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iOS逆向：举例详解

- 最新版本：`v0.8`
- 更新时间：`20240224`

简介

通过具体的例子，详细介绍iOS逆向的过程，以便于更好的理解如何进行iOS逆向的开发。具体例子有，WhatsApp中的StringAppend_100314974函数。

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- crifan/ios_re_detail_example: iOS逆向：举例详解

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鸣谢

感谢我的老婆**陈雪**的包容理解和悉心照料，才使得我 `crifan` 有更多精力去专注技术专研和整理归纳出这些电子书和技术教程，特此鸣谢。

其他

作者的其他电子书

本人 `crifan` 还写了其他 `150+` 本电子书教程，感兴趣可移步至：

crifan/crifan_ebook_readme: Crifan的电子书的使用说明

关于作者

关于作者更多介绍，详见：

关于CrifanLi李茂 – 在路上

iOS逆向举例概览

iOS逆向涉及内容较多，各种工具和过程，对于新手来说，即使看了些教程，也不能透彻的理解。

此处通过具体的详细的例子，去解释如何进行iOS逆向的过程。希望对你增加iOS逆向的理解有帮助。

静态分析

动态调试

静态分析+动态调试

要实现iOS逆向的静态分析和动态调试，需要用到很多相关工具：

- 静态分析
  - IDA
    - 分析函数代码逻辑，尤其是通过伪代码和汇编
- 动态调试
  - Xcode + lldb
  - Xcode+iOSOpenDev

iOS逆向WhatsApp

此处介绍iOS逆向WhatsApp的iOS版本相关例子。

StringAppend_100314974

此处以iOS的app `WhatsApp` 的二进制 `WhatsApp` 中的 `StringAppend_100314974` 函数为例，详细介绍，如何进行iOS逆向的静态分析和动态调试。

背景

对于一般的函数，没有特殊处理，比如混淆的话，往往是：

直接通过IDA伪代码，即可看出函数大体逻辑，甚至是完全看懂逻辑的所有细节

而此处要举例的函数，则是：

iOS的ObjC代码，但是底层涉及到iOS的Swift语言实现的，所以底层很难直接看到是什么类和函数

此处详细介绍，如何用各种工具，去一点点分析和调试，最终才能一步步的，彻底的搞懂代码逻辑。

目标

搞懂 `WhatsApp` 中的 `StringAppend_100314974` 函数的逻辑。

逆向过程

现在开始具体说明：

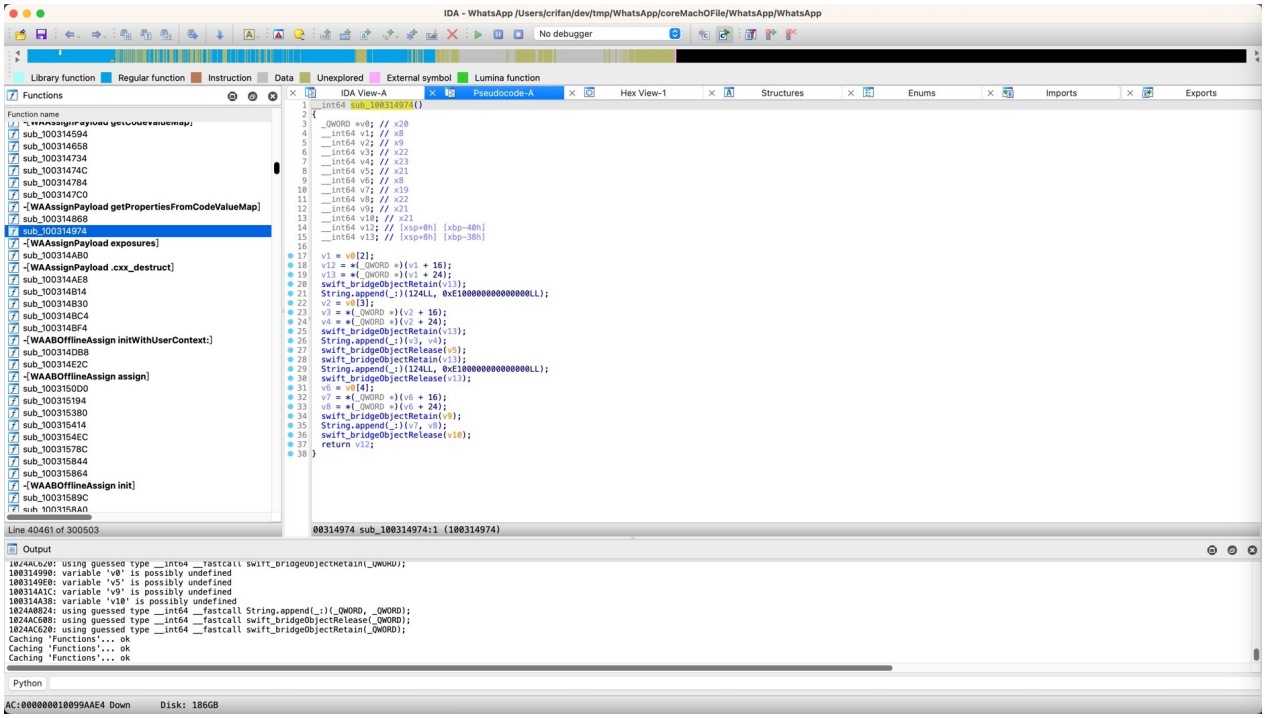
WhatsApp中的函数，二进制内函数偏移量地址是：`0x100314974`

最开始，用IDA打开并自动分析后，去查看IDA伪代码是：

- sub_100314974

```
__int64 sub_100314974()
{
  _QWORD *v0; // x20
  __int64 v1; // x8
  __int64 v2; // x9
  __int64 v3; // x22
  __int64 v4; // x23
  __int64 v5; // x21
  __int64 v6; // x8
  __int64 v7; // x19
  __int64 v8; // x22
  __int64 v9; // x21
  __int64 v10; // x21
  __int64 v12; // [xsp+0h] [xbp-40h]
  __int64 v13; // [xsp+8h] [xbp-38h]


  v1 = v0[2];
  v12 = *(_QWORD *)(v1 + 16);
  v13 = *(_QWORD *)(v1 + 24);
  swift_bridgeObjectRetain(v13);
  String.append(_:)(124LL, 0xE100000000000000LL);
  v2 = v0[3];
  v3 = *(_QWORD *)(v2 + 16);
  v4 = *(_QWORD *)(v2 + 24);
  swift_bridgeObjectRetain(v13);
  String.append(_:)(v3, v4);
  swift_bridgeObjectRelease(v5);
  swift_bridgeObjectRetain(v13);
  String.append(_:)(124LL, 0xE100000000000000LL);
  swift_bridgeObjectRelease(v13);
  v6 = v0[4];
  v7 = *(_QWORD *)(v6 + 16);
  v8 = *(_QWORD *)(v6 + 24);
  swift_bridgeObjectRetain(v9);
  String.append(_:)(v7, v8);
  swift_bridgeObjectRelease(v10);
  return v12;
}
```



很明显，最开始的默认的IDA伪代码看不出此处函数的代码逻辑 =不知道函数具体是做什么的

然后，经过分析和调试，慢慢搞懂了代码逻辑，再回来给IDA伪代码中去优化改名：

- 函数名改名
  - sub_100314974 -> StringAppend_100314974
- 变量名改名
  - `v1` -> `universeInfo`
  - `v12` -> `userInfoNameStringObjPart1`
  - `v13` -> `userInfoNameStringObjPart2`
  - `v2` -> `experimentInfo`
  - `v6` -> `bucketInfo`
  - ...
- 加上注释

然后才能慢慢搞懂，逐渐的彻底搞懂代码的全部逻辑

接着去解释中间是，如何：

- 静态分析
- 动态调试

的。

先去动态调试代码逻辑：

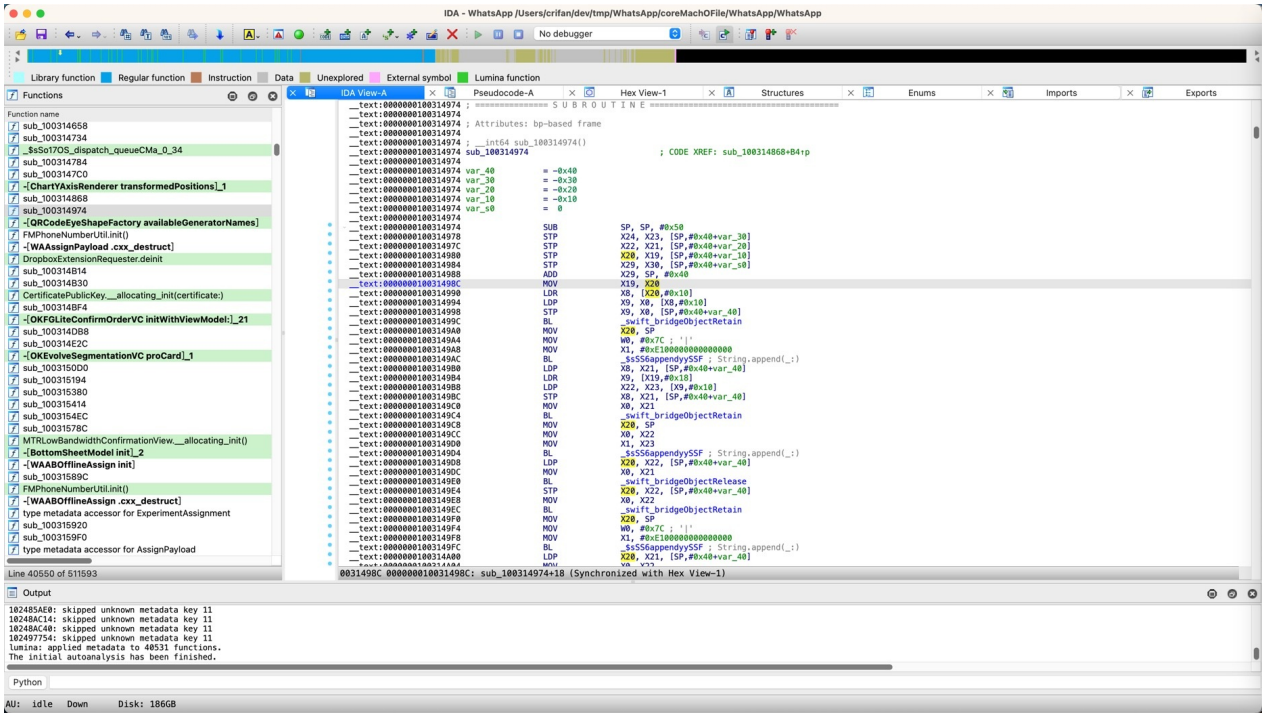
此时先要搞清楚：

传入的参数值：

且通过后续研究，比如查看IDA的汇编代码：

```
__text:0000000100314974 sub_100314974                           ; CODE XREF: sub_100314
868+B4↑p
__text:0000000100314974
__text:0000000100314974 var_40          = -0x40
__text:0000000100314974 var_30          = -0x30
__text:0000000100314974 var_20          = -0x20
__text:0000000100314974 var_10          = -0x10
__text:0000000100314974 var_s0          =  0
__text:0000000100314974                 SUB             SP, SP, #0x50
__text:0000000100314978                 STP             X24, X23, [SP,#0x40 var_30]
__text:000000010031497C                 STP             X22, X21, [SP,#0x40 var_20]
__text:0000000100314980                 STP             X20, X19, [SP,#0x40 var_10]
__text:0000000100314984                 STP             X29, X30, [SP,#0x40 var_s0]
__text:0000000100314988                 ADD             X29, SP, #0x40
__text:000000010031498C                 MOV             X19, X20
__text:0000000100314990                 LDR             X8, [X20,#0x10]
__text:0000000100314994                 LDP             X9, X0, [X8,#0x10]
__text:0000000100314998                 STP             X9, X0, [SP,#0x40 var_40]
__text:000000010031499C                 BL              _swift_bridgeObjectRetain
__text:00000001003149A0                 MOV             X20, SP
__text:00000001003149A4                 MOV             W0, #0x7C ; '|'
__text:00000001003149A8                 MOV             X1, #0xE100000000000000
__text:00000001003149AC                 BL              _$sSS6appendyySSF ; String.appe
nd(_:)
__text:00000001003149B0                 LDP             X8, X21, [SP,#0x40 var_40]
__text:00000001003149B4                 LDR             X9, [X19,#0x18]
__text:00000001003149B8                 LDP             X22, X23, [X9,#0x10]
__text:00000001003149BC                 STP             X8, X21, [SP,#0x40 var_40]
__text:00000001003149C0                 MOV             X0, X21
__text:00000001003149C4                 BL              _swift_bridgeObjectRetain
__text:00000001003149C8                 MOV             X20, SP
__text:00000001003149CC                 MOV             X0, X22
__text:00000001003149D0                 MOV             X1, X23
__text:00000001003149D4                 BL              _$sSS6appendyySSF ; String.appe
nd(_:)
__text:00000001003149D8                 LDP             X20, X22, [SP,#0x40 var_40]
__text:00000001003149DC                 MOV             X0, X21
__text:00000001003149E0                 BL              _swift_bridgeObjectRelease
```

```
__text:00000001003149E4                 STP             X20, X22, [SP,#0x40 var_40]
__text:00000001003149E8                 MOV             X0, X22
__text:00000001003149EC                 BL              _swift_bridgeObjectRetain
__text:00000001003149F0                 MOV             X20, SP
__text:00000001003149F4                 MOV             W0, #0x7C ; '|'
__text:00000001003149F8                 MOV             X1, #0xE100000000000000
__text:00000001003149FC                 BL              _$sSS6appendyySSF ; String.appe
nd(_:)
__text:0000000100314A00                 LDP             X20, X21, [SP,#0x40 var_40]
__text:0000000100314A04                 MOV             X0, X22
__text:0000000100314A08                 BL              _swift_bridgeObjectRelease
__text:0000000100314A0C                 LDR             X8,  X19,#0x20]
__text:0000000100314A10                 LDP             X19, X22,  X8,#0x10]
__text:0000000100314A14                 STP             X20, X21, [SP,#0x40 var_40]
__text:0000000100314A18                 MOV             X0, X21
__text:0000000100314A1C                 BL              _swift_bridgeObjectRetain
__text:0000000100314A20                 MOV             X20, SP
__text:0000000100314A24                 MOV             X0, X19
__text:0000000100314A28                 MOV             X1, X22
__text:0000000100314A2C                 BL              _$sSS6appendyySSF ; String.appe
nd(_:)
__text:0000000100314A30                 LDP             X19, X20, [SP,#0x40 var_40]
__text:0000000100314A34                 MOV             X0, X21
__text:0000000100314A38                 BL              _swift_bridgeObjectRelease
__text:0000000100314A3C                 MOV             X0, X19
__text:0000000100314A40                 MOV             X1, X20
__text:0000000100314A44                 LDP             X29, X30, [SP,#0x40 var_s0]
__text:0000000100314A48                 LDP             X20, X19, [SP,#0x40 var_10]
__text:0000000100314A4C                 LDP             X22, X21, [SP,#0x40 var_20]
__text:0000000100314A50                 LDP             X24, X23, [SP,#0x40 var_30]
__text:0000000100314A54                 ADD             SP, SP, #0x50 ; 'P'
__text:0000000100314A58                 RET
__text:0000000100314A58 ; End of function sub_100314974
```



