Use Task.Start() to create a new thread and run the task ❷.
- 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 < 5000000000; 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 return** ❷.
- Task.Run() will get a new thread from C# CLR thread pool and offload the for loop to that thread.

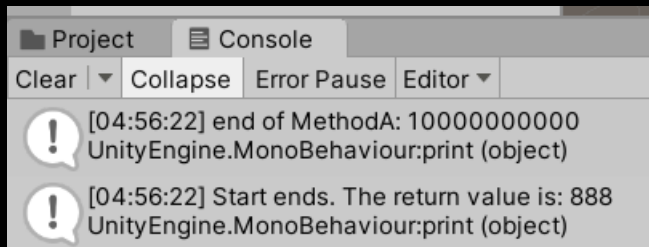


Question: The "Start ends" message is supposed to be shown after the for loop is finished. How to fix this problem?

```
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     void Start() {
10         MethodA();
11         print("Start ends");
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     ❷ async Task MethodA() {
24         ❶ 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     }
32 }
```


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     ❹ async Task Start() {
10         ❸ 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     ❶ async Task<int> MethodA() {
24         ❷ 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         ❷ 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 communicate 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

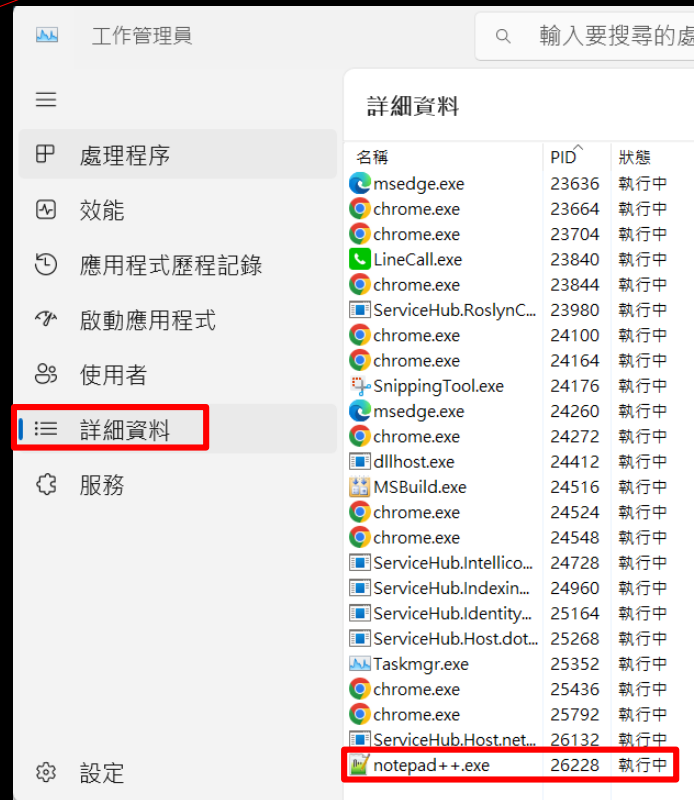
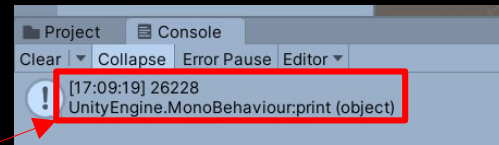
Comparison

- **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 breakpoint **❶** 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 browser **❷**.

```
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 }
```

VS Studio Thread Browser and Code Editor

Thread Browser Table:

ID	受控 ID	分類	名稱	位置
3400314432	0	?	背景工作執行緒	Void UnityEngine.SendMouseEvents.UpdateMouse ()+0x0 at :-1
3002784736	0	?	背景工作執行緒	<無法使用>
3002784128	0	?	背景工作執行緒	<無法使用>
3002783824	0	?	背景工作執行緒	Timer-Scheduler
3002783520	0	?	背景工作執行緒	Int32 System.Threading.WaitHandle.WaitOneNative (SafeHandle, UInt32, Boolean, Boolean)+0x4
3002783216	0	?	Thread-202	Void <MyThreadMethod>d_1.MoveNext ()+0x64 at C:\work\unity\1112-1 互動程式 I\Assets\EX_

Code Editor (EX_Thread_02.cs):

```
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 }
```

EX: Create a Task in Unity3D

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

```
1 using System.Threading.Tasks;
2 using UnityEngine;
3
4 public class EX_Thread_03 : MonoBehaviour
5 {
6     void Start()
7     {
8         Task task = new Task(MyTaskMethod);
9         task.Start();
10    }
11
12    void MyTaskMethod()
13    {
14        for (int i = 0; i < 10000; i++)
15        {
16            print(i);
17        }
18    }
19 }
```

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

```
1 using System.Threading.Tasks;
2 using UnityEngine;
3
4 public class EX_Thread_04 : MonoBehaviour
5 {
6     void Start()
7     {
8         MyTaskMethod();
9         print("start finished.");
10    }
11
12    async Task MyTaskMethod()
13    {
14        await Task.Run(() => {
15            for (int i = 0; i < 10000; i++)
16            {
17                //print(i);
18            }
19        });
20        print("loop finished.");
21    }
22 }
```

An async/await non-blocking task.

```
1 using System.Threading.Tasks;
2 using UnityEngine;
3
4 public class EX_Thread_04 : MonoBehaviour
5 {
6     async void Start()
7     {
8         await MyTaskMethod();
9         print("start finished.");
10    }
11
12    async Task MyTaskMethod()
13    {
14        await Task.Run(() => {
15            for (int i = 0; i < 10000; i++)
16            {
17                //print(i);
18            }
19        });
20        print("loop finished.");
21    }
22 }
```

An async/await non-blocking task with
await invocation.



