

# Hitchhikers Guide for Unity

## Reversing iOS games

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# Who Am I?

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This is only for  
educational purposes



This Talk does not  
encourage the usage or  
creation of cheats



# Agenda

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02

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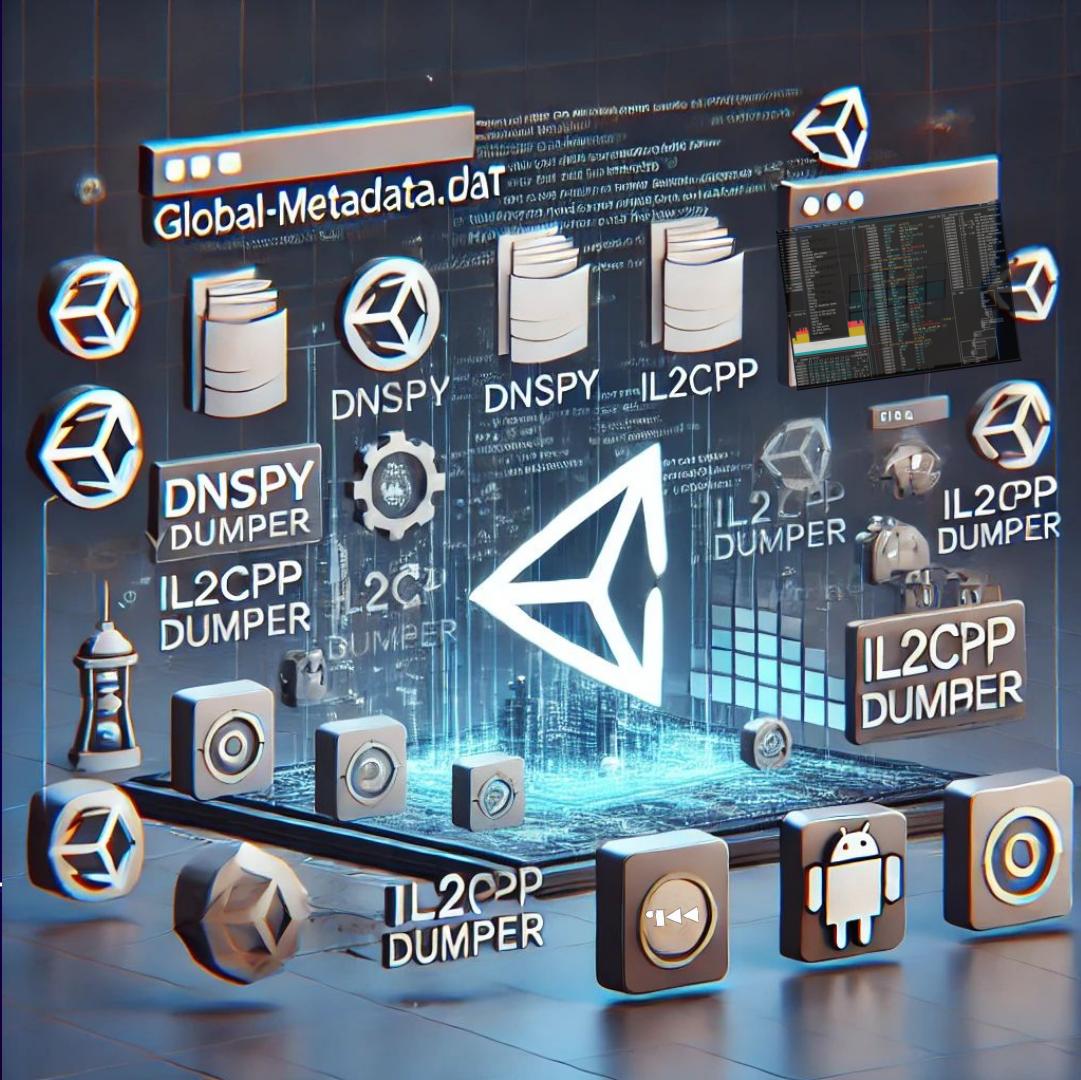
Decompilation using r2ai

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Dynamic instrumentation on Games



# Reverse Engineering on Unity





# What is Unity

- Game development platform that provides a wide array of tools and features for creating both 2D and 3D games.  
Some key features:
  - **Cross-Platform Development:** build games and deploy them across multiple platforms. (including iOS & Android)
  - **Integrated Services:** provides a range of integrated services, including analytics and monetization.
  - **C# Language**



