

Code Modification

Going beyond the basics and modifying the game's code.

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Using GDB with Ghidra and melonDS

What you'll need:

- The latest version of [Ghidra](#)
- A build of melonDS that has the GDB enabled
- The easiest way to get this is to grab a GitHub action build of melonDS. You can find that [here](#). (Note: you'll need to be signed into a GitHub account to download these builds)
- The [GNU ARM Embedded Toolchain](#) installed on your system
- A Ghidra database of NSMB DS
- Eventually, NSMB Central will host a shared Ghidra project so we have one centralized project anyone can contribute to. For now, you can generate a Ghidra project using [this tool](#). If you need help, please ask in our Discord!

Configuring melonDS

To enable the GDB, you need to do the following:

1. Click on the **Config** menu at the top of the emulator, then click on **Emu Settings**
2. Click on the **Devtools** tab
3. Check Enable **GDB stub**
4. If you do not see the Devtools tab, then you have not built melonDS with GDB enabled. Please check the link at the start of the guide to find a download with GDB enabled or build it yourself enabling GDB in CMake

melonDS is ready to go!

Setting up Ghidra

To begin, open your Ghidra project in the code viewer as you normally would.

1. Click on File -> Configure, which should open a list of tools

2. Check the "Debugger" box



Debugger

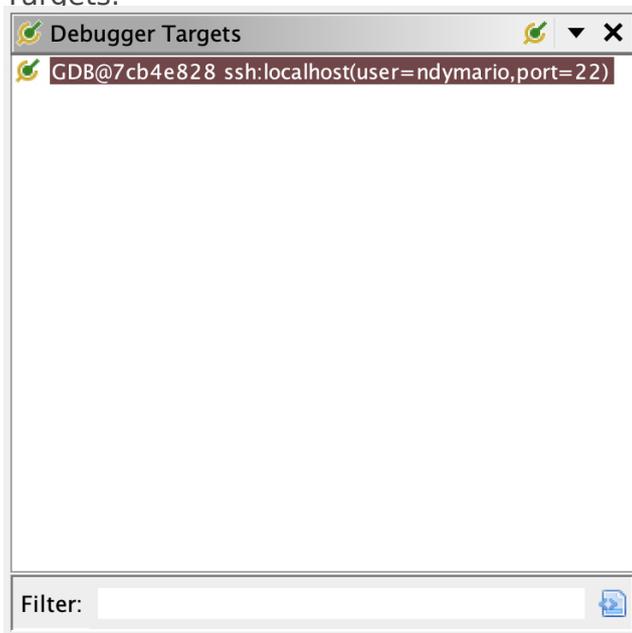
[Configure](#)

This should cause windows to appear in your current project, likely making the following steps redundant. If you are unable to find a window, the following steps will either open the window, or present it to you in the project.

Creating a Debugger Target

This method has been tested on Linux and macOS. You should be able to follow these steps using WSL on Windows. Follow [this guide](#) if you need help setting up WSL.

To begin, open the Debugger Targets window by navigating to Windows -> Debugger -> Debugger Targets.



As you'll notice, there is an active connection in the

screenshot but nothing on your end...let's fix that!

Click on the  button to open the **connect** window.

If you are on Linux:

- Choose **gdb** in the dropdown
- Set **arm-none-eabi-gdb -ex "set arch armv5t"** as the **GDB Launch Command**

-

If you have not added `arm-none-eabi-gdb` to your PATH, you'll need to provide the absolute path

- Click 

If you are on macOS

- Choose **`gdb via SSH`** in the dropdown
- Set **`arm-none-eabi-gdb -ex "set arch armv5t"`** as the **GDB Launch Command**

If you have not added `arm-none-eabi-gdb` to your PATH, you'll need to provide the absolute path

- Set **SSH hostname** to **`localhost`**
- Set **SSH username** to your username

You can use the command **`whoami`** in the terminal to get your username if you don't know it

- Click 

If you are on Windows

This still needs to be tested on Windows. This guide will be updated when steps have been made

You have now created a Debugger Target

Connecting to melonDS

The **`gdb interpreter`** should have opened for you when you connected to the **debugging target**.

If you have lost the interpreter window, open the objects window (Window -> Debugger -> Objects) and click on  to bring the menu back

- In melonDS, open your ROM. (You can either boot directly to the game or launch the firmware)

Now, in the interpreter menu, run the command **`target remote localhost:[ARM9 Port]`** (Where [ARM9 Port] is the ARM9 Port set in the Devtools tab.)

By default, it should be 3333. The command would be **`target remote localhost:3333`**

If melonDS pauses after running this command, GDB is now talking to melonDS

- If the connection immediately closes after running the command: change the ARM9 port to something else, restart melonDS, and close the current GDB connection.

You have now connected Ghidra to melonDS

Using Breakpoints

If you would like to set breakpoints