才搞清楚此处是特殊的：通过X20传递了参数的

而不是普通的，通过X0、X1、X2等寄存器传递参数的

然后去调试查看寄存器值：

```
(lldb) reg r x0 x1 x19 x20
      x0 = 0x000000016d658c90
      x1 = 0x00000002828d0780
     x19 = 0x00000002828d0780
     x20 = 0x00000002833c1140
(lldb) po $x20
MainAppLibrary.ExperimentAssignment
```

发现是：

- 类 `MainAppLibrary.ExperimentAssignment`

后续确认，是个：Swift的类，而不是普通的ObjC的类

如此，想要搞清楚，该类的具体细节，比如有哪些属性（字段）和函数等等，就无法直接查看到

然后需要去通过分析才能找到。

经过：

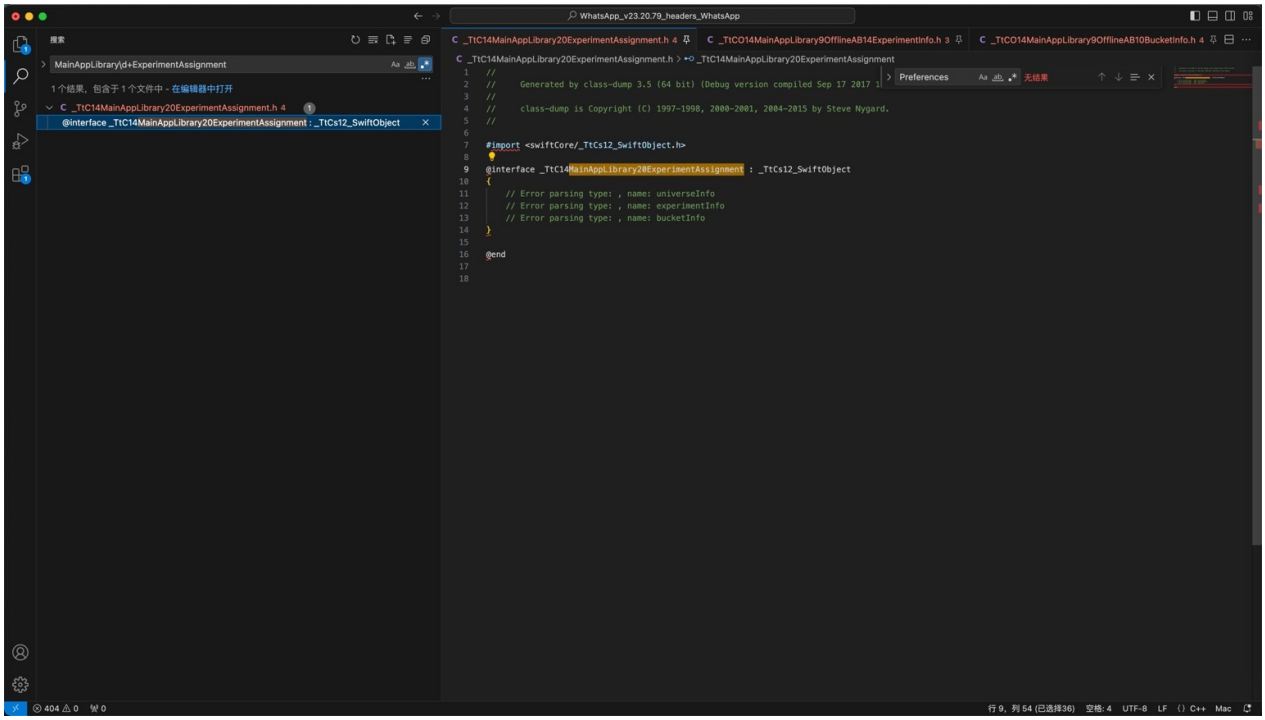
- 用class-dump导出的头文件
  - 详见
    - class-dump · iOS逆向开发：静态分析
  - 找到类的字段=属性名称
- 导出的静态字符串等资源
  - 详见
    - 查看信息和导出字符串 · iOS逆向开发：静态分析
- IDA中类的定义
  - 找到类的字段=属性，以及具体的偏移量定义

最后找到了：

之前导出的头文件中，搜：

`MainAppLibrary\d+ExperimentAssignment`

找到的：



- /Users/crifan/dev/dev_root/iosReverse/WhatsApp/headers/WhatsApp_v23.20.79_headers_WhatsApp/_TtC14MainAppLibrary20ExperimentAssignment.h

```
//
//     Generated by class-dump 3.5 (64 bit) (Debug version compiled Sep 17 2017 16:24:48).
//
//     class-dump is Copyright (C) 1997-1998, 2000-2001, 2004-2015 by Steve Nygard.
//

#import <swiftCore/_TtCs12_SwiftObject.h>

@interface _TtC14MainAppLibrary20ExperimentAssignment : _TtCs12_SwiftObject
{
    // Error parsing type: , name: universeInfo
    // Error parsing type: , name: experimentInfo
    // Error parsing type: , name: bucketInfo
}

@end
```

-》能看出：

- 类 `_TtC14MainAppLibrary20ExperimentAssignment`
  - 有3个属性
    - `universeInfo`
    - `experimentInfo`
    - `bucketInfo`

但是具体内部偏移量，不清楚。

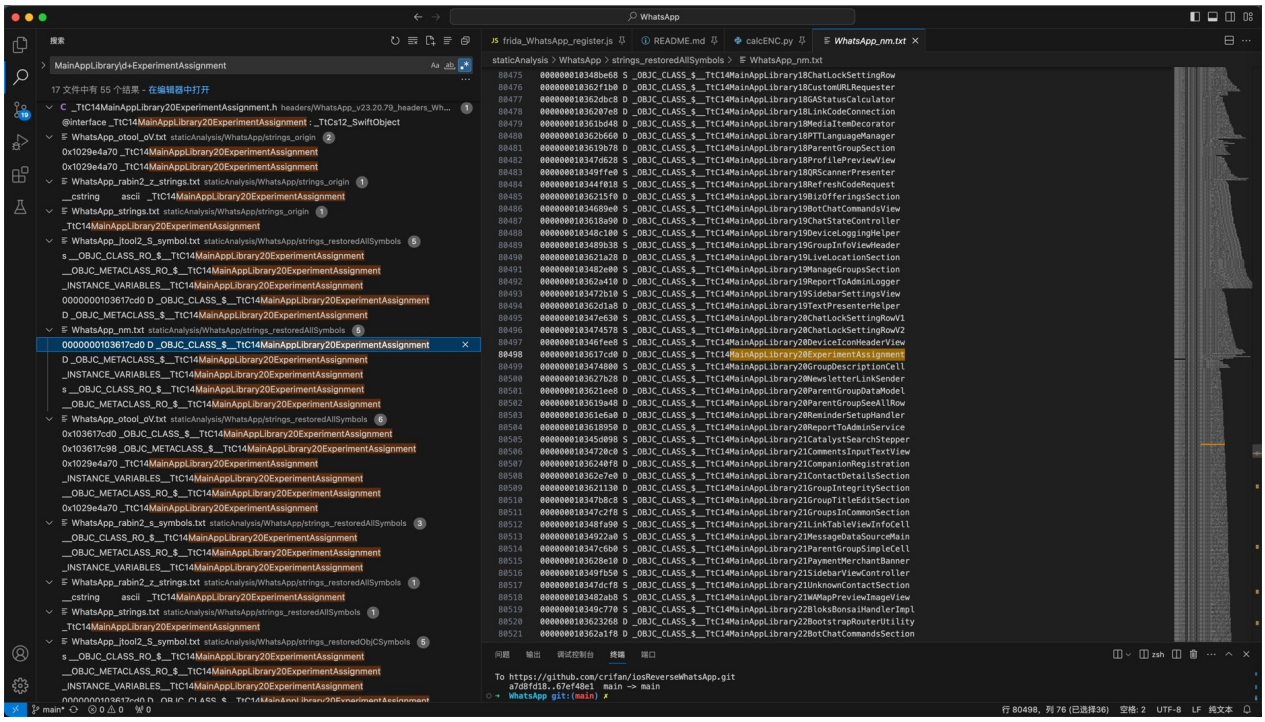
然后去找

- 类 `_TtC14MainAppLibrary20ExperimentAssignment`

然后通过之前导出的静态字符串资源中，搜索

`MainAppLibrary\d+ExperimentAssignment`

而找到的：



- /Users/crifan/dev/dev_root/iosReverse/WhatsApp/staticAnalysis/WhatsApp/strings_restoredAllSymbols/WhatsApp_nm.txt

```
0000000103617cd0 D _OBJC_CLASS_$__TtC14MainAppLibrary20ExperimentAssignment
```

- /Users/crifan/dev/dev_root/iosReverse/WhatsApp/staticAnalysis/WhatsApp/strings_restoredAllSymbols/WhatsApp_otool_oV.txt

```
000000001030a7aa8 0x103617cd0 _OBJC_CLASS_$__TtC14MainAppLibrary20ExperimentAssignment
    isa        0x103617c98 _OBJC_METACLASS_$__TtC14MainAppLibrary20ExperimentAssignment
    superclass 0x0 _OBJC_CLASS_$__TtCs12_SwiftObject
...
    data       0x1030dfe79 Swift class
...
        name           0x1029e4a70 _TtC14MainAppLibrary20ExperimentAssignment
...
        ivars          0x1030dfe10 __OBJC_$_INSTANCE_VARIABLES__TtC14MainAppLibrary20Ex
perimentAssignment
```

找到了：

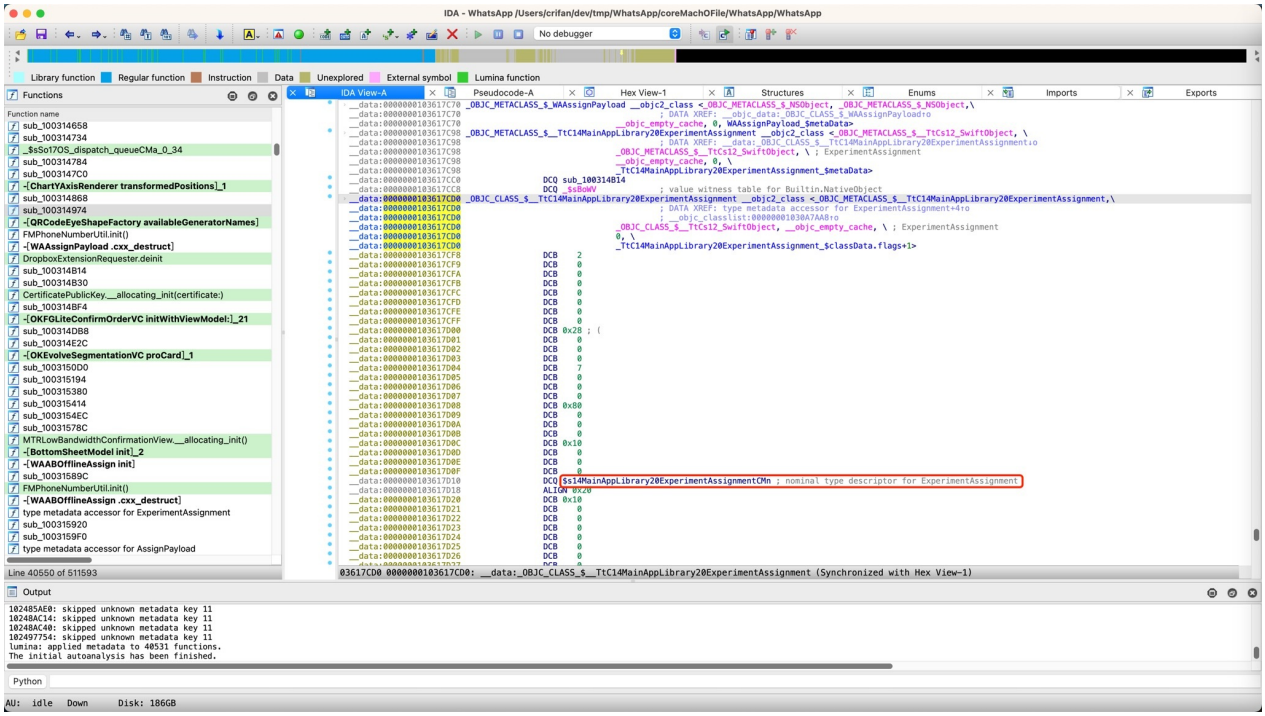
- `OBJC_CLASS____TtC14MainAppLibrary20ExperimentAssignment`