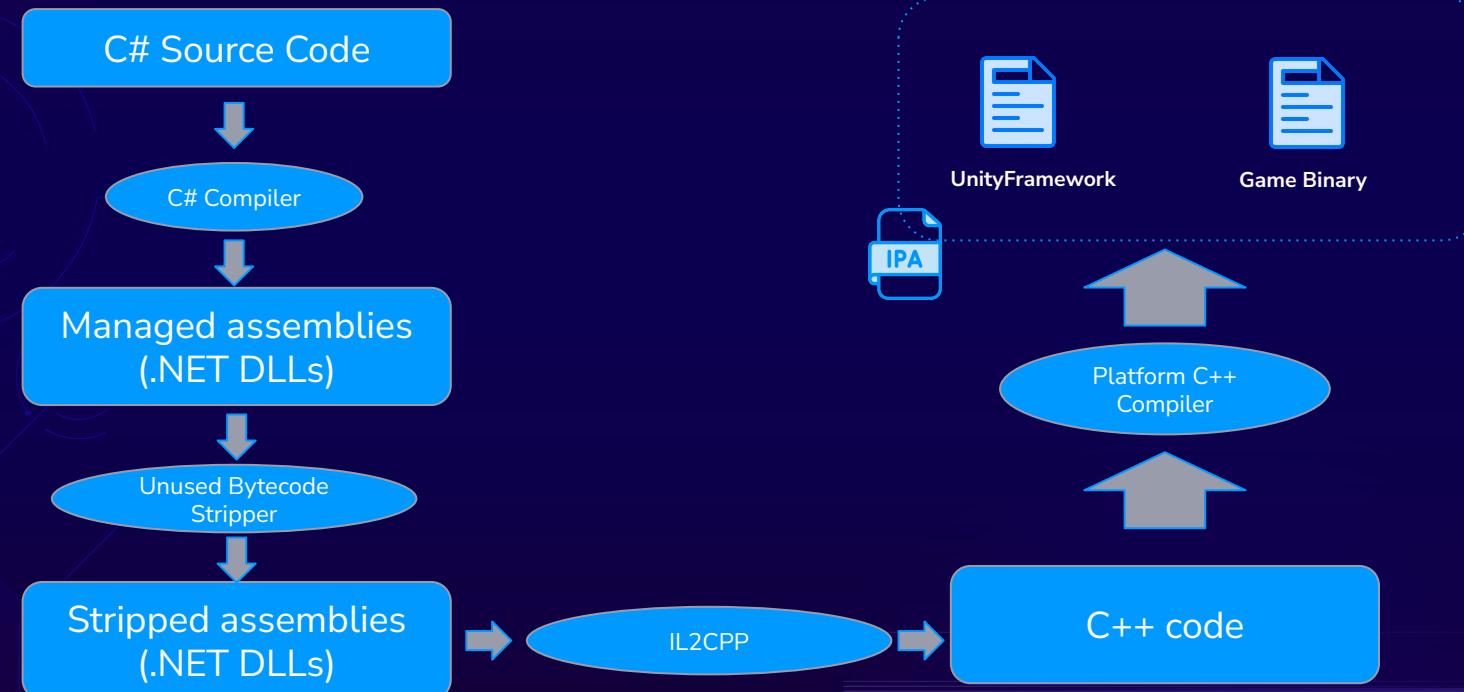
# iOS Build Process

- Source Code is written in C# and compiled to .NET assembly.
- Compiles the .NET assembly code via IL2CPP.
  - IL2CPP is an AOT Compiler to translate IL to C++
- The compiled code is found inside UnityFramework.framework.
- The main binary is just a wrapper between iOS and Unity.





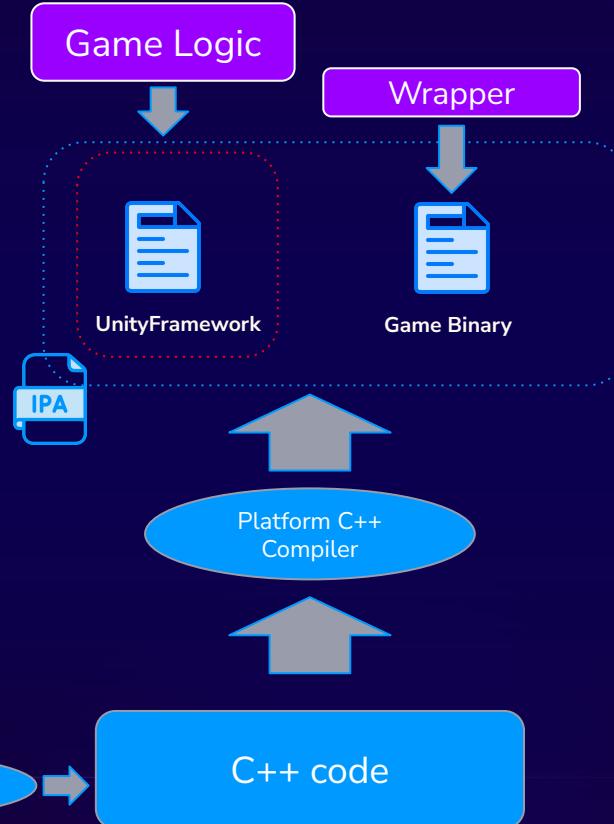
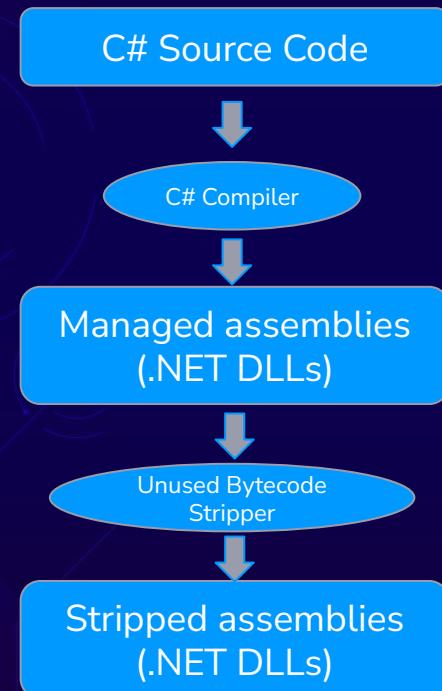
# iOS Build Process



<https://docs.unity3d.com/es/2017.4/Manual/IL2CPP-HowItWorks.html>



# iOS Build Process



<https://docs.unity3d.com/es/2017.4/Manual/IL2CPP-HowItWorks.html>



# iOS Build Process

```
→ ls Frameworks/UnityFramework.framework
```

|                                      |                                       |                                       |
|--------------------------------------|---------------------------------------|---------------------------------------|
| AppLovinSDKResources.bundle          | FirebaseInstallations_Privacy.bundle  | UnityFramework                        |
| ChartboostSDKResources.bundle        | FirebaseRemoteConfig_Privacy.bundle   | UserMessagingPlatformResources.bundle |
| FBLPromises_Privacy.bundle           | GTMSessionFetcher_Core_Privacy.bundle | _CodeSignature                        |
| FirebaseABTesting_Privacy.bundle     | GoogleDataTransport_Privacy.bundle    | iso3166_1_2_to_iso3166_1_3.plist      |
| FirebaseAuth_Privacy.bundle          | GoogleService-Info.plist              | leveldb_Privacy.bundle                |
| FirebaseCoreExtension_Privacy.bundle | GoogleUtilities_Privacy.bundle        | nanopb_Privacy.bundle                 |
| FirebaseCoreInternal_Privacy.bundle  | Info.plist                            | web_back.png                          |
| FirebaseCore_Privacy.bundle          | MTGSDK.bundle                         | web_back@2x.png                       |
| FirebaseCrashlytics_Privacy.bundle   | PrivacyInfo.xcprivacy                 | web_forward.png                       |
| FirebaseDynamicLinks_Privacy.bundle  | Promises_Privacy.bundle               | web_forward@2x.png                    |



# Game Metadata

- Platform-independent data file created by IL2CPP containing all of the .NET metadata.
- Includes definitions for all of the types, methods, properties, fields.
- Little-endian 32-bit width set of data with tables linked via indices.
- Inside the **global-metadata.dat** file.
- Some games obfuscate it.





