Reflection

问题

- 像Python一样，直接 `obj.__class__` 就拿到所有关于object的类型信息
- 像Python一样，利用字符串调用函数和获取属性 `getattr('foo')`
- 通过字符串去创建一个对象
- 怎么才能更方便的做序列化

What

RTTI

Run-time type information (RTTI) is a mechanism that allows the type of an object to be determined during program execution.

- dynamic_cast
- typeid
- type_info
    - Used to hold the type information returned by the `typeid` operator.

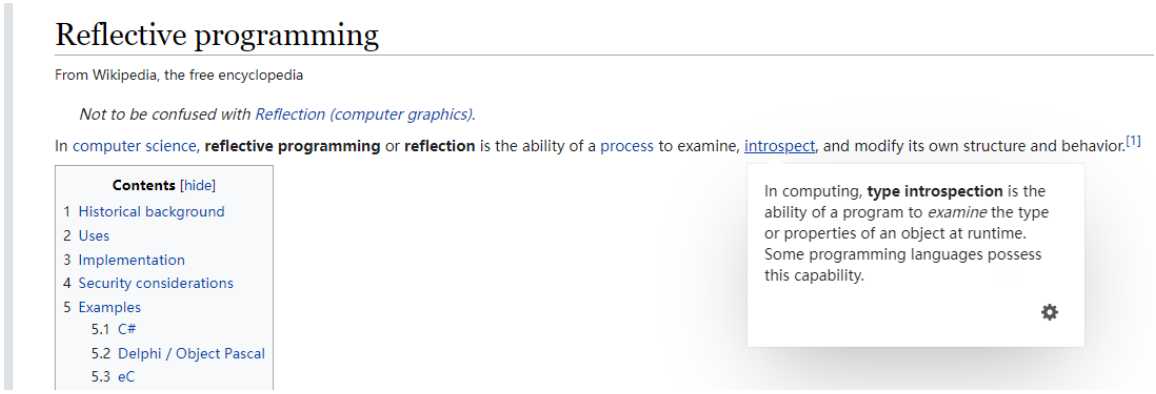
```
class type_info {
public:
    type_info(const type_info& rhs) = delete; // cannot be copied
    virtual ~type_info();
    size_t hash_code() const;
    _CRTIMP_PURE bool operator==(const type_info& rhs) const;
    type_info& operator=(const type_info& rhs) = delete; // cannot be copied
    _CRTIMP_PURE bool operator!=(const type_info& rhs) const;
    _CRTIMP_PURE int before(const type_info& rhs) const;
    size_t hash_code() const noexcept;
    _CRTIMP_PURE const char* name() const;
    _CRTIMP_PURE const char* raw_name() const;
};
```

Reflection

Reflection and Semantics in a Procedural Language

> Brian Cantwell Smith. "Reflection and Semantics in a Procedural Language". PhD. Thesis. Massachusetts Institute of Technology. MIT-LCS-TR-272. January 1982.

WikiPedia



[Java(Oracle) - Package java.lang.reflect Description]

> Provides classes and interfaces for obtaining reflective information about classes and objects. Reflection allows programmatic access to information about the fields, methods and constructors of loaded classes, and the use of reflected fields, methods, and constructors to operate on their underlying counterparts, within security restrictions.

[C# - Reflection]

> Reflection provides objects (of type Type) that describe assemblies, modules, and types. You can use reflection to dynamically create an instance of a type, bind the type to an existing object, or get the type from an existing object and invoke its methods or access its fields and properties. If you are using attributes in your code, reflection enables you to access them.

Function

- 获得对象的信息：Module、类型、属性、方法
- 动态生成对象，甚至新生成类
- 可以在运行时利用反射信息访问对象的属性，方法

Why

思考：new一个对象，调用一个函数很简单，为什么非得用反射，反射的意义？

- 可以通过配置文件快速修改运行时的对象，不需要重新编译
- 放置在游戏场景里的actor实例，如何感知自己是啥类型，有哪些属性需要暴露给编辑器修改？如何根据类型再去生成一系列兄弟actor？所以ue里面一些很基础的接口get actor of class, spawn actor from class 都是依赖反射
- 序列化、反序列化变得相当简单