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 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

```
1  using System;
2  using System.IO;
3  using System.Threading.Tasks;
4  using UnityEngine;
5
6  public class EX_FileIO_01 : MonoBehaviour
7  {
8      async private void Start()
9      {
10         string path = Path.Combine(Application.streamingAssetsPath, "test.txt");
11         string content = await ReadFileAsync(path);
12         print(content);
13     }
14
15     public async Task<string> ReadFileAsync(string filePath)
16     {
17         string content = "";
18         try
19         {
20             content = await File.ReadAllTextAsync(filePath);
21         }
22         catch (Exception ex)
23         {
24             print("Error reading file: " + ex.Message);
25         }
26         return content;
27     }
28 }
```

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.

```
1  using System.IO;
2  using System.Threading.Tasks;
3  using UnityEngine;
4
5  public class EX_StreamIO_01 : MonoBehaviour
6  {
7      async void Start()
8      {
9          string path = Path.Combine(Application.streamingAssetsPath, "test.txt");
10         await ReadFileAsync(path);
11     }
12
13     public async Task ReadFileAsync(string filePath)
14     {
15         using (FileStream fs = new FileStream(filePath, FileMode.Open, FileAccess.Read, FileShare.Read, 4096, true))
16         using (StreamReader reader = new StreamReader(fs))
17         {
18             string line;
19             while ((line = await reader.ReadLineAsync()) != null)
20             {
21                 // Process one line of data.
22                 print(line);
23             }
24         }
25     }
26 }
```

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.



互動程式設計III

Interactive Programming Design Integration

- **Multitasking**
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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

```
1 using System.Collections;
2 using UnityEngine;
3 using UnityEngine.Networking;
4
5 public class EX_HTTP_01 : MonoBehaviour
6 {
7     void Start()
8     {
9         // A correct website page.
10        StartCoroutine(GetRequest("https://www.example.com"));
11
12        // A non-existing page.
13        //StartCoroutine(GetRequest("https://error.html"));
14    }
15
16    IEnumerator GetRequest(string uri)
17    {
18        using (UnityWebRequest webRequest = UnityWebRequest.Get(uri))
19        {
20            // Request and wait for the desired page.
21            yield return webRequest.SendWebRequest();
22
23            switch (webRequest.result)
24            {
25                case UnityWebRequest.Result.ConnectionError:
26                case UnityWebRequest.Result.DataProcessingError:
27                    Debug.LogError(uri + ": Error: " + webRequest.error);
28                    break;
29                case UnityWebRequest.Result.ProtocolError:
30                    Debug.LogError(uri + ": HTTP Error: " + webRequest.error);
31                    break;
32                case UnityWebRequest.Result.Success:
33                    Debug.Log(uri + ": \nReceived: " + webRequest.downloadHandler.text);
34                    break;
35            }
36        }
37    }
38 }
```

Asynchronous HTTP Content Retrieval

- Using System.Net.Http API

```
1 using System;
2 using System.Net.Http;
3 using System.IO;
4 using System.Threading.Tasks;
5 using UnityEngine;
6
7 public class EX_HTTP_02 : MonoBehaviour
8 {
9     private static readonly HttpClient client = new HttpClient();
10
11     async void Start()
12     {
13         string url = "https://example.com";
14         await FetchAndProcessDataAsync(url);
15     }
16
17     private async Task FetchAndProcessDataAsync(string url)
18     {
19         try
20         {
21             using (HttpWebResponse response =
22                 await client.GetAsync(url, HttpCompletionOption.ResponseHeadersRead))
23             {
24                 // 下列代碼會檢查是否response.IsSuccessStatusCode==true，成立即拋出錯誤
25                 response.EnsureSuccessStatusCode();
26                 using (Stream stream = await response.Content.ReadAsStreamAsync())
27                 using (StreamReader reader = new StreamReader(stream))
28                 {
29                     {
30                         string content = await reader.ReadToEndAsync();
31                         Debug.Log("Received content: " + content);
32                     }
33                 }
34             }
35         }
36         catch (Exception ex)
37         {
38             Debug.LogError("Error fetching data: " + ex.Message);
39         }
40     }
41 }
```



互動程式設計III

Interactive Programming Design Integration

- **Multitasking**
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 - **Appendix**

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>



互動程式設計III

Interactive Programming Design Integration

Q&A