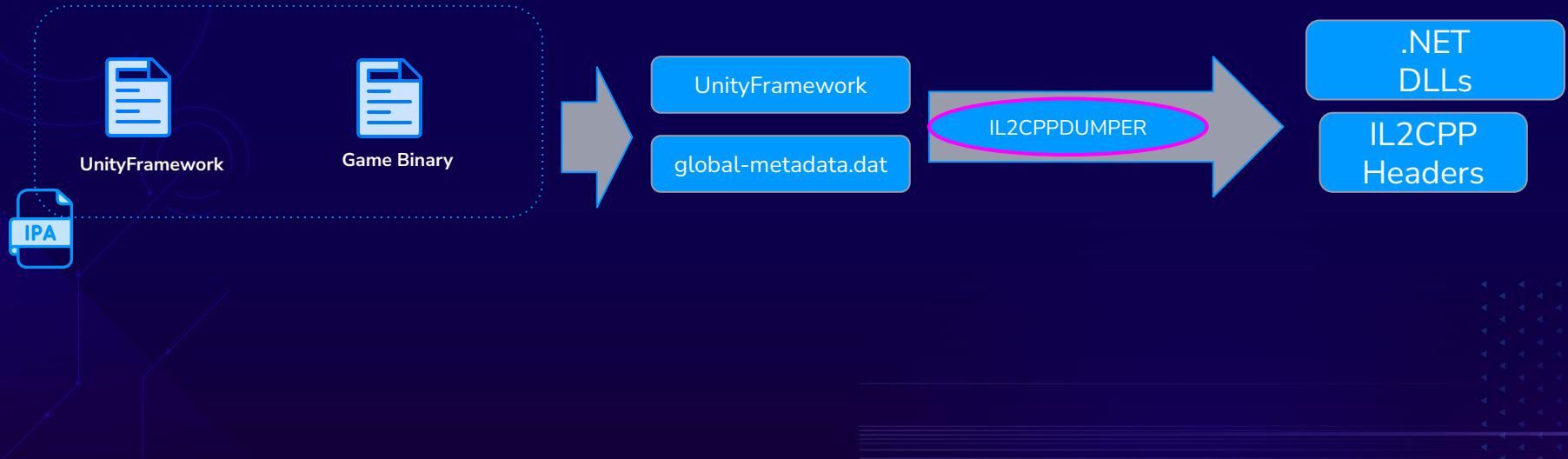
# Where can we find Game Metadata?

- Usually found inside the IPA at **Data/Managed/Metadata**.
- Sometimes can be hidden or obfuscated.
- With r2Frida, we can identify the path listing the memory maps.

```
[0x48251c000]> :dm~global-metadata~r--  
0x0000000482dc0000 - 0x00000004836e4000 r-- /private/var/containers/Bundle/Application/879FA4B2-D597-43AC-8555-F238  
CB3E14CB/[REDACTED]Data/Managed/Metadata/global-metadata.dat  
[0x48251c000]> px 32 @ 0x0000000482dc0000  
- offset - 0 1 2 3 4 5 6 7 8 9 A B C D E F 0123456789ABCDEF  
0x482dc0000 af1b b1fa 1d00 0000 0001 0000 d82a 0200 .....*...  
0x482dc0010 d82b 0200 0094 0700 d8bf 0900 00b8 1800 .+.....  
[0x48251c000]>
```



# Extracting Game Metadata





# Extracting Game Metadata

- Using IL2CppDumper
- IL2CPP Headers are stored inside a **script.json**

```
$ IL2CppDumper UnityFramework global-metadata.dat
Initializing metadata...
Metadata Version: 29
Initializing il2cpp file...
IL2Cpp Version: 29
Searching...
Change il2cpp version to: 29,1
CodeRegistration : 50017d0
MetadataRegistration : 50caec0
Dumping...
Done!
Generate struct...
Done!
Generate dummy dll...
Done!
Press any key to exit...
```



# Extracting Game Metadata

```
{  
    "Address": 40852676,  
    "Name": "TRGameRunner$$AddScore",  
    "Signature": "void TRGameRunner__AddScore (TRGameRunner_o*  
    __this, int32_t value, const MethodInfo* method);",  
    "TypeSignature": "viii"  
},  
{  
    "Address": 40852924,  
    "Name": "TRGameRunner$$AddGems",  
    "Signature": "void TRGameRunner__AddGems (TRGameRunner_o*  
    __this, int32_t inCount, System_String_o* inSource, const  
    MethodInfo* method);",  
    "TypeSignature": "viiii"  
},  
{  
    "Address": 40875372,  
    "Name": "TRGameRunner$$AddCoinsToScore",  
    "Signature": "void TRGameRunner__AddCoinsToScore  
(TRGameRunner_o* __this, int32_t count, bool ignoreMultiplier,  
    const MethodInfo* method);",  
    "TypeSignature": "viiii"  
},  
{  
    "Address": 40876056,  
    "Name": "TRGameRunner$$UpdatePowerProgress",  
    "Signature": "void TRGameRunner__UpdatePowerProgress  
(TRGameRunner_o* __this, float percent, const MethodInfo*  
    method);",  
    "TypeSignature": "vifi"  
},
```

# Symbolicating an iOS game





# Why?

- There is no symbols, which makes it a tough task

```
[0x026fb56c]> i
fd      3
file    UnityFramework
size    0x5df8460
humansz 94.0M
mode    r-x
format  mach064
iowr    false
block   0x100
type    Dynamically bound shared library
arch    arm
...
os      ios
pic     false
relocs  true
sanitize false
static  false
stripped true
subsys  darwin
va      true
```

```
[0x026fb56c]> pd
;-- func.026fb56c:
0x026fb56c  f657bda9    stp x22, x21, [sp, -0x30]!
0x026fb570  f44f01a9    stp x20, x19, [sp, 0x10]
0x026fb574  fd7b02a9    stp x29, x30, [sp, 0x20]
0x026fb578  fd830091    add x29, sp, 0x20
0x026fb57c  f50302aa    mov x21, x2
0x026fb580  f40301aa    mov x20, x1
0x026fb584  f30300aa    mov x19, x0
0x026fb588  969801f0    adrp x22, 0x5a0e000
0x026fb58c  c8fa5839    ldrb w8, [x22, 0x63e]
0x026fb590  e8010037    tbnz w8, 0, 0x26fb5cc
0x026fb594  c08101b0    adrp x0, 0x5734000
0x026fb598  00e00f91    add x0, x0, 0x3f8
0x026fb59c  fba6fa97    bl sym.func.025a5188
0x026fb5a0  c08101f0    adrp x0, 0x5736000
0x026fb5a4  00600391    add x0, x0, 0xd8
0x026fb5a8  f8a6fa97    bl sym.func.025a5188
0x026fb5ac  c08101f0    adrp x0, 0x5736000
0x026fb5b0  00e03c91    add x0, x0, 0xf38
0x026fb5b4  f5a6fa97    bl sym.func.025a5188
0x026fb5b8  e08101d0    adrp x0, 0x5739000
0x026fb5bc  00000791    add x0, x0, 0x1c0
0x026fb5c0  f2a6fa97    bl sym.func.025a5188
0x026fb5c4  28000000    ...
```



# il2cpp.r2.js

- URL: <https://github.com/radareorg/radare2/blob/master/scripts/il2cpp.r2.js>
- Gets all symbols and functions from the Game Metadata and creates r2 flags into the UnityFramework image.
- Requires emulating the binary to process all the new references (aae)