然后去IDA中看看：

- `OBJC_CLASS____TtC14MainAppLibrary20ExperimentAssignment`
  - 偏移量=地址：`0x103617cd0`

而找到

```
__data:0000000103617CD0 _OBJC_CLASS_$__TtC14MainAppLibrary20ExperimentAssignment __objc
2_class $_OBJC_METACLASS_$__TtC14MainAppLibrary20ExperimentAssignment,\
__data:0000000103617CD0                                         ; DATA XREF: type metad
ata accessor for ExperimentAssignment+4↑o
__data:0000000103617CD0                                         ; __objc_classlist:0000
0001030A7AA8↑o
__data:0000000103617CD0                                 _OBJC_CLASS_$__TtCs12_SwiftObjec
t, __objc_empty_cache, \ ; ExperimentAssignment
__data:0000000103617CD0                                 0, \
__data:0000000103617CD0                                 _TtC14MainAppLibrary20Experiment
Assignment_$classData.flags 1>
__data:0000000103617CF8                 DCB    2
__data:0000000103617CF9                 DCB    0
__data:0000000103617CFA                 DCB    0
__data:0000000103617CFB                 DCB    0
__data:0000000103617CFC                 DCB    0
__data:0000000103617CFD                 DCB    0
__data:0000000103617CFE                 DCB    0
__data:0000000103617CFF                 DCB    0
__data:0000000103617D00                 DCB 0x28 ; (
__data:0000000103617D01                 DCB    0
__data:0000000103617D02                 DCB    0
__data:0000000103617D03                 DCB    0
__data:0000000103617D04                 DCB    7
__data:0000000103617D05                 DCB    0
__data:0000000103617D06                 DCB    0
__data:0000000103617D07                 DCB    0
__data:0000000103617D08                 DCB 0x80
__data:0000000103617D09                 DCB    0
__data:0000000103617D0A                 DCB    0
__data:0000000103617D0B                 DCB    0
__data:0000000103617D0C                 DCB 0x10
__data:0000000103617D0D                 DCB    0
__data:0000000103617D0E                 DCB    0
__data:0000000103617D0F                 DCB    0
__data:0000000103617D10                 DCQ $s14MainAppLibrary20ExperimentAssignmentCMn
; nominal type descriptor for ExperimentAssignment
__data:0000000103617D18                 ALIGN 0x20
__data:0000000103617D20                 DCB 0x10
__data:0000000103617D21                 DCB    0
```



继而找到：

```
__data 0000000103617D10                DCQ $s14MainAppLibrary20ExperimentAssignmentCMn
; nominal type descriptor for ExperimentAssignment
```

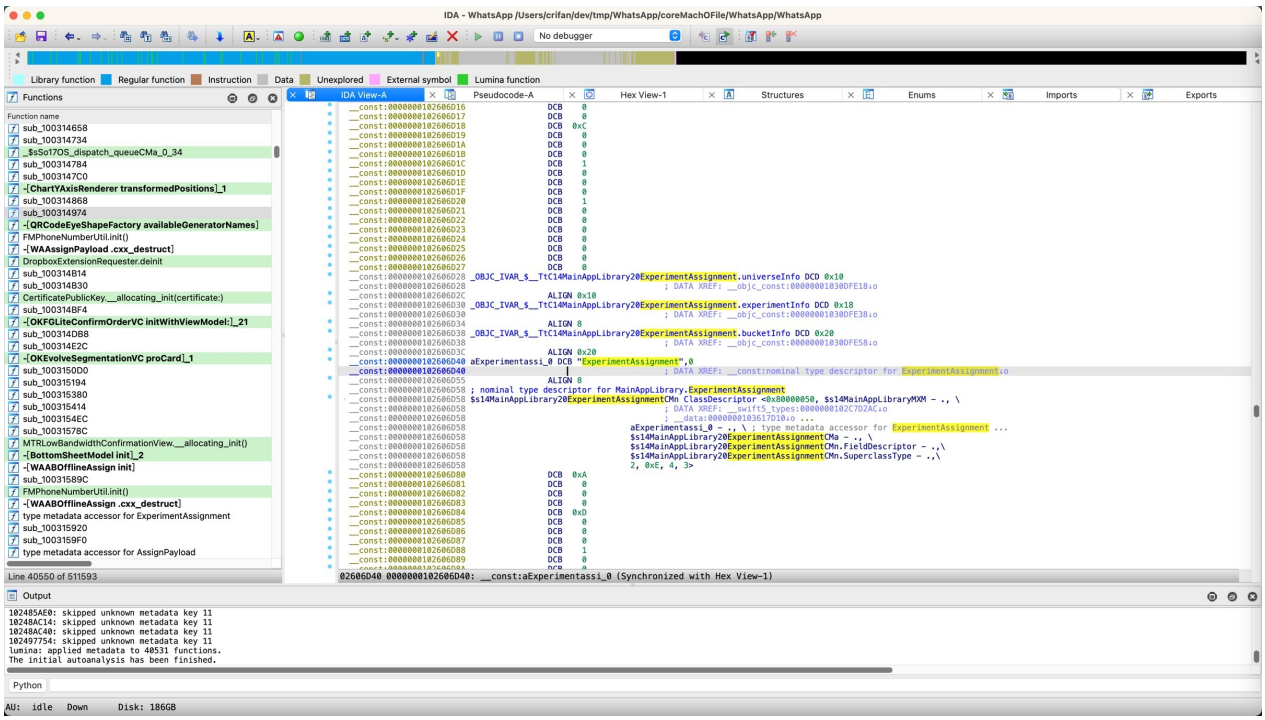
双击

- `$s14MainAppLibrary20ExperimentAssignmentCMn`

进去看到定义：

即：

- 类 `MainAppLibrary.ExperimentAssignment` 的具体定义




```
__const:0000000102606D27                    DCB    0
__const:0000000102606D28 _OBJC_IVAR_$__TtC14MainAppLibrary20ExperimentAssignment.univer
seInfo DCD 0x10
__const:0000000102606D28                                        ; DATA XREF: __objc_co
nst:00000001030DFE18↓o
__const:0000000102606D2C                    ALIGN 0x10
__const:0000000102606D30 _OBJC_IVAR_$__TtC14MainAppLibrary20ExperimentAssignment.experi
mentInfo DCD 0x18
__const:0000000102606D30                                        ; DATA XREF: __objc_co
nst:00000001030DFE38↓o
__const:0000000102606D34                    ALIGN 8
__const:0000000102606D38 _OBJC_IVAR_$__TtC14MainAppLibrary20ExperimentAssignment.bucket
Info DCD 0x20
__const:0000000102606D38                                        ; DATA XREF: __objc_co
nst:00000001030DFE58↓o
__const:0000000102606D3C                    ALIGN 0x20
__const:0000000102606D40 aExperimentassi_0 DCB "ExperimentAssignment",0
__const:0000000102606D40                                        ; DATA XREF: __const:n
ominal type descriptor for ExperimentAssignment↓o
__const:0000000102606D55                    ALIGN 8
__const:0000000102606D58 ; nominal type descriptor for MainAppLibrary.ExperimentAssignm
ent
__const:0000000102606D58 $s14MainAppLibrary20ExperimentAssignmentCMn ClassDescriptor <0
x80000050, $s14MainAppLibraryMXM - ., \
__const:0000000102606D58                                        ; DATA XREF: __swift5_
types:0000000102C7D2AC↓o
__const:0000000102606D58                                        ; __data:0000000103617
D10↓o ...
__const:0000000102606D58                                aExperimentassi_0 - ., \ ; ty
pe metadata accessor for ExperimentAssignment ...
__const:0000000102606D58                                $s14MainAppLibrary20Experimen
tAssignmentCMa - ., \
__const:0000000102606D58                                $s14MainAppLibrary20Experimen
tAssignmentCMn.FieldDescriptor - .,\
```

```
__const:0000000102606D58                                $s14MainAppLibrary20Experimen
tAssignmentCMn.SuperclassType - .,\
__const:0000000102606D58                                2, 0xE, 4, 3>
__const:0000000102606D80                DCB  0xA
__const:0000000102606D81                DCB    0
```

此处其实就可以看出：

- `MainAppLibrary.ExperimentAssignment` == `_TtC14MainAppLibrary20ExperimentAssignment`
  - [+0x10] = `universeInfo`
  - [+0x18] = `experimentInfo`
  - [+0x20] = `bucketInfo`

后续去（Xcode调试中的lldb调试界面）查看内存中的数据，就是可以对得上的：

```
(lldb) x/8gx $x20
0x2833c1140: 0x0000000105dbbcd0 0x0000000200000003
0x2833c1150: 0x00000002819ecea0 0x00000002819ecf00
0x2833c1160: 0x00000002833b9b00 0x0000000000000000
0x2833c1170: 0x00000001efe1f820 0x0000000000000000
(lldb) po 0x0000000105dbbcd0
MainAppLibrary.ExperimentAssignment
(lldb) po 0x00000002819ecea0
MainAppLibrary.OfflineAB.UniverseInfo
(lldb) po 0x00000002819ecf00
MainAppLibrary.OfflineAB.ExperimentInfo
(lldb) po 0x00000002833b9b00
MainAppLibrary.OfflineAB.BucketInfo
```

如此，即可推断和确认和计算出此处的值：

- `MainAppLibrary.ExperimentAssignment` == `0x00000002833c1140` == `0x2833c1140`
  - [+0x10] = `universeInfo`
    - `0x00000002819ecea0`
  - [+0x18] = `experimentInfo`
    - `0x00000002819ecf00`
  - [+0x20] = `bucketInfo`
    - `0x00000002833b9b00`

而至此，理论上，其实可以通过：

IDA汇编代码 + IDA伪代码

能看出：

```
v1 = v0[2];

v2 = v0[3];

v6 = v0[4];
```

==

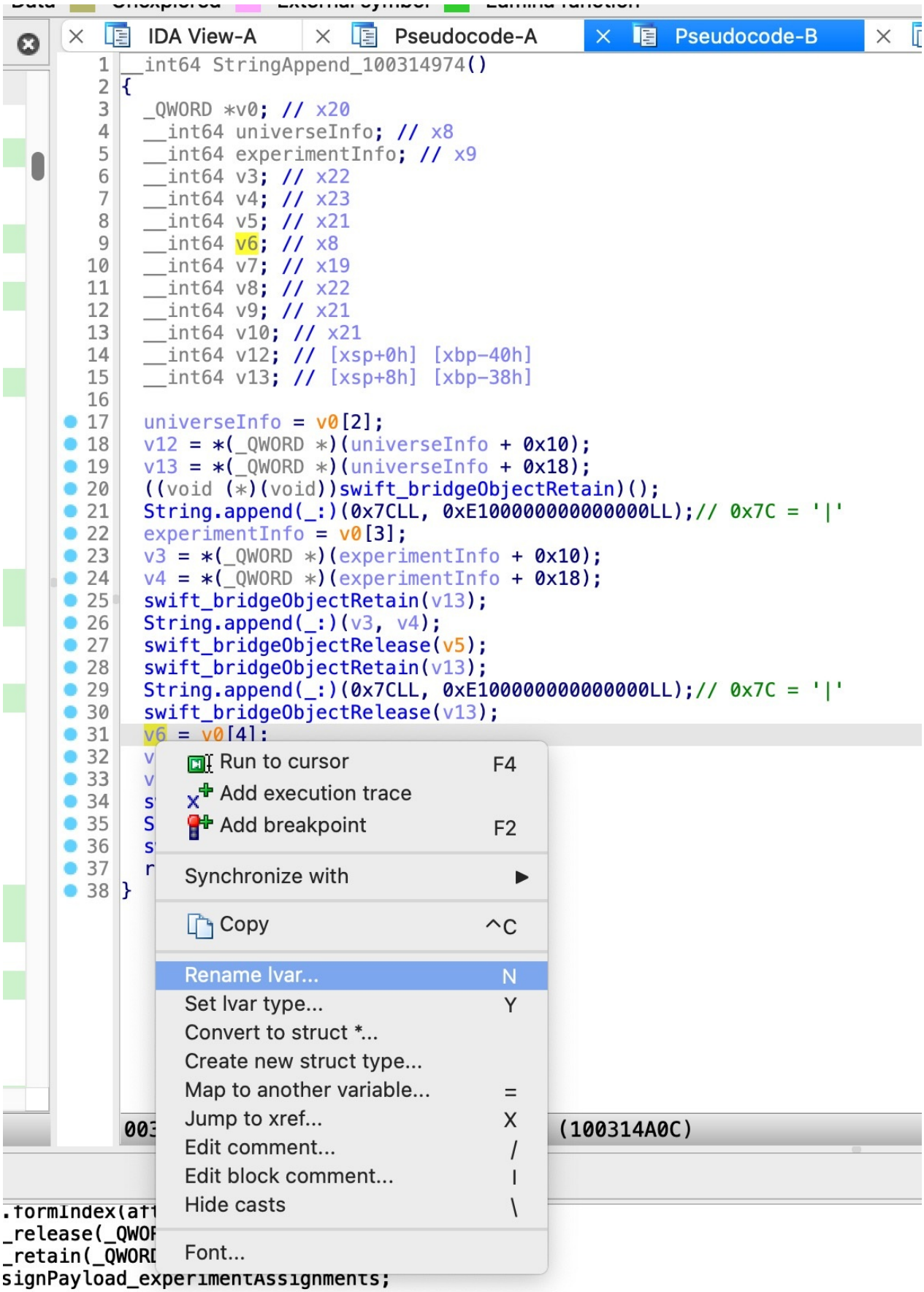
```
__text:0000000100314990                 LDR             X8, [X20,#0x10]
__text:00000001003149B4                 LDR             X9, [X19,#0x18]
__text:0000000100314A0C                 LDR             X8, [X19,#0x20]
```