思考：反射有什么缺点吗

- 对于非原生支持反射的语言而言，实现起来并不容易
- 会有性能损耗
- 不利于代码的阅读，难以从源代码理清逻辑
- 破坏类的封装性

How

其它语言的实现方法

Java

C#

C++反射实现

常用套路分为流派：

1. 手动注册类型信息
2. 预编译器生成类型信息

手动注册类型信息

宏

```
struct Test
{
    DECLARE_STRUCT(Test);
    DEFINE_FIELD(1, int, a)
    DEFINE_FIELD(2, int, b)
    DEFINE_FIELD(3, int, c)
    DEFINE_METADATA(3)
}
```

模版 C++ Reflection Library - rttr

Manual registration

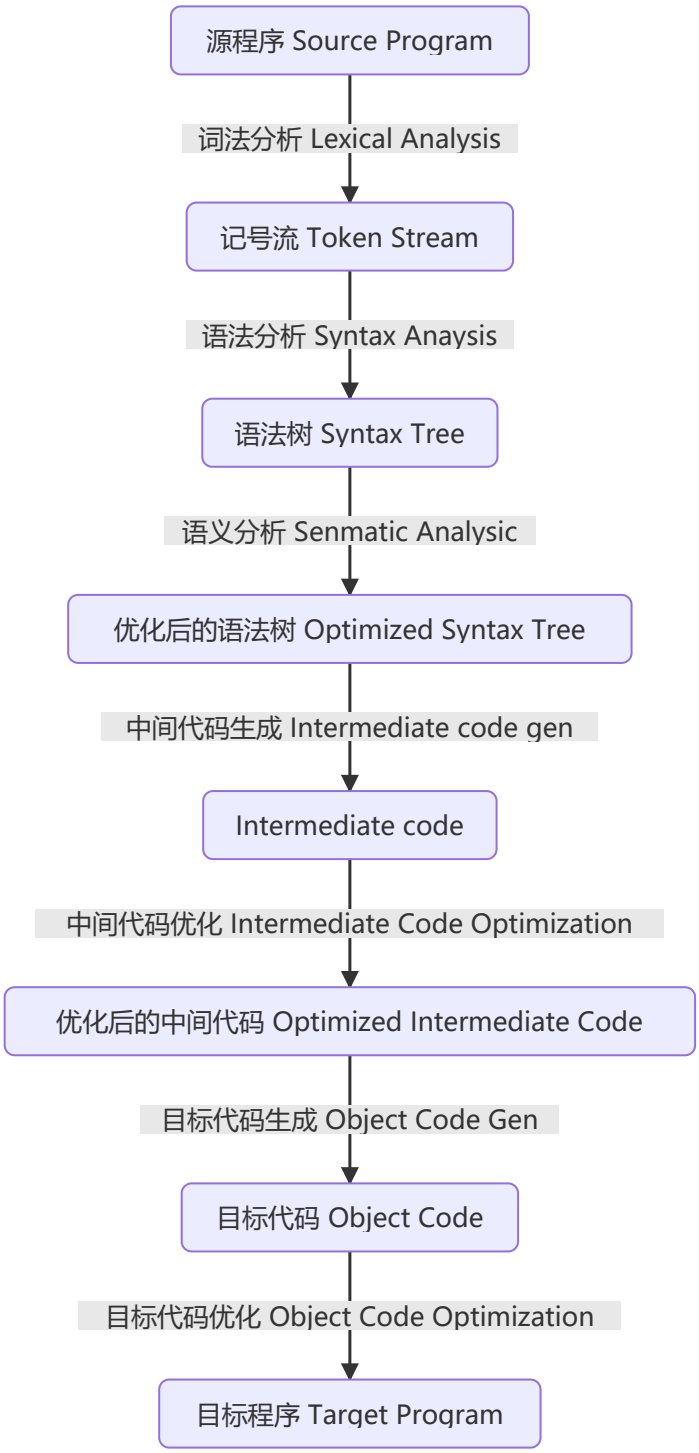
```
#include <rttr/registration>
using namespace rttr;

struct MyStruct {
    MyStruct() {};

    void func(double) {};
    int data;
};

RTTR_REGISTRATION
{
    registration::class_<MyStruct>("MyStruct")
         .constructor<>()
         .property("data", &MyStruct::data)
         .method("func", &MyStruct::func);
}
```

```
// Iterate over members
{
    type t = type::get<MyStruct>();
    for (auto& prop : t.get_properties())
        std::cout << "name: " << prop.get_name();

    for (auto& meth : t.get_methods())
        std::cout << "name: " << meth.get_name();
}

// Constructing types
```

```
{
    type t = type::get_by_name("MyStruct");
    variant var = t.create();    // will invoke the previously registered ctor

    constructor ctor = t.get_constructor();  // 2nd way with the constructor
class
    var = ctor.invoke();
    std::cout << var.get_type().get_name(); // prints 'MyStruct'
}

// Set/get properties
{
    MyStruct obj;

    property prop = type::get(obj).get_property("data");
    prop.set_value(obj, 23);

    variant var_prop = prop.get_value(obj);
    std::cout << var_prop.to_int(); // prints '23'
}

// Invoke Methods
{
    method meth = type::get(obj).get_method("func");
    meth.invoke(obj, 42.0);

    variant var = type::get(obj).create();
    meth.invoke(var, 42.0);
}
```