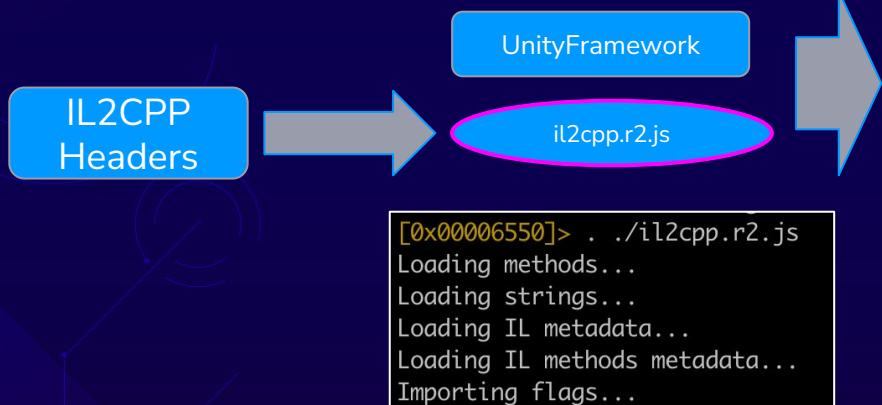
```
{  
    "Address": 28825424,  
    "Name": "Store.Shop.GemController$$GiveGems",  
},
```



```
0x01b7d750 0 sym.il.Store.Shop.GemController__GiveGems
```



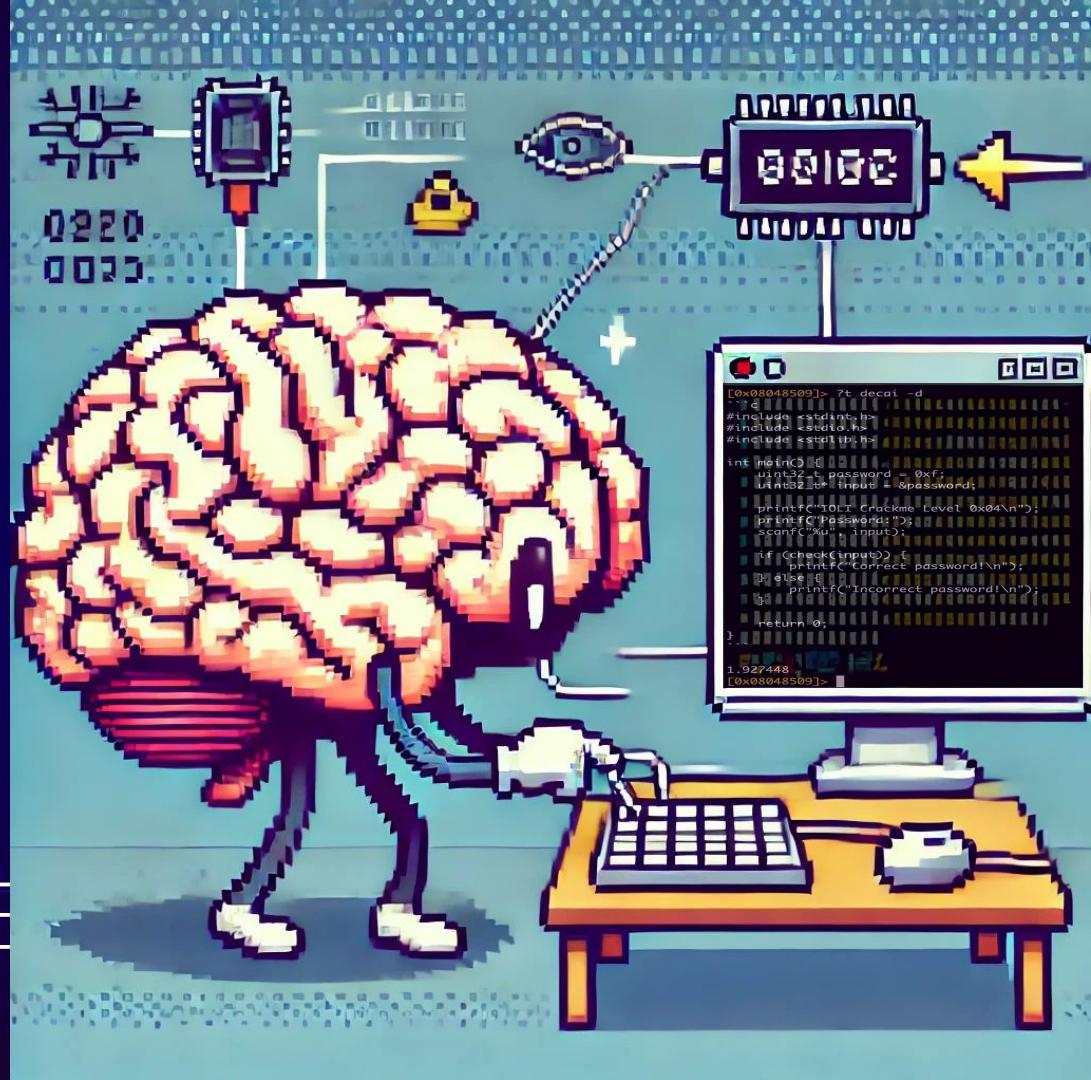
# Parsing Game Metadata



```
[0x026fb56c [xAdvC]0 0% 245 UnityFramework> ofsQ:pd $r.. @ sym.func._026fb56c
    ; func._026fb56c:
    ; CALL XREF from sym.Func._02bc3054 @ +0x54(x)
684: sym.il.TRGamerunner__AddCoinsToScore (int64_t arg1, int64_t arg2, int64_t arg3);
`- args(x0, x1, x2) vars({:sp[0x10..0x20]})

0x026fb56c f657bd09 stp x22, x21, [sp, -0x0]!
0x026fb570 f44f01a9 stp x20, x19, [var_10h]
0x026fb574 f47b02a9 stp x29, x30, [var_20h]
0x026fb578 fd830091 add x29, sp, 0x20
0x026fb57c f50302aa mov x21, x2
0x026fb580 f40301aa mov x20, x1
0x026fb584 f30300aa mov x19, x0
0x026fb588 969801f0 addp x22, 0x5a0e0000
0x026fb58c c5fa5839 ldrb w8, [x22, 0x63e]
0x026fb590 e8010037 tbnz w8, 0, 0x26fb5cc ; unlikely
0x026fb594 c08101b0 addp x0, il.meta.UnityEngine.Purchasing.AppleReceiptParser_TypeInfo0 ; 0x573400
0x026fb598 00e00f91 add x0, x0, 0x3f8 ; 0x57343f8
0x026fb59c fba0fa97 bl sym.func._025a5188 ;[1] : sym.func._025a5188(0x57343f8, 0x0, 0x0, 0x0)
0x026fb5a0 c08101f0 addp x0, il.meta.GameServer_TypeInfo0 ; 0x5736000
0x026fb5a4 00e00391 add x0, x0, 0xd8 ; 0x5736008
0x026fb5a8 f8a0fa97 bl sym.func._025a5188 ;[1] ; sym.func._025a5188(0x5736008, 0x0, 0x0, 0x0)
0x026fb5ac c08101f0 addp x0, il.meta.GameServer_TypeInfo0 ; 0x5736000
0x026fb5b0 00e03c91 add x0, x0, 0xf38 ; 0x5736f38
0x026fb5b4 f5a0fa97 bl sym.func._025a5188 ;[1] ; sym.func._025a5188(0x5736f38, 0x0, 0x0, 0x0)
0x026fb5b8 e80101d0 addp x0, il.meta.RegionSpeedEnhancementConfigData_TypeInfo0 ; 0x5739000
0x026fb5bc 00000791 add x0, x0, 0x1c0 ; 0x57391c0 ; "W\x8d"; il.meta.RewardedAdManager_TypeInfo0448
0x026fb5c0 f2a0fa97 bl sym.func._025a5188 ;[1] ; sym.func._025a5188(0x57391c0, 0x0, 0x0, 0x0)
0x026fb5c4 28008052 mov w8, 1
```