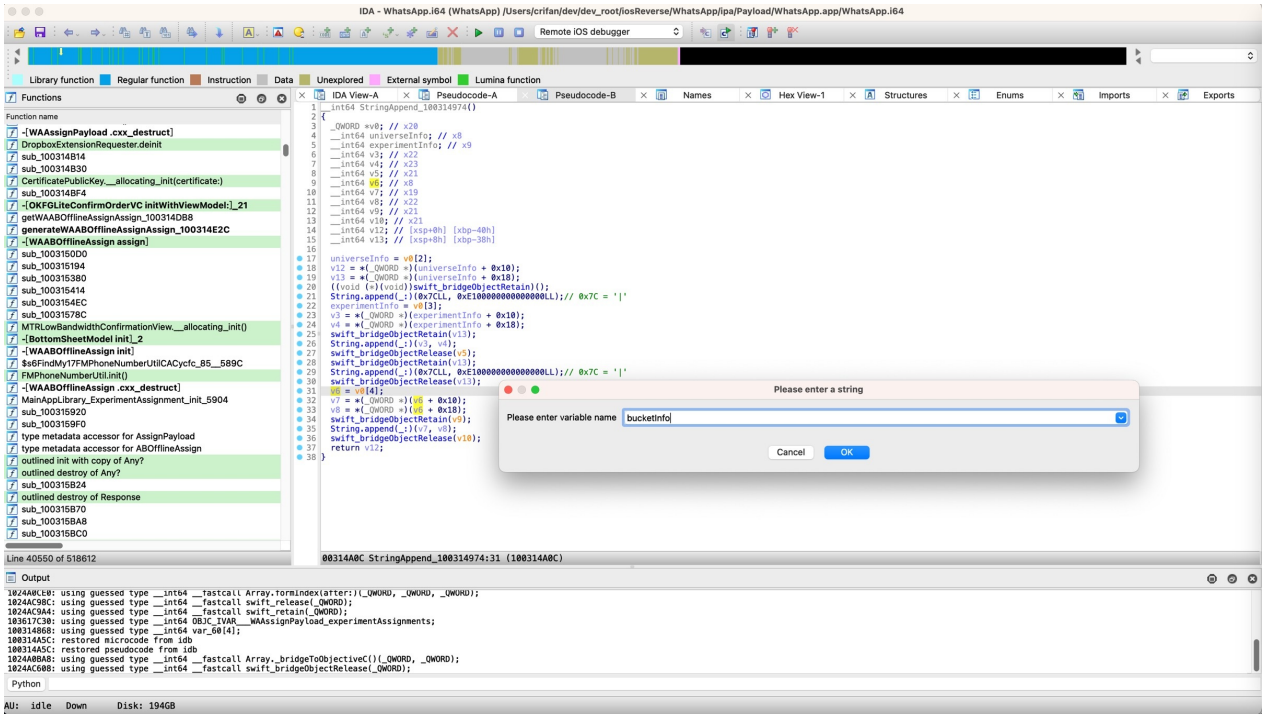
其实就分别对应着上面的：

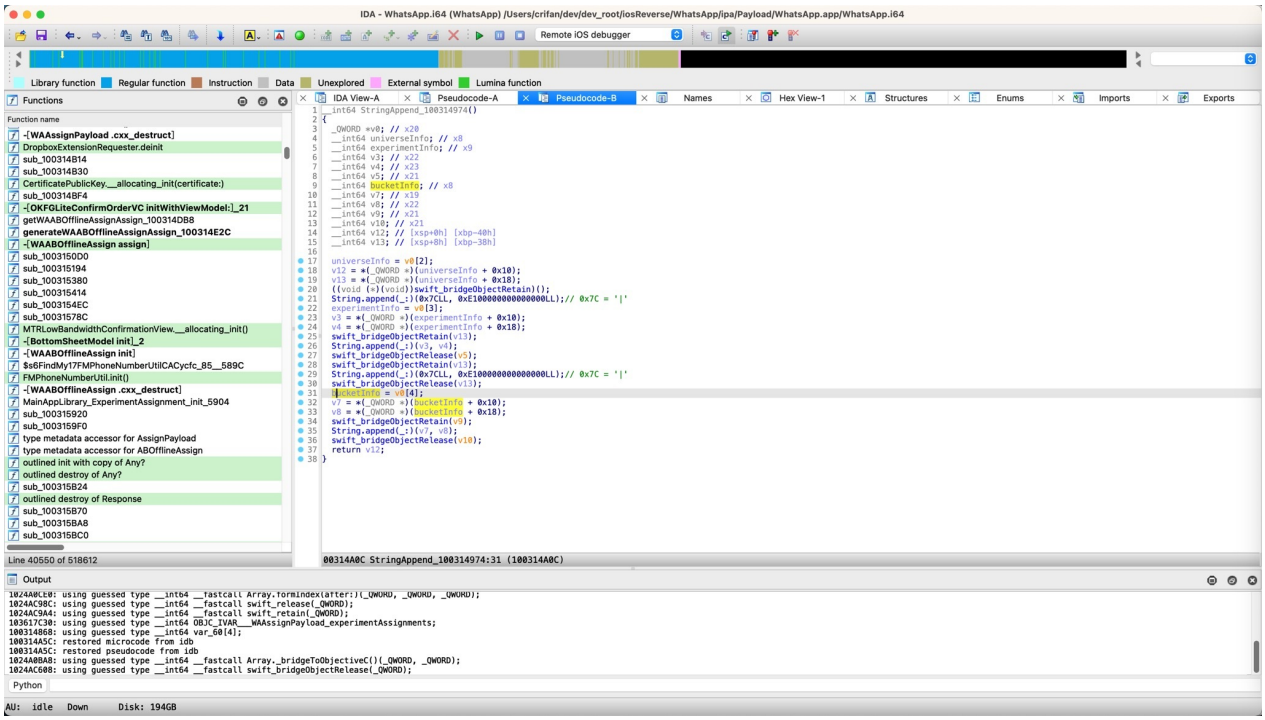
- `[+0x10] = universeInfo`
  - `0x00000002819ecea0`
- `[+0x18] = experimentInfo`
  - `0x00000002819ecf00`
- `[+0x20] = bucketInfo`
  - `0x00000002833b9b00`

如此，即可去分别：

优化IDA伪代码，给变量重命名：


IDA View-A
Pseudocode-A
Pseudocode-B
__int64 StringAppend_100314974()
{
_QWORD *v0; // x20
__int64 universeInfo; // x8
__int64 experimentInfo; // x9
__int64 v3; // x22
__int64 v4; // x23
__int64 v5; // x21
__int64 v6; // x8
__int64 v7; // x19
__int64 v8; // x22
__int64 v9; // x21
__int64 v10; // x21
__int64 v12; // [xsp+0h] [xbp-40h]
__int64 v13; // [xsp+8h] [xbp-38h]
universeInfo = v0[2];
v12 = *(_QWORD *)(universeInfo + 0x10);
v13 = *(_QWORD *)(universeInfo + 0x18);
((void (*)(void))swift_bridgeObjectRetain)();
String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
experimentInfo = v0[3];
v3 = *(_QWORD *)(experimentInfo + 0x10);
v4 = *(_QWORD *)(experimentInfo + 0x18);
swift_bridgeObjectRetain(v13);
String.append(_:)(v3, v4);
swift_bridgeObjectRelease(v5);
swift_bridgeObjectRetain(v13);
String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
swift_bridgeObjectRelease(v13);
v6 = v0[4];
}
Run to cursor F4
Add execution trace
Add breakpoint F2
Synchronize with
Copy ^C
Rename lvar... N
Set lvar type... Y
Convert to struct *...
Create new struct type...
Map to another variable... =
Jump to xref... X
Edit comment... /
Edit block comment... I
Hide casts \
Font...
(100314A0C)





此时，IDA伪代码就变成了：

```
__int64 StringAppend_100314974()
{
  _QWORD  v0; // x20
  __int64 universeInfo; // x8
  __int64 experimentInfo; // x9
  __int64 v3; // x22
  __int64 v4; // x23
  __int64 v5; // x21
  __int64 bucketInfo; // x8
  __int64 v7; // x19
  __int64 v8; // x22
```

```
  __int64 v9; // x21
  __int64 v10; // x21
  __int64 v12; // [xsp+0h] [xbp-40h]
  __int64 v13; // [xsp+8h] [xbp-38h]


  universeInfo = v0[2];
  v12 = *(_QWORD *)(universeInfo + 0x10);
  v13 = *(_QWORD *)(universeInfo + 0x18);
  ((void (*)(void))swift_bridgeObjectRetain)();
  String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
  experimentInfo = v0[3];
  v3 = *(_QWORD *)(experimentInfo + 0x10);
  v4 = *(_QWORD *)(experimentInfo + 0x18);
  swift_bridgeObjectRetain(v13);
  String.append(_:)(v3, v4);
  swift_bridgeObjectRelease(v5);
  swift_bridgeObjectRetain(v13);
  String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
  swift_bridgeObjectRelease(v13);
  bucketInfo = v0[4];
  v7 = *(_QWORD *)(bucketInfo + 0x10);
  v8 = *(_QWORD *)(bucketInfo + 0x18);
  swift_bridgeObjectRetain(v9);
  String.append(_:)(v7, v8);
  swift_bridgeObjectRelease(v10);
  return v12;
}
```

-》很明显，代码逻辑，就慢慢的，逐渐的，更加清晰了。

而后续的逻辑，看起来，主要就是：

```
String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'

String.append(_:)(v3, v4);

String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'

String.append(_:)(v7, v8);
```

本来以为很简单，直接去：

找到具体的：原先字符串和拼接字符串，即可

之前调试已经知道，希望的最终的值是：

```
▿ Swift.__SwiftDeferredNSArray 0x282642100 (
  dummy_aa_offline_rid_universe_ios|dummy_aa_offline_rid_experiment_ios|control,
  hide_link_device_button_release_rollout_universe|hide_link_device_button_release_roll
out_experiment|control,
  ios_prod_latam_tos_reg_universe|ios_prod_latam_tos_reg_experiment|test
)
```

所以，此处第一轮，应该是：

- `dummy_aa_offline_rid_universe_ios|dummy_aa_offline_rid_experiment_ios|control,`

而去掉竖杠 `|` ，则应该分别是：

- `dummy_aa_offline_rid_universe_ios`
- `dummy_aa_offline_rid_experiment_ios`
- `control`

所以就去调试

结果去调试时，却发现找不到我们要的字符串的值

和预想的逻辑对不上

比如，第一个，不是：

- `dummy_aa_offline_rid_universe_ios`

首先是：

```
    0x102ab89a0 <+44 :  mov    x20, sp
    0x102ab89a4 <+48 :  mov    w0, #0x7c
    0x102ab89a8 <+52 :  mov    x1, # 0x1f00000000000000
    0x102ab89ac <+56 :  bl     0x104c44824               ; symbol stub for: String.appen
d(_:)
```

此时值：

```
(lldb) reg r x0 x1
      x0 = 0x000000000000007c
      x1 = 0xe100000000000000
```

-》好像此处Swift函数 `String.append(_:)` 中， `x0` 和 `x1` ，就不是我们要的普通的字符串

找不到我们要的： `dummy_aa_offline_rid_universe_ios`

后来自己研究出了，看起来是放到了： `x20` = `sp` 中了？

去看看，果然还是有字符串值的：

其次是，虽然有字符串值，但是也还不是我们要的值：

```
(lldb) reg r x20 sp
     x20 = 0x000000016d658c20
      sp = 0x000000016d658c20
(lldb) x/8gx 0x000000016d658c20
0x16d658c20: 0xd000000000000021 0x80000001051946f0
0x16d658c30: 0x0000000000000002 0x00000002833c1140
0x16d658c40: 0x0000000105da1628 0x0000000105dbbcd0
0x16d658c50: 0x00000002833c1140 0x00000002828d0780
(lldb) po 0x80000001051946f0
9223372041235285744
(lldb) x/s 0x80000001051946f0
```

```
0x1051946f0: "dummy_aa_offline_user_rid_ios"
```