预编译器生成类型信息

编译器实现



编译器在编译的过程中可以获得所有的类型信息，因此分析编译器生成的中间文件提取数据信息可能是一条可行的路。

工具生成代码 qt

QT有一个预编译器：MOC，在源码输入编译器之前，会先经过 MOC 处理一遍。

UE4反射类型定义

https://cloud.tencent.com/developer/article/1606872

When / Where / Who

UE4在什么时候执行了反射，在哪里执行了反射，生成的内容在哪里

UE4反射机制

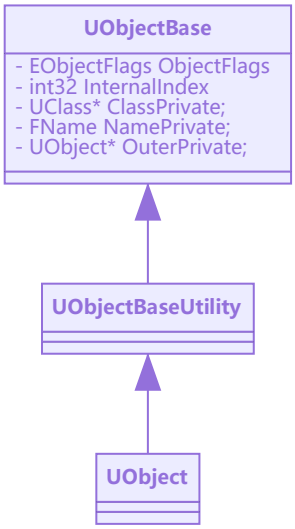
UObject

要描述UE4的反射机制，首先先得了解UE4中的万物之源UObject

```
// .\Runtime\CoreUObject\Private\UObject\UObjectHash.cpp

FUObjectArray GUObjectArray;

class FUObjectHashTables
{
    ...
public:
    static FUObjectHashTables& Get()
    {
        static FUObjectHashTables Singleton;
        return Singleton;
    }
    ...
}

// .\Runtime\CoreUObject\Private\UObject\UObjectBase.cpp
UObjectBase::UObjectBase(...)
{
    AddObject(...);
}

void UObjectBase::AddObject(...)
{
    ...
    GUObjectArray.AllocateUObjectIndex(this);
    ...
    HashObject(this);
    ...
}
```

- `FUObjectArray FUObjectArray` 是一个全局指针数组，存储了所有使用 `NewObject` 创建的对象
- `FUObjectHashTables` 记录了对象间的各种关系，在 GC 销毁对象时，会释放 `FUObjectArray` 中的内存和 `FUObjectHashTables` 的对象关系