# Decompilation using r2ai





# What is r2ai



- r2-like REPL using r2pipe to interact with a IA model from within an radare2 session.
- We can use a local or a remote model (OpenAI, Anthropic, Bedrock)
- Embed the output of an r2 command and resolve questions on the given data.

```
[0x00000000]> !r2ai
[R2AI] OpenAI API key loaded from ~/.r2ai.openai-key
[R2AI] Anthropic API key loaded from ~/.r2ai.anthropic-key
[r2ai:0x100003a84]>
```

```
r2pm -ci r2ai
```



# Decai

- DeCAI is a **Decentralized and Collaborative AI framework** that focuses on collaborative, decentralized AI model training.
  - The key idea is to enable multiple contributors to train models collaboratively.
- Radare2 has a decai plugin which allow us to communicate with some AI models.
- Supported remote APIs:
  - Anthropic
  - OpenAI
  - Huggingface



```
r2pm -ci decai
```

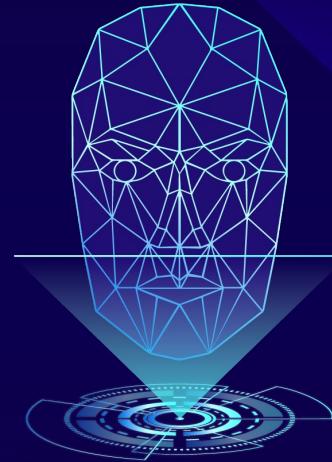
```
[0x00000000]> decai
Usage: decai (-h) ...
decai -H      - help setting up r2ai
decai -d [f1 ..] - decompile given functions
decai -dd [...] - same as above, but ignoring cache
decai -D [query] - decompile current function with given extra query
decai -e      - display and change eval config vars
decai -h      - show this help
decai -i [f] [q] - include given file and query
decai -n      - suggest better function name
decai -q [text] - query language model with given text
decai -Q [text] - query on top of the last output
decai -r      - change role prompt (same as: decai -e prompt)
decai -v      - show local variables
decai -V      - find vulnerabilities
decai -x      - eXplain current function
[0x00000000]>
```



# Decompiling with AI

- Configure the API (Claude, OpenAi, r2Ai-server, ...)
- Configure the language
- Have fun: **decai -d**

```
[0x01b7d750]> decai -e
decai -e api=claude
decai -e host=http://localhost
decai -e port=8080
decai -e prompt=Only respond with code.
rom comment - remove dead assignments -
ble
decai -e ctxfile=
decai -e cmds=pdc
decai -e cache=false
decai -e lang="C#"
decai -e hlang=English
decai -e debug=false
decai -e model=
[0x01b7d750]> █
```





# Decompiling with AI

```
[0x01b7d750]> decai -d
using System;

public class GemController
{
    public void GiveGems(int amount, string reason, bool showAnimation, Action callback)
    {
        if (amount <= 0)
        {
            return;
        }

        int currentGems = GetGems();
        int newGemCount = currentGems + amount;

        SetGems(newGemCount);
        SaveShopData();
        LogGemAnalytics(amount, reason);

        if (showAnimation)
        {
            PlayGemAnimation(amount, currentGems, newGemCount, callback);
        }
        else
        {
            UpdateGemDisplay(newGemCount);
            callback?.Invoke();
        }
    }
}
```

```
[0x00473368]> af
[0x00473368]> decai -d
public static bool IsDeviceJailbroken()
{
    string[] jailbreakPaths = {
        "/Applications/Cydia.app",
        "/Library/MobileSubstrate/MobileSubstrate.dylib",
        "/bin/bash",
        "/usr/sbin/sshd",
        "/etc/apt",
        "/private/jailbreak.txt"
    };

    foreach (string path in jailbreakPaths)
    {
        if (File.Exists(path))
        {
            return true;
        }
    }

    try
    {
        File.WriteAllText("/private/jailbreak.txt", "This is a test.");
        File.Delete("/private/jailbreak.txt");
        return true;
    }
    catch
    {
        return false;
    }
}
```