即，此处：

- 打印出的字符串是：
  - `dummy_aa_offline_user_rid_ios`
- 希望的字符串是
  - `dummy_aa_offline_rid_universe_ios`

所以就怀疑，难道是，Swift的字符串拼接函数：`String.append(_:)`，内部有额外的逻辑？

经过一番研究：

- 【未解决】iOS逆向WhatsApp：Swift函数String.append(_:)的字符串拼接的实现逻辑

没有发现啥特殊的逻辑。

正在一筹莫展之际，无意间发现别的帖子：

Swift 里字符串（十）修改字符串 – huahuahu (wordpress.com)

好像是Swift的String，比较特殊？

所以再转去研究：

Swift中的String的类的具体定义

- String字符串 · iOS逆向：Swift逆向

最终彻底搞懂了：

核心就一句话：

- Swift中(Native的)LargeString中：真正字符串的地址=`objectAddr + 0x20`

所以此处是：

```
(lldb) p/x 0x80000001051946f0 + 0x20
(unsigned long) 0x8000000105194710
(lldb) po 0x8000000105194710
9223372041235285776
(lldb) x/s 0x8000000105194710
0x105194710: "dummy_aa_offline_rid_universe_ios"
```

如此，最终才彻底搞清楚了：

- Swift中字符串拼接函数：`String.append(_:)`，内部没有特殊逻辑
  - 但是传入的参数，此处其实是多个来源
    - 2个寄存器：`x0`和`x1`
      - 其实保存的好像也是：Swift中的small string，用2个寄存器=2个64位保存对应的值
    - sp堆栈
      - 保存的是Swift的large string，也是2个64位的地址保存其值

综合起来就是：

- `Swift的String.append(_:)`
  - `originSwiftString.append(toAppendSwiftString)`
    - originSwiftString：放在了sp堆栈中
      - 只不过也要2个64位地址保存：`[sp]`、`[sp+0x08]`
    - toAppendSwiftString：放在了寄存器中
      - 只不过要2个寄存器保存：x0、x1

最终，才真正搞懂，此处后续字符串的拼接的逻辑。

注：

关于另外的几个类的属性字段的定义，详见

- /Users/crifan/dev/dev_root/iosReverse/WhatsApp/WhatsApp_v23.25.85/headers/headers_WhatsApp_v23.25.85_WhatsApp_paradiseduo_dsdump/_TtC7Catalog24VariantTypeBaseViewModel.h

```
...

0x0010381f460 _TtCO14MainAppLibrary9OfflineAB10BucketInfo : Swift._SwiftObject @rpath l
ibswiftCore.dylib
{
    0x0010  name (0x10)
    0x0020  size (0x8)
    0x0028  configList (0x8)
}

0x0010381f510 _TtCO14MainAppLibrary9OfflineAB14ConfigVariable : Swift._SwiftObject @rpa
th libswiftCore.dylib
{
    0x0010  code (0x8)
    0x0018  name (0x10)
    0x0028  value (0x10)
}

0x0010381f5c0 _TtCO14MainAppLibrary9OfflineAB14ExperimentInfo : Swift._SwiftObject @rpa
th libswiftCore.dylib
{
    0x0010  name (0x10)
    0x0020  startTime (0x8)
    0x0028  endTime (0x8)
    0x0030  bucketList (0x8)
    0x0038  userFilter (0x28)
}

...

0x0010381f730 _TtCO14MainAppLibrary9OfflineAB12UniverseInfo : Swift._SwiftObject @rpath/
libswiftCore.dylib
{
    0x0010  name (0x10)
    0x0020  unit (0x10)
    0x0030  experimentList (0x8)
    0x0038  userFilter (0x28)
}
```

```
'''
```

此处就不赘述了。

然后就可以去计算出此处拼接处的字符串了：

```
(lldb) x/8gx 0x00000002833c1140
0x2833c1140: 0x0000000105dbbcd0 0x0000000200000003
0x2833c1150: 0x00000002819ecea0 0x00000002819ecf00
0x2833c1160: 0x00000002833b9b00 0x0000000000000000
0x2833c1170: 0x00000001efe1f820 0x0000000000000000
(lldb) po 0x00000002819ecea0
MainAppLibrary.OfflineAB.UniverseInfo
(lldb) po 0x00000002819ecf00
MainAppLibrary.OfflineAB.ExperimentInfo
(lldb) po 0x00000002833b9b00
MainAppLibrary.OfflineAB.BucketInfo

(lldb) x/6gx 0x00000002819ecea0
0x2819ecea0: 0x0000000105dc0398 0x0000000200000003
0x2819eceb0: 0xd000000000000021 0x80000001051946f0
0x2819ecec0: 0x6469725f72657375 0xe800000000000000
(lldb) x/6gx 0x00000002819ecf00
0x2819ecf00: 0x0000000105dc0238 0x0000000200000003
0x2819ecf10: 0xd000000000000023 0x80000001051946a0
0x2819ecf20: 0x0000000006316eff0 0x0000000065e82280
(lldb) x/6gx 0x00000002833b9b00
0x2833b9b00: 0x0000000105dc00e8 0x0000000200000003
0x2833b9b10: 0x006c6f72746e6f63 0xe700000000000000
0x2833b9b20: 0x0000000000001388 0x00000002833b9b90

(lldb) x/s 0x8000000105194710
0x105194710: "dummy_aa_offline_rid_universe_ios"
(lldb) x/s 0x80000001051946c0
0x1051946c0: "dummy_aa_offline_rid_experiment_ios"
(lldb) p/c 0x006c6f72746e6f63
(long) control\0
```

-》

- `"dummy_aa_offline_rid_universe_ios"`
- `"dummy_aa_offline_rid_experiment_ios"`
- `"control"`

由此得到最终拼接后的字符串：

- `dummy_aa_offline_rid_universe_ios|dummy_aa_offline_rid_experiment_ios|control`

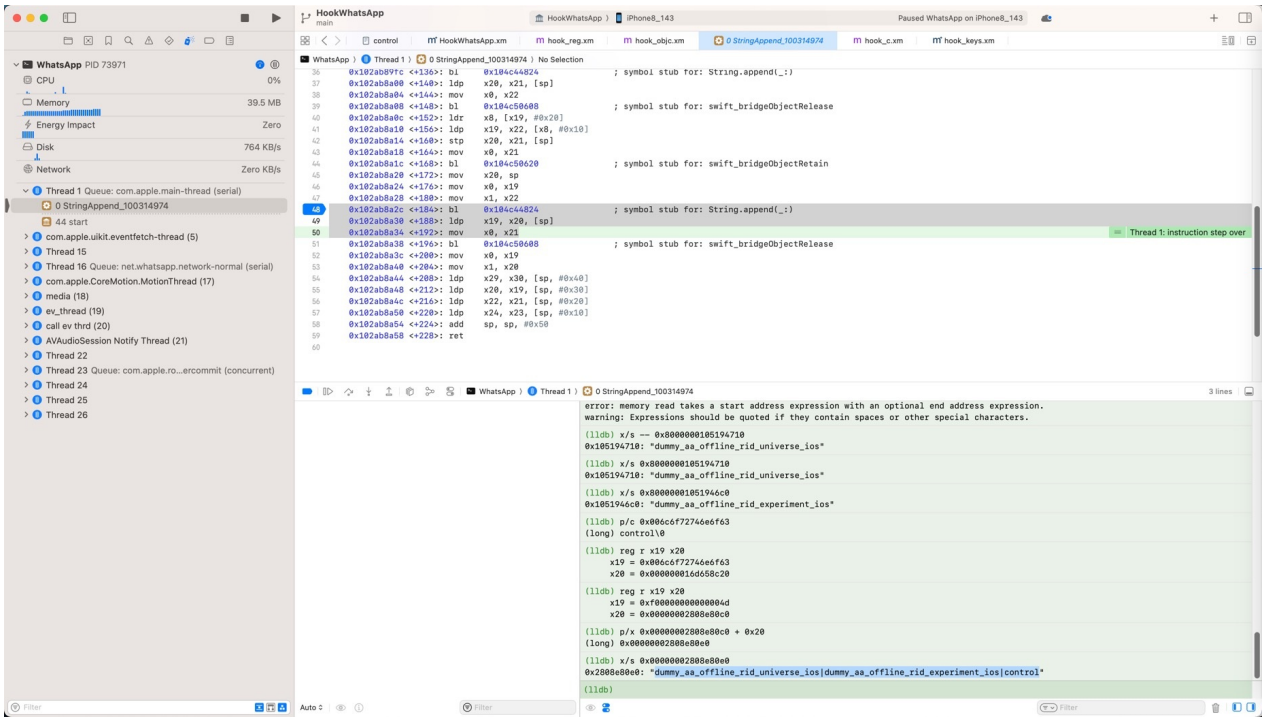
去调试确认和我们算出的值是一样的：

```
    0x102ab8a2c <+184>: bl     0x104c44824               ; symbol stub for: String.appen
d(_:)
    0x102ab8a30 <+188>: ldp    x19, x20, [sp]
```

```
    0x102ab8a34 <+192>: mov    x0, x21
```

->

```
(lldb) reg r x19 x20
     x19 = 0xf0000000000004d
     x20 = 0x00000002808e80c0
(lldb) p/x 0x00000002808e80c0 + 0x20
(long) 0x00000002808e80e0
(lldb) x/s 0x00000002808e80e0
0x2808e80e0: "dummy_aa_offline_rid_universe_ios|dummy_aa_offline_rid_experiment_ios|con
trol"
```



是一样的。

如此，继续去优化IDA伪代码：

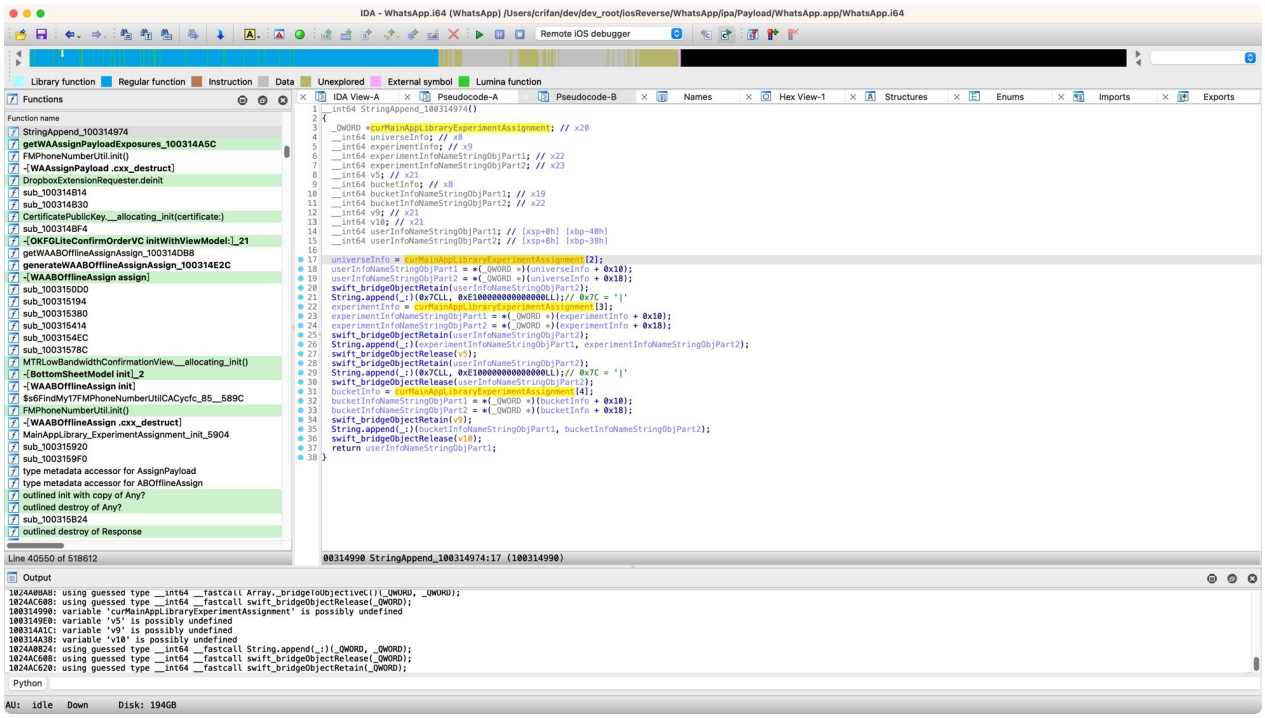
去改名：

```
__int64 StringAppend_100314974()
{
  _QWORD  curMainAppLibraryExperimentAssignment; // x20
  __int64 universeInfo; // x8
  __int64 experimentInfo; // x9
  __int64 experimentInfoNameStringObjPart1; // x22
  __int64 experimentInfoNameStringObjPart2; // x23
  __int64 v5; // x21
  __int64 bucketInfo; // x8
  __int64 bucketInfoNameStringObjPart1; // x19
  __int64 bucketInfoNameStringObjPart2; // x22
  __int64 v9; // x21
  __int64 v10; // x21
  __int64 userInfoNameStringObjPart1; // [xsp+0h] [xbp-40h]
```

```
__int64 userInfoNameStringObjPart2; // [xsp+8h] [xbp-38h]


universeInfo = curMainAppLibraryExperimentAssignment[2];
userInfoNameStringObjPart1 = *(_QWORD *)(universeInfo + 0x10);
userInfoNameStringObjPart2 = *(_QWORD *)(universeInfo + 0x18);
swift_bridgeObjectRetain(userInfoNameStringObjPart2);
String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
experimentInfo = curMainAppLibraryExperimentAssignment[3];
experimentInfoNameStringObjPart1 = *(_QWORD *)(experimentInfo + 0x10);
experimentInfoNameStringObjPart2 = *(_QWORD *)(experimentInfo + 0x18);
swift_bridgeObjectRetain(userInfoNameStringObjPart2);
String.append(_:)(experimentInfoNameStringObjPart1, experimentInfoNameStringObjPart2);

swift_bridgeObjectRelease(v5);
swift_bridgeObjectRetain(userInfoNameStringObjPart2);
String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
swift_bridgeObjectRelease(userInfoNameStringObjPart2);
bucketInfo = curMainAppLibraryExperimentAssignment[4];
bucketInfoNameStringObjPart1 = *(_QWORD *)(bucketInfo + 0x10);
bucketInfoNameStringObjPart2 = *(_QWORD *)(bucketInfo + 0x18);
swift_bridgeObjectRetain(v9);
String.append(_:)(bucketInfoNameStringObjPart1, bucketInfoNameStringObjPart2);
swift_bridgeObjectRelease(v10);
return userInfoNameStringObjPart1;
}
```