> 语法解释：`<|--` 表示继承，`+` 表示 `public`，`-` 表示 `private`

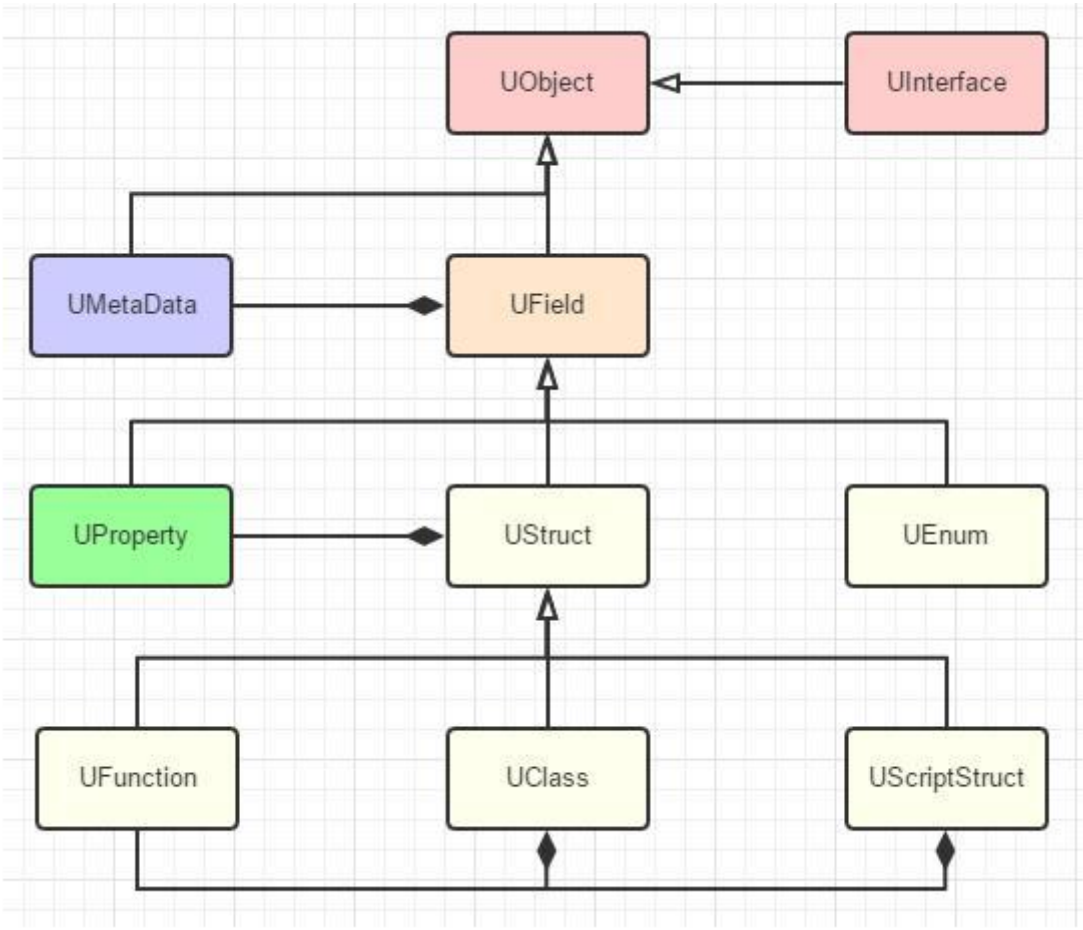



```
// .\Runtime\CoreUObject\Public\UObject\UObjectBase.h
class COREUOBJECT_API UObjectBase
{
    ...

private:
    /** Flags used to track and report various object states. This needs to be 8
byte aligned on 32-bit
        platforms to reduce memory waste */
    EObjectFlags                    ObjectFlags;

    /** Index into GObjectArray...very private. */
    int32                           InternalIndex;

    /** Class the object belongs to. */
    UClass*                         ClassPrivate;

    /** Name of this object */
    FName                           NamePrivate;

    /** Object this object resides in. */
    UObject*                        OuterPrivate;

    ...
}

// .\Runtime\CoreUObject\Public\UObject\UObjectBaseUtility.h
class COREUOBJECT_API UObjectBaseUtility : public UObjectBase
{
    ...
}

// .\Runtime\CoreUObject\Public\UObject\Object.h
```

```
class COREUOBJECT_API UObject : public UObjectBaseUtility
{
    ...
}
```

使用

```
UCLASS()
class Project_API UMyClass : public UObject
{
    GENERATED_BODY()
public:
    UFUNCTION(BluprintCallable)
    void MyFunc();
private:
    UPROPERTY(EditAnywhere, BlueprintReadWrite, meta=(AllowPrivateAccess =
"true"))
    int MyIntValue;
}
```



1. UObject
2. UField
3. UStruct

> 4. UProperty
> 5. UEnum
> 6. UClass
> 7. UFunction
> 8. UScriptStruct

UnrealHeaderTool和UnrealBuildTool

UHT解析原理

LL & LR

FHeaderParser::ParseHeader