# Dynamic Instrumentation an iOS Game

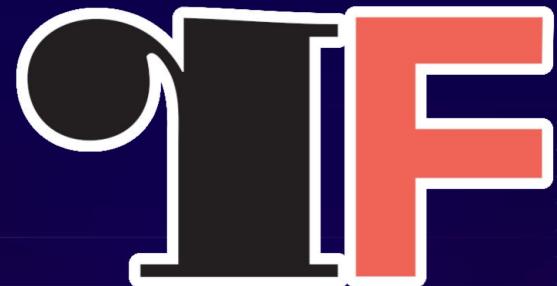


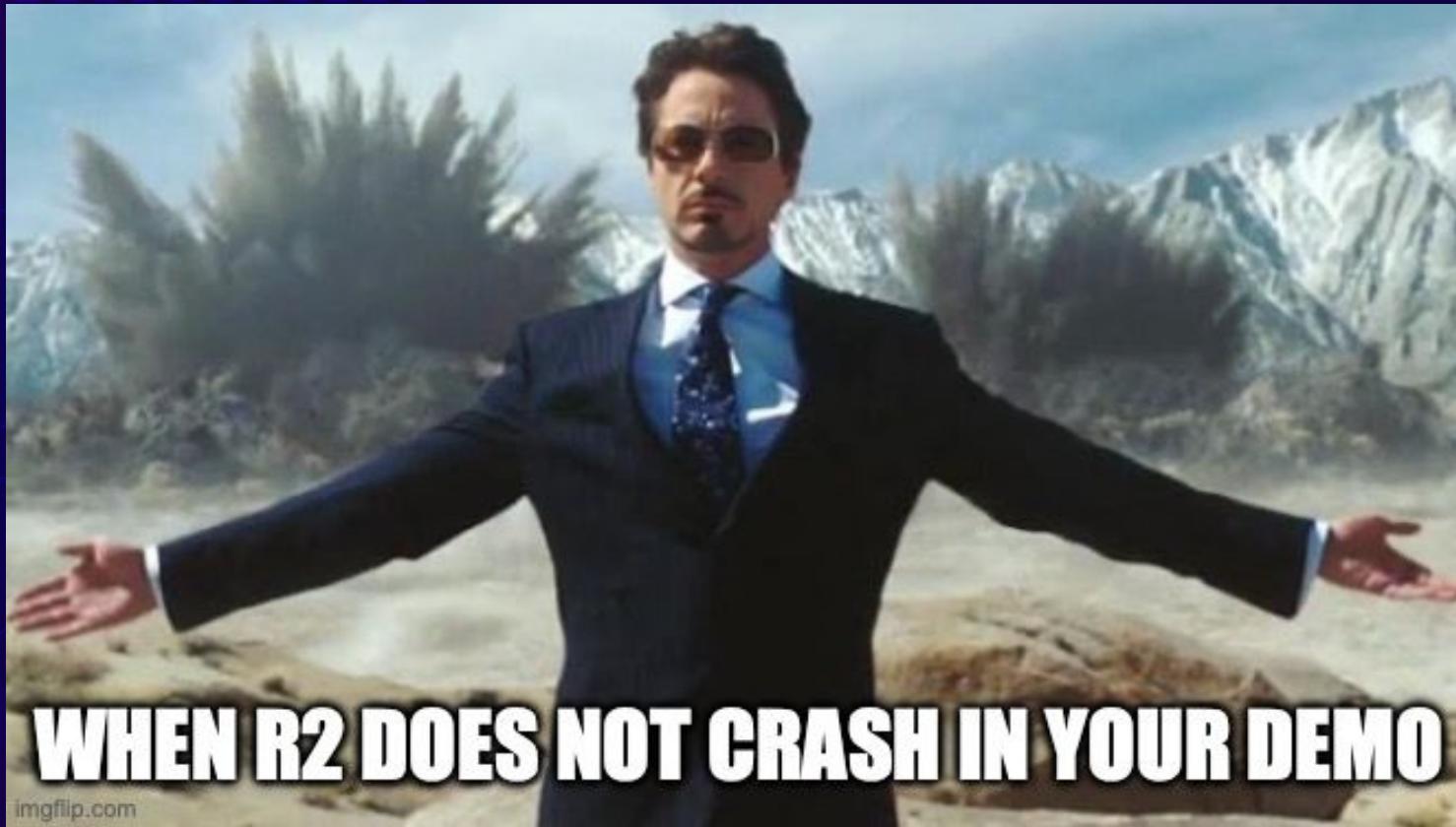


# r2Frida

- Radare2 IO plugin to use Frida from r2 shell.
- Combines the power of static (Radare2) & dynamic analysis (Frida)
- Features
  - Attach to (or spawn) any local or remote process (USB, TCP)
  - Ability to read and write memory from target process
  - **Ability to read the disassembly in memory**
  - **Ability to modify the application in memory**
- Written in C and Typescript
- Open Source

<https://github.com/nowsecure/r2frida>





**WHEN R2 DOES NOT CRASH IN YOUR DEMO**

imgflip.com



Can we “improve”  
the game experience?



# Pause the Game

:db sets a breakpoint to the address

Base Address

```
[0x104f30474]> :dm~Unity~r-x  
0x0000000100c70000 - 0x0000000104d00000 r-x /private/var/containers/Bundle/Application/A4C  
22ED3-2E76-4E62-8F7F-E99BA80E30F1/[REDACTED]/Frameworks/UnityFramework.framework/UnityF  
ramework  
[0x104f30474]> :dm~Unity~r-x:0[0]  
0x0000000100c70000  
[0x104f30474]> ? 0x0000000100c70000 + 0xAC474~hex[1]  
0x100d1c474  
[0x104f30474]> :db 0x100d1c474  
[0x104f30474]> Breakpoint 0x100d1c474 hit
```

GameController  
Ptr

```
[0x102e24000]> :dr.  
fp : 0x000000016cf7d40 lr : 0x000000010350f548 pc : 0x00000001034c0474  
sp : 0x000000016cf7d20 nzcv : 0x0000000000000000 x0 : 0x00000009ab362640  
q0 : 0x0000000000000000 d0 : 0x0000000000000000 s0 : 0x0000000000000000  
x1 : 0x0000000000000000 q1 : 0x0000000000000000 d1 : 0x0000000000000000  
s1 : 0x0000000000000000 x2 : 0x0000000b9be9f350 q2 : 0x0000000000000000  
d2 : 0x0000000000000000 s2 : 0x0000000000000000 x3 : 0x000000010350623c
```

# Boost Player

**:dxc** allows us to call a Native Function defined at the address

```
[0x102e24000]> :dxc 0x1034bb638 0x00000009ab362640  
"0x0"  
[0x102e24000]> :dc  
[0x102e24000]> Continue thread(s).
```

```
{  
    "Address": 685624,  
    "Name": "GameController$$BoostPlayer",  
    "Signature": "void GameController__BoostPlayer  
(GameController_o* __this, float distance, bool isMega, const  
MethodInfo* method);",  
    "TypeSignature": "vifii"  
},
```

```
[0x000a7638]> decai -d  
public class GameController  
{  
    public void BoostPlayer(int arg1, int arg2)  
    {  
        var player = GetPlayerFromArgument(arg1);  
        if (player == null)  
        {  
            HandleTutorialHints();  
            return;  
        }  
  
        float shakeIntensity = 175.0f;  
        float shakeDuration = 0.75f;  
        float shakeFrequency = 2.0f;  
  
        GameCamera.Shake(shakeIntensity, shakeDuration, shakeFrequency, 0);  
  
        var audioManager = GetAudioManager();  
        if (audioManager != null)  
        {  
            audioManager.PlayFX(1.0f, 3, 0);  
        }  
    }  
}
```



# Avoiding Obstacles

```
{  
    "Address": 680020,  
    "Name":  
"GameController$$HandleCollisionWithObstacles",  
    "Signature": "void  
GameController__HandleCollisionWithObstacles  
(GameController_o* __this, const MethodInfo*  
method);",  
    "TypeSignature": "vii"  
},
```

```
[0x102e24000]> wa ret @ 0x102c0a054  
INFO: Written 4 byte(s) (ret) = wx c0035fd6 @ 0x102c0a054  
[0x102e24000]> pd 1 @ 0x102c0a054  
          0x102c0a054      c0035fd6      ret  
[0x102e24000]> █
```

```
[0x000a6054]> decai -d  
public class GameController  
{  
    public void HandleCollisionWithObstacles()  
    {  
        ...  
        foreach (var obstacle in obstacles)  
        {  
            ...  
            if (!player.IsStumbling)  
            {  
                if (obstacle.IsDeadly)  
                {  
                    player.Kill(obstacle.IsSpike ? 2 : 3);  
                    gameCamera.Shake(1f, 1f, 1f, 0f);  
                }  
                else  
                {  
                    player.Stumble(0f);  
                    gameCamera.Shake(1f, 1.5f, 1f, 0f);  
                }  
            }  
        }  
    }  
}
```



# Endless Game

```
{  
    "Address": 683924,  
    "Name": "GameController$$HandleEndGame",  
    "Signature": "void GameController__HandleEndGame  
(GameController_o* __this, const MethodInfo*  
method);",  
    "TypeSignature": "vii"  
},
```

```
{  
    "Address": 661160,  
    "Name": "GameController$$ResurrectPlayer",  
    "Signature": "bool  
GameController__ResurrectPlayer (GameController_o*  
__this, bool isSaveMe, const MethodInfo* method);",  
    "TypeSignature": "iiii"  
},
```





Can we get extra  
resources?