如此，其实代码逻辑已经很清楚了。

不过另外想到了：

如果IDA此处能识别：

- 类MainAppLibrary\d+ExperimentAssignment

就好了？就可以自动识别出：具体属性和字段了

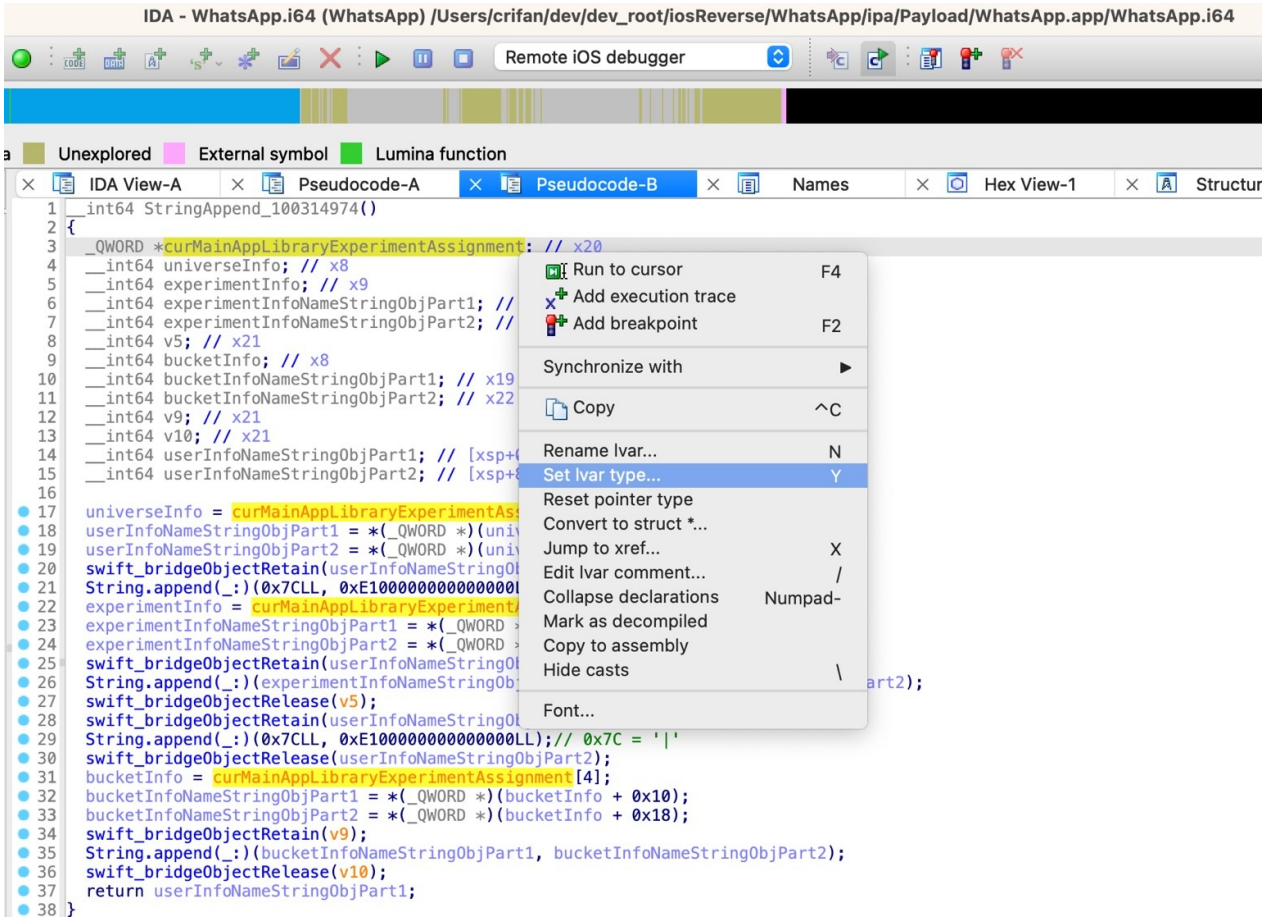
而去试了试，前面搜到的，也确认IDA有的：

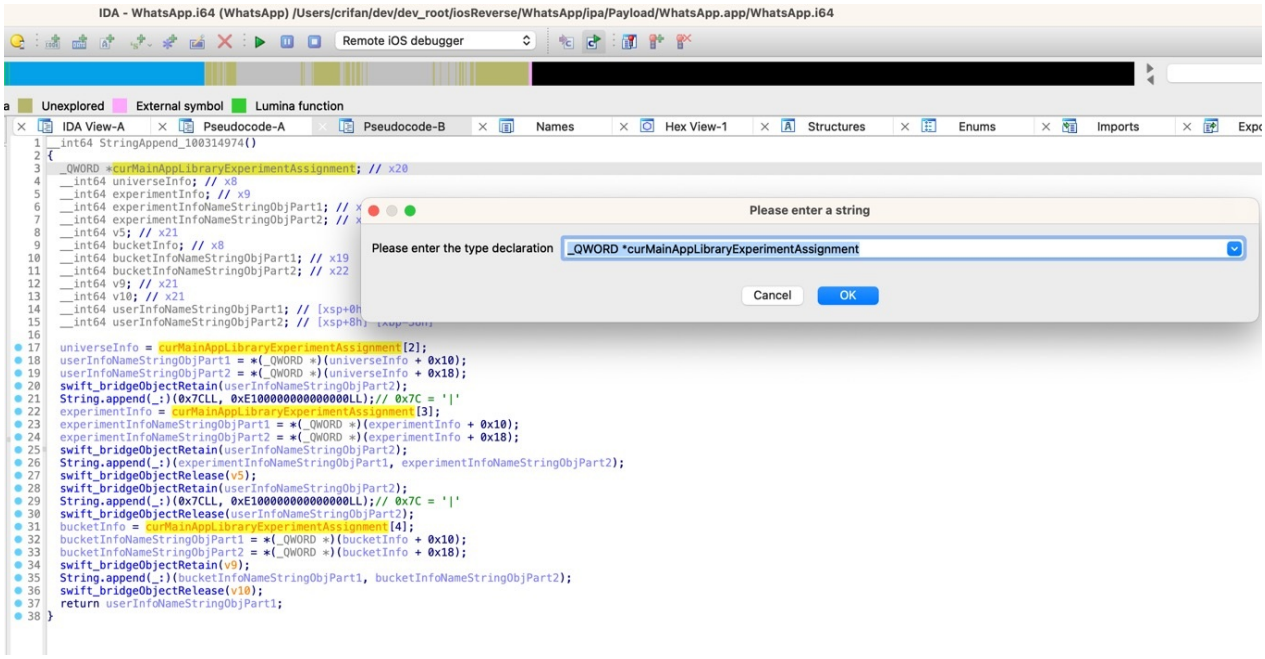
- 类名：_TtC14MainAppLibrary20ExperimentAssignment

即给此处变量更改类型type为：

- _TtC14MainAppLibrary20ExperimentAssignment*

操作步骤：



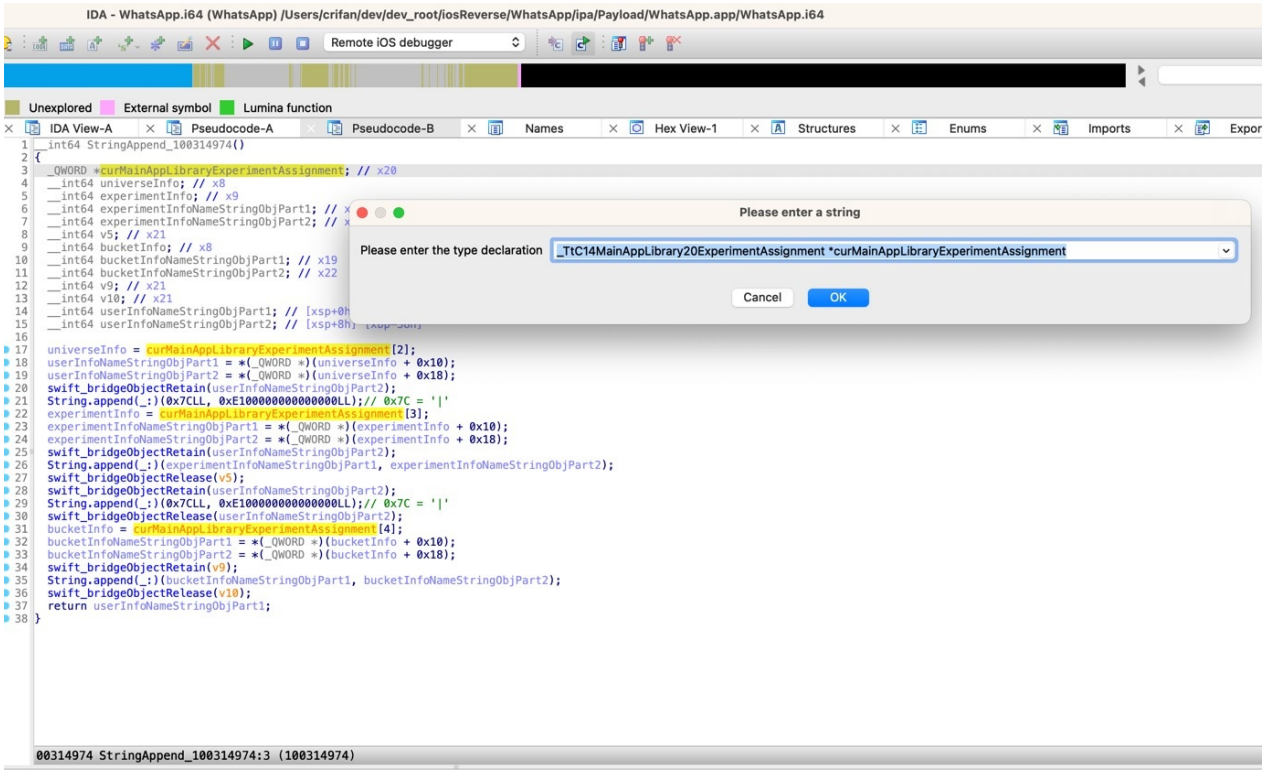


从：

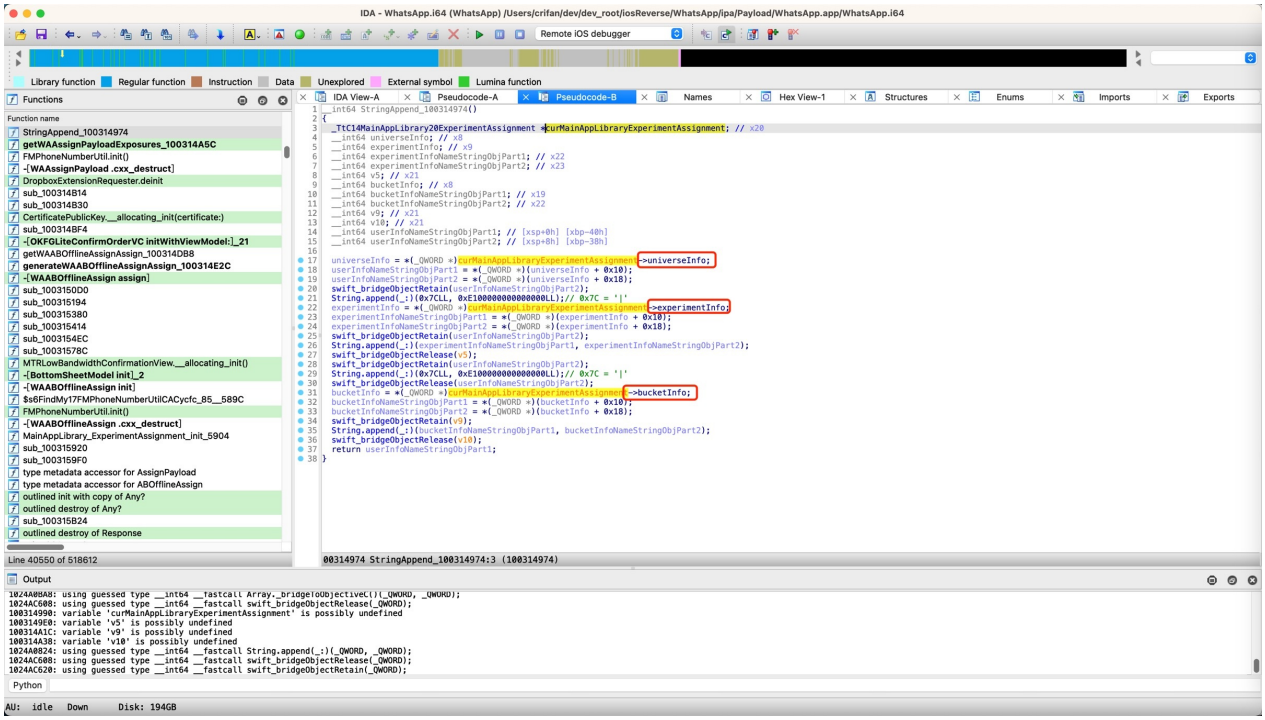
- `_QWORD *curMainAppLibraryExperimentAssignment`