# Adding Coins

```
100: sym.il.CharacterPlayer__AddCoins (int64_t arg1, int64_t arg2);
`- args(x0, x1)
    0x000d0468  3f040071    cmp w1, 1
    0x000d046c  eb020054    b.lt 0xd04c8
    0x000d0470  084041b9    ldr w8, [x0, 0x140]
    0x000d0474  0801010b    add w8, w8, w1
    0x000d0478  084001b9    str w8, [x0, 0x140]
    0x000d047c  084441b9    ldr w8, [x0, 0x144]
    0x000d0480  0801010b    add w8, w8, w1
    0x000d0484  084401b9    str w8, [x0, 0x144]
    0x000d0488  094841b9    ldr w9, [x0, 0x148]
    0x000d048c  0801096b    subs w8, w8, w9
    0x000d0490  cb010054    b.lt 0xd04c8
    0x000d0494  093041b9    ldr w9, [x0, 0x130]
; arg1 ; fcn.0000ba84
```

```
{
    "Address": 853096,
    "Name": "CharacterPlayer$$AddCoins",
    "Signature": "void CharacterPlayer__AddCoins (CharacterPlayer_o* __this, int32_t count, const MethodInfo* method);",
    "TypeSignature": "viii"
},
```

```
[0x000d0468]> decai -d
public class CharacterPlayer
{
    public int AddCoins(int coins)
    {
        if (coins < 1)
            return this.CoinsCount;

        this.CoinsCount += coins * 500;
        this.CoinsCollectedCount++;

        if (this.CoinsCollectedCount > this.MaxCoinsCollected)
            this.MaxCoinsCollected = this.CoinsCollectedCount;

        this.LastCollectedCoins = coins;

        return this.CoinsCount;
    }

    private int CoinsCount;
    private int CoinsCollectedCount;
    private int MaxCoinsCollected;
    private int LastCollectedCoins;
}
```



# Adding Coins

‘wa allows us to assembly multiple instructions and write it at the current offset.

```
[0x10136c468]> pd 5
 0x10136c468      3f040071      cmp w1, 1
 0x10136c46c      eb020054      b.lt 0x10136c4c8          ; likely
 0x10136c470      084041b9      ldr w8, [x0, 0x140]
 0x10136c474      0801010b      add w8, w8, w1
 0x10136c478      084001b9      str w8, [x0, 0x140]      ; [0x00000140:4] =
0xffffffff
[0x10136c468]> 'wa mov w1, 100;nop
INFO: Written 8 byte(s) (mov w1, 100;nop) = wx 810c80521f2003d5 @ 0x10136c468
[0x10136c468]> pd 5
 0x10136c468      810c8052      mov w1, 0x64
 0x10136c46c      1f2003d5      nop
 0x10136c470      084041b9      ldr w8, [x0, 0x140]
 0x10136c474      0801010b      add w8, w8, w1
 0x10136c478      084001b9      str w8, [x0, 0x140]      ; [0x00000140:4] =
0x63
[0x10136c468]> █
```

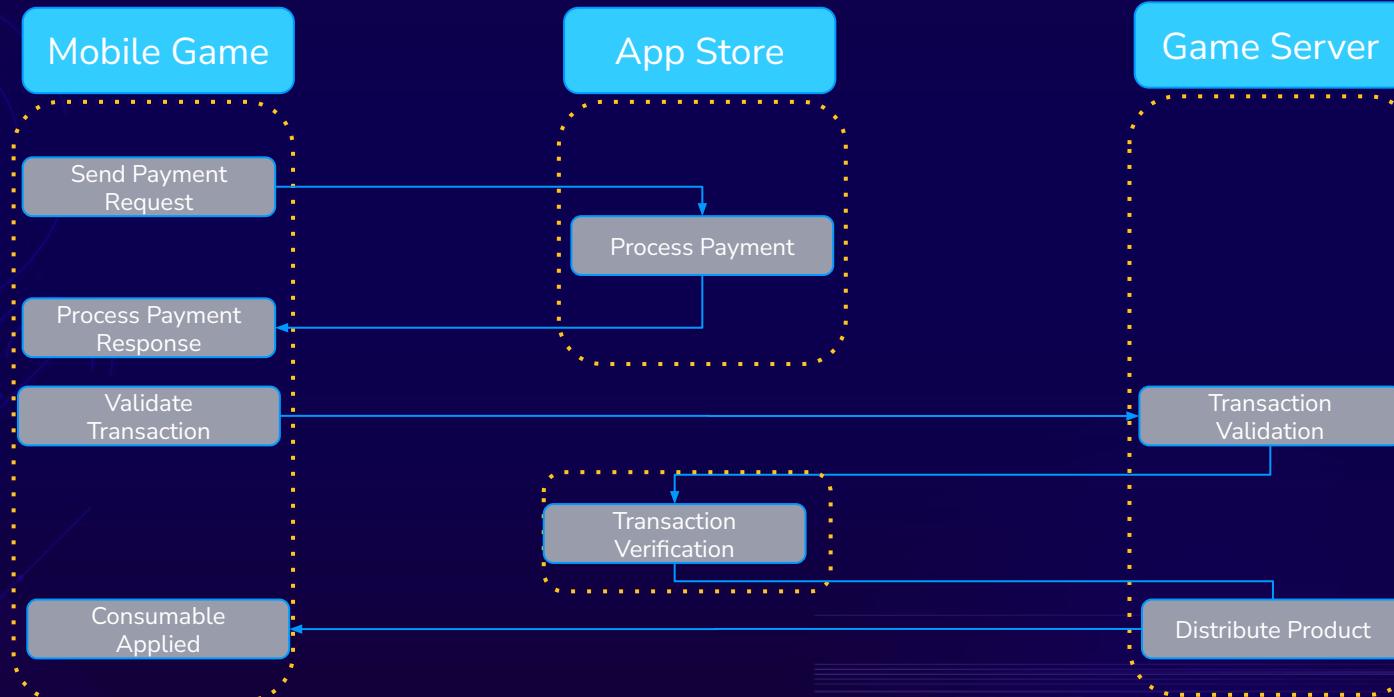


Can we manipulate a purchase?



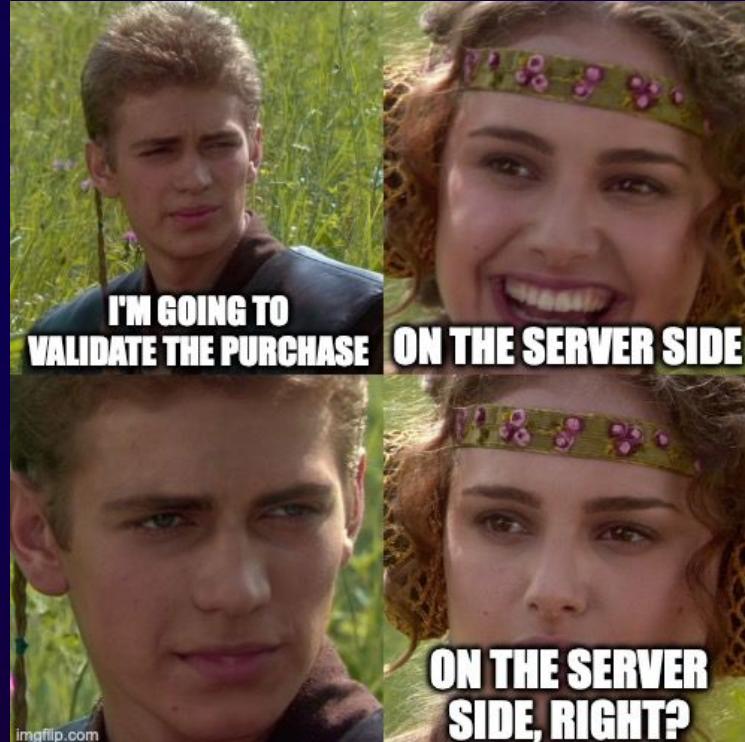


# Manipulating In-app Purchases



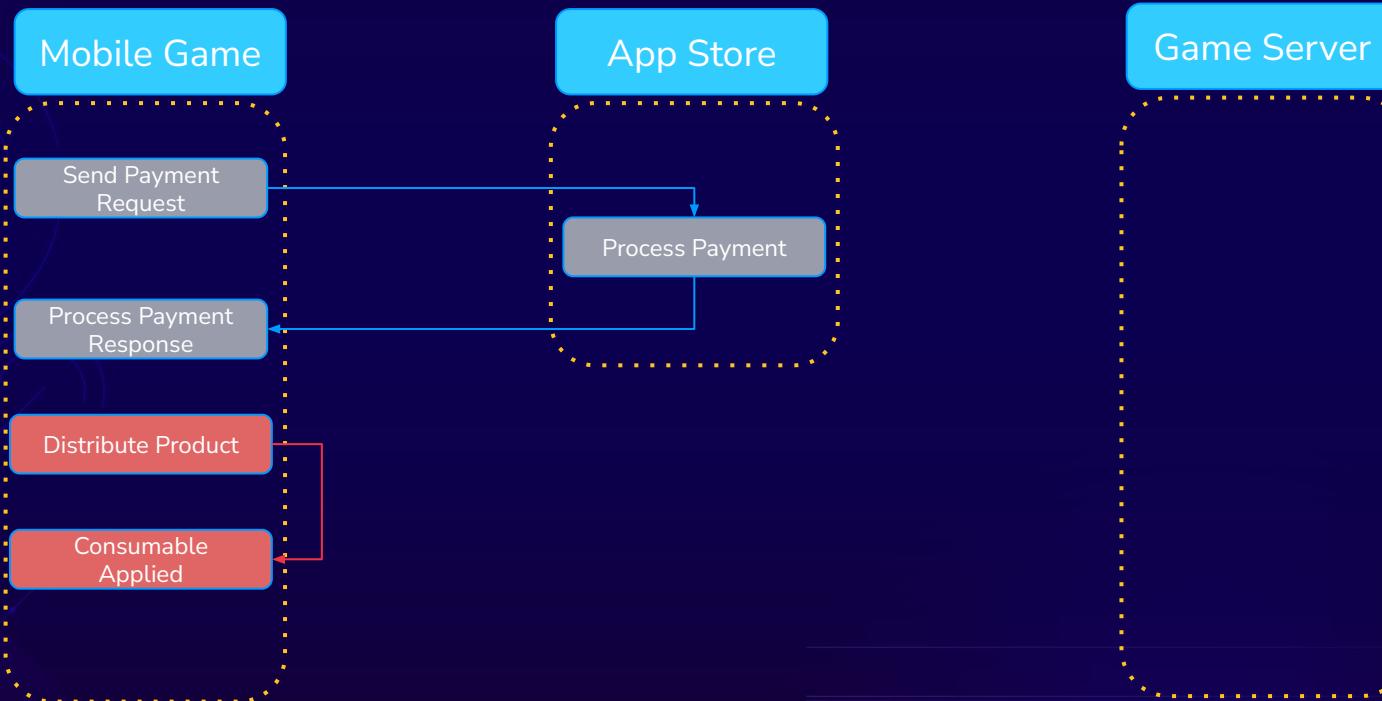


# Manipulating In-app Purchases





# Manipulating In-app Purchases





# Manipulating In-app Purchases

```
[0x01b7c32c]> decai -d
func purchase(_ arg1: Int, _ arg2: Int) -> Int {
    let metaInfo = 0x416e000 + 0x788
    let flagAddress = 0x43ea000 + 0x641

    if UnsafePointer<UInt8>(bitPattern: flagAddress)?.pointee == 0 {
        initializeMetaInfo(metaInfo)
        UnsafeMutablePointer<UInt8>(bitPattern: flagAddress)?.pointee = 1
    }

    initiatePurchaseAnalyticsEvent(arg1, arg2)

    if UnsafePointer<UInt8>(bitPattern: metaInfo)?.pointee != 0 {
        if !isEditorMode() {
            initiatePurchase(arg1)
            return 0
        }
        let purchaseData = getPurchaseData(arg1)
        return giveItemsForPurchase(purchaseData)
    } else {
        handleMetaInfoError()
        if !isEditorMode() {
            initiatePurchase(arg1)
            return 0
        }
    }
}

return 0
}
```

```
func giveItemsForPurchase(_ purchaseId: Int) {
    guard let purchase = getPurchase(purchaseId) else {
        restoreTransactions()
        return
    }

    for item in purchase.items {
        switch item.type {
        case .gems:
            giveGems(item.amount)
        case .disableAds:
            disableAds()
        case .infinityPack:
            giveInfinityPack()
        case .inventory:
            giveInventoryItem(item.id, amount: item.amount)
        }
    }

    saveShopData()
}
```



# Wrapping up

- How to reverse engineer a Unity Game on iOS.
- How to identify and parse the Game Metadata.
- How to symbolicate an iOS Game to ease the RE process.
- How to manipulate in memory an iOS Game for fun and profit.

For the future:

- Use of radare2 to extract the metadata from global-metadata files.
- Identify obfuscated Metadata files and dump it from Memory.
- Decrypt protected Metadata files.

# THANKS

Does anyone  
have any  
questions? ►



r2con 2024



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