改为：

- `_TtC14MainAppLibrary20ExperimentAssignment *curMainAppLibraryExperimentAssignment`



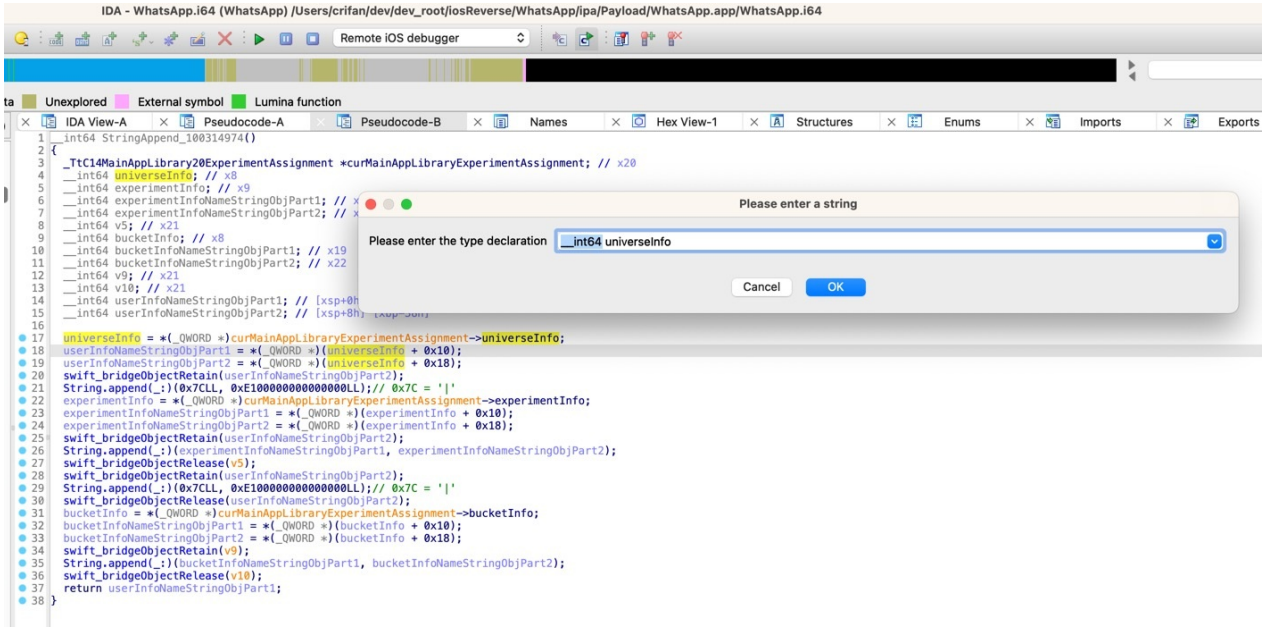
IDA中可见，的确自动识别成，类的属性=字段=成员的引用了：



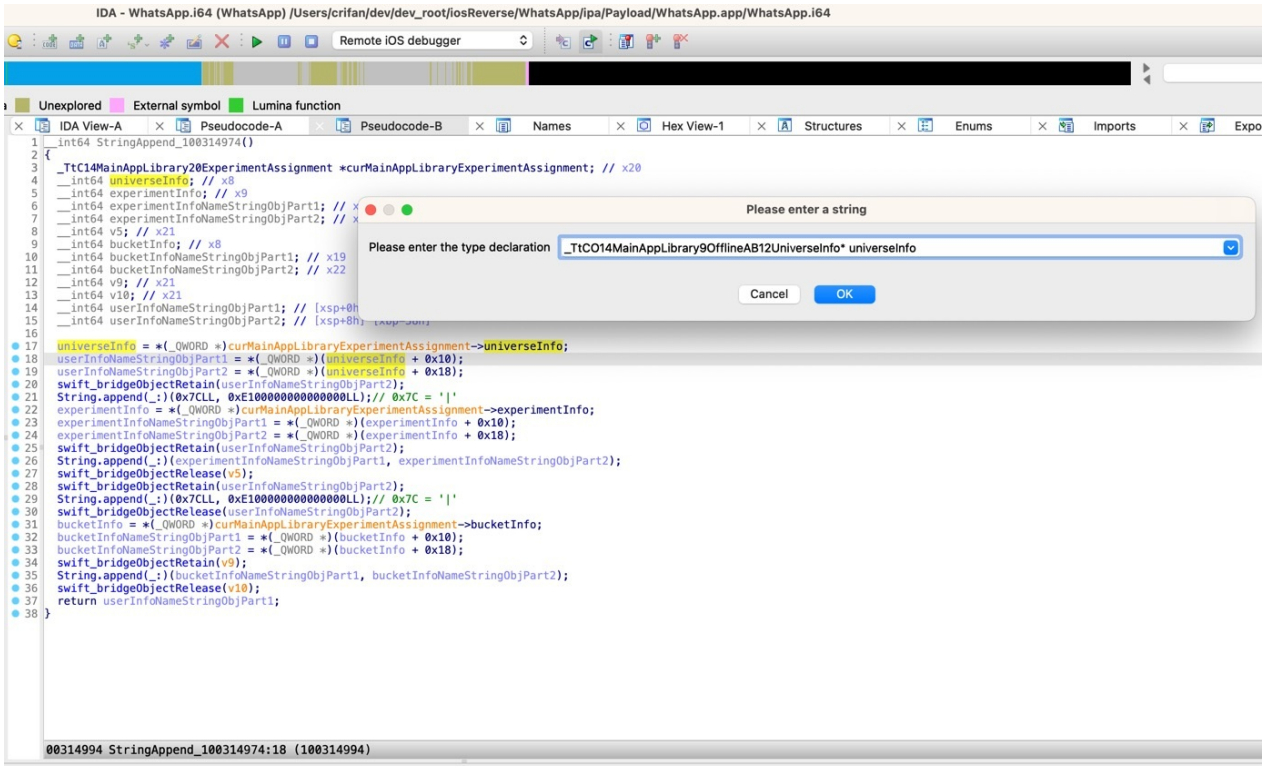
另外，再去给：

- universeInfo
- experimentInfo
- bucketInfo

也分别去修改类型为对应的类名：



- `__int64 universeInfo` -> `_TtCO14MainAppLibrary9OfflineAB12UniverseInfo* universeInfo`

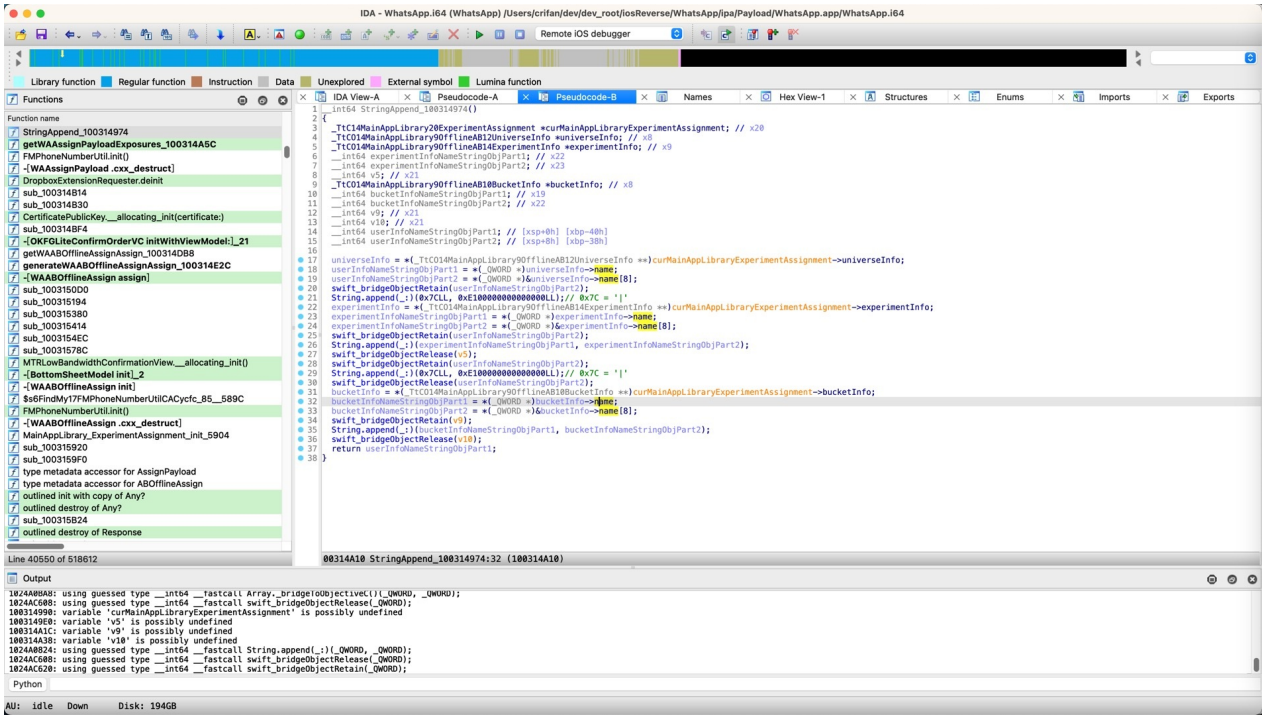


优化后的代码：

```
__int64 StringAppend_100314974()
{
  _TtC14MainAppLibrary20ExperimentAssignment *curMainAppLibraryExperimentAssignment; // x20
  _TtCO14MainAppLibrary9OfflineAB12UniverseInfo *universeInfo; // x8
  _TtCO14MainAppLibrary9OfflineAB14ExperimentInfo *experimentInfo; // x9
  __int64 experimentInfoNameStringObjPart1; // x22
  __int64 experimentInfoNameStringObjPart2; // x23
  __int64 v5; // x21
  _TtCO14MainAppLibrary9OfflineAB10BucketInfo *bucketInfo; // x8
  __int64 bucketInfoNameStringObjPart1; // x19
  __int64 bucketInfoNameStringObjPart2; // x22
  __int64 v9; // x21
  __int64 v10; // x21
  __int64 userInfoNameStringObjPart1; // [xsp+0h] [xbp-40h]
  __int64 userInfoNameStringObjPart2; // [xsp+8h] [xbp-38h]


  universeInfo = *(_TtCO14MainAppLibrary9OfflineAB12UniverseInfo **)curMainAppLibraryExperimentAssignment->universeInfo;
  userInfoNameStringObjPart1 = *(_QWORD *)universeInfo->name;
  userInfoNameStringObjPart2 = *(_QWORD *)&universeInfo->name[8];
  swift_bridgeObjectRetain(userInfoNameStringObjPart2);
  String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
  experimentInfo = *(_TtCO14MainAppLibrary9OfflineAB14ExperimentInfo **)curMainAppLibraryExperimentAssignment->experimentInfo;
  experimentInfoNameStringObjPart1 = *(_QWORD *)experimentInfo->name;
  experimentInfoNameStringObjPart2 = *(_QWORD *)&experimentInfo->name[8];
  swift_bridgeObjectRetain(userInfoNameStringObjPart2);
  String.append(_:)(experimentInfoNameStringObjPart1, experimentInfoNameStringObjPart2);
```

```
  swift_bridgeObjectRelease(v5);
  swift_bridgeObjectRetain(userInfoNameStringObjPart2);
  String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
  swift_bridgeObjectRelease(userInfoNameStringObjPart2);
  bucketInfo = *(_TtCO14MainAppLibrary9OfflineAB10BucketInfo **)curMainAppLibraryExperi
mentAssignment->bucketInfo;
  bucketInfoNameStringObjPart1 = *(_QWORD *)bucketInfo->name;
  bucketInfoNameStringObjPart2 = *(_QWORD *)&bucketInfo->name[8];
  swift_bridgeObjectRetain(v9);
  String.append(_:)(bucketInfoNameStringObjPart1, bucketInfoNameStringObjPart2);
  swift_bridgeObjectRelease(v10);
  return userInfoNameStringObjPart1;
}
```



逆向前后对比

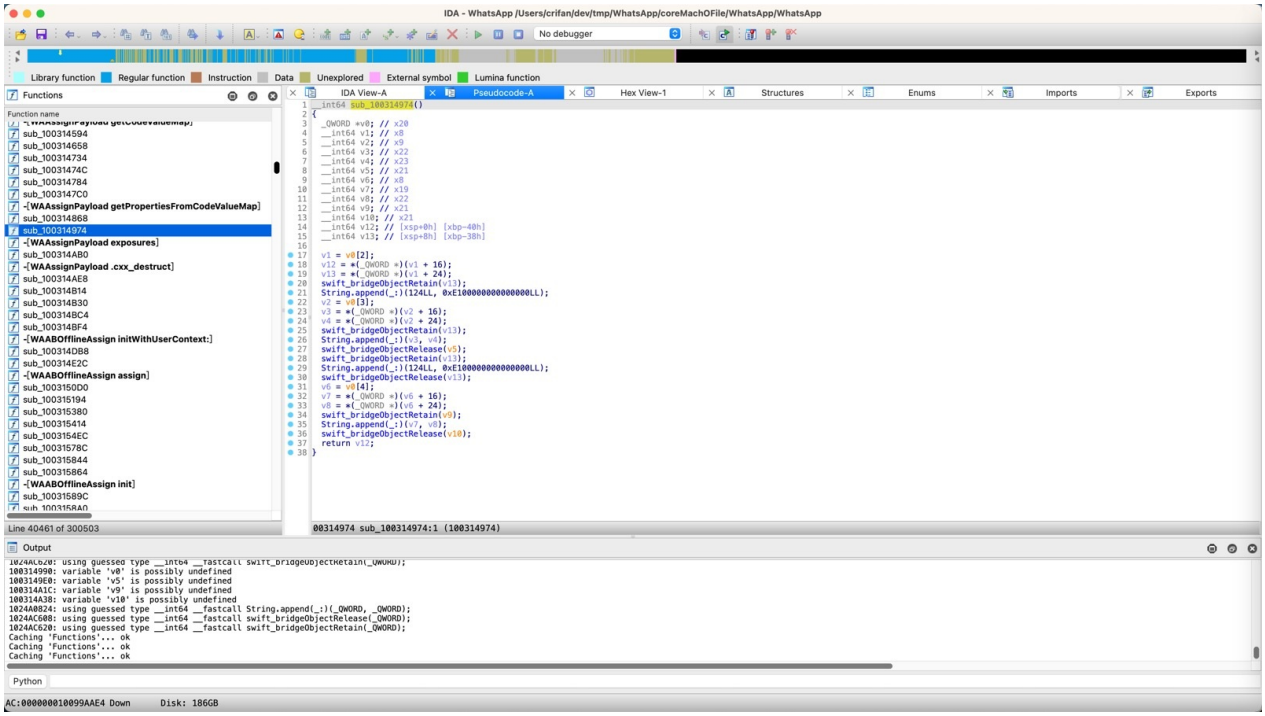
逆向之前

IDA伪代码

最初的IDA的相关伪代码，优化之前，是：

```
__int64 sub_100314974()
{
  _QWORD *v0; // x20
  __int64 v1; // x8
  __int64 v2; // x9
  __int64 v3; // x22
  __int64 v4; // x23
  __int64 v5; // x21
  __int64 v6; // x8
  __int64 v7; // x19
  __int64 v8; // x22
  __int64 v9; // x21
  __int64 v10; // x21
  __int64 v12; // [xsp+0h] [xbp-40h]
  __int64 v13; // [xsp+8h] [xbp-38h]


  v1 = v0[2];
  v12 = *(_QWORD *)(v1 + 16);
  v13 = *(_QWORD *)(v1 + 24);
  swift_bridgeObjectRetain(v13);
  String.append(_:)(124LL, 0xE100000000000000LL);
  v2 = v0[3];
  v3 = *(_QWORD *)(v2 + 16);
  v4 = *(_QWORD *)(v2 + 24);
  swift_bridgeObjectRetain(v13);
  String.append(_:)(v3, v4);
  swift_bridgeObjectRelease(v5);
  swift_bridgeObjectRetain(v13);
  String.append(_:)(124LL, 0xE100000000000000LL);
  swift_bridgeObjectRelease(v13);
  v6 = v0[4];
  v7 = *(_QWORD *)(v6 + 16);
  v8 = *(_QWORD *)(v6 + 24);
  swift_bridgeObjectRetain(v9);
  String.append(_:)(v7, v8);
  swift_bridgeObjectRelease(v10);
  return v12;
}
```



逆向后

IDA伪代码

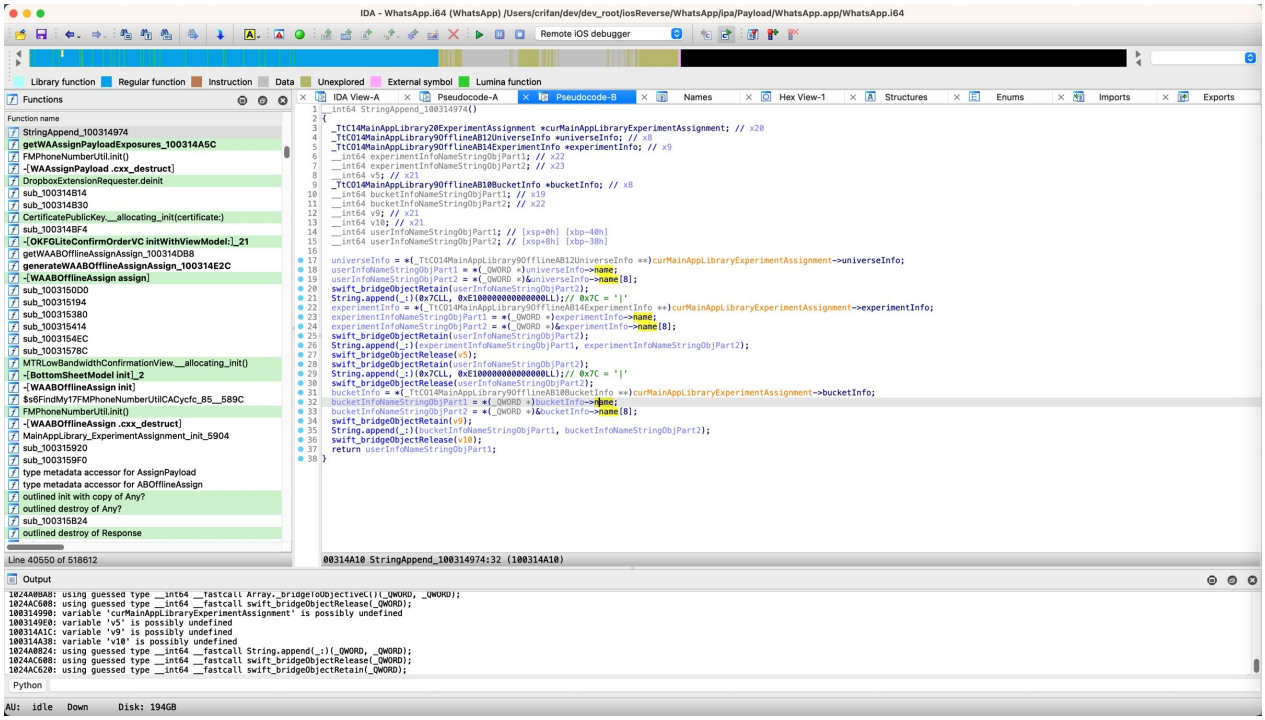
逆向后，经过分析，优化之后的：IDA伪代码：

```
__int64 StringAppend_100314974()
{
  _TtC14MainAppLibrary20ExperimentAssignment *curMainAppLibraryExperimentAssignment; //
 x20
  _TtCO14MainAppLibrary9OfflineAB12UniverseInfo *universeInfo; // x8
  _TtCO14MainAppLibrary9OfflineAB14ExperimentInfo *experimentInfo; // x9
  __int64 experimentInfoNameStringObjPart1; // x22
  __int64 experimentInfoNameStringObjPart2; // x23
  __int64 v5; // x21
  _TtCO14MainAppLibrary9OfflineAB10BucketInfo *bucketInfo; // x8
  __int64 bucketInfoNameStringObjPart1; // x19
  __int64 bucketInfoNameStringObjPart2; // x22
  __int64 v9; // x21
  __int64 v10; // x21
  __int64 userInfoNameStringObjPart1; // [xsp+0h] [xbp-40h]
  __int64 userInfoNameStringObjPart2; // [xsp+8h] [xbp-38h]


  universeInfo = *(_TtCO14MainAppLibrary9OfflineAB12UniverseInfo **)curMainAppLibraryEx
perimentAssignment->universeInfo;
  userInfoNameStringObjPart1 = *(_QWORD *)universeInfo->name;
  userInfoNameStringObjPart2 = *(_QWORD *)&universeInfo->name[8];
  swift_bridgeObjectRetain(userInfoNameStringObjPart2);
  String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
  experimentInfo = *(_TtCO14MainAppLibrary9OfflineAB14ExperimentInfo **)curMainAppLibra
ryExperimentAssignment->experimentInfo;
  experimentInfoNameStringObjPart1 = *(_QWORD *)experimentInfo->name;
```

```
  experimentInfoNameStringObjPart2 = *(_QWORD *)&experimentInfo->name[8];
  swift_bridgeObjectRetain(userInfoNameStringObjPart2);
  String.append(_:)(experimentInfoNameStringObjPart1, experimentInfoNameStringObjPart2);

  swift_bridgeObjectRelease(v5);
  swift_bridgeObjectRetain(userInfoNameStringObjPart2);
  String.append(_:)(0x7CLL, 0xE100000000000000LL);// 0x7C = '|'
  swift_bridgeObjectRelease(userInfoNameStringObjPart2);
  bucketInfo = *(_TtCO14MainAppLibrary9OfflineAB10BucketInfo **)curMainAppLibraryExperi
mentAssignment->bucketInfo;
  bucketInfoNameStringObjPart1 = *(_QWORD *)bucketInfo->name;
  bucketInfoNameStringObjPart2 = *(_QWORD *)&bucketInfo->name[8];
  swift_bridgeObjectRetain(v9);
  String.append(_:)(bucketInfoNameStringObjPart1, bucketInfoNameStringObjPart2);
  swift_bridgeObjectRelease(v10);
  return userInfoNameStringObjPart1;
}
```



代码逻辑

经过分析和调试，以及代码优化后，就真正的，完全的，彻底的搞懂了代码逻辑。

然后就可以分析和整理出函数的逻辑了：

- `StringAppend_100314974`
  - 输入：`MainAppLibrary.ExperimentAssignment` 的实例
  - 处理过程
    - 获取 `MainAppLibrary.ExperimentAssignment` 的 `universeInfo`
      - 再获取 `universeInfo` 的 `name`
        - 其是 `Swift` 的（Native）`Large String`
    - 去拼接上：`"|"`

        - 其是个 `Swift` 的 `small string`
    - 继续类似逻辑
        - 获取 `MainAppLibrary.ExperimentAssignment` 的 `experimentInfo`
            - 再获取 `experimentInfo` 的 `name`
                - 其是 `Swift` 的 `Large String`
        - 拼接 `"|"`
        - 获取 `MainAppLibrary.ExperimentAssignment` 的 `bucketInfo`
            - 再获取 `bucketInfo` 的 `name`
                - 其是 `Swift` 的 `Small String`
    - 最终得到拼接后的最终的字符串
- 处理逻辑概述：用 `universeInfo` 、 `experimentInfo` 、 `bucketInfo` 的 `name` ，中间加上 `|` ，拼接后的字符串
- 输出=返回值：
    - 最终拼接后的字符串
    - 举例
        - `"dummy_aa_offline_rid_universe_ios|dummy_aa_offline_rid_experiment_ios|control"`

如此，实现了：

通过静态分析（IDA的汇编代码和伪代码、class-dump导出的头文件、导出的字符串等资源）和动态调试（Xcode、lldb、iOSOpenDev插件hook代码等），加上此处特定的，Swift的String的Append函数以及String的内部类型和逻辑（String分Small String和Large String），最终才彻底搞懂代码逻辑，以及去优化IDA伪代码为，最终的代码，人类能看懂的代码。

附录

下面列出相关参考资料。

参考资料

- 【整理】iOS逆向心得：举例说明如何静态分析和动态调试出最终完整的代码逻辑
- 【未解决】iOS逆向WhatsApp：Swift函数String.append(_:)的字符串拼接的实现逻辑
- 【已解决】iOS逆向：Swift中String字符串的内部结构和逻辑
- 【已解决】iOS逆向WhatsApp：类MainAppLibrary.OfflineAB.UniverseInfo
- 【已解决】iOS逆向WhatsApp：类MainAppLibrary.OfflineAB.ExperimentInfo
- 【已解决】iOS逆向WhatsApp：类MainAppLibrary.OfflineAB.BucketInfo
-
- String字符串 · iOS逆向：Swift逆向
-
- Swift 里字符串（十）修改字符串 – huahuahu (wordpress.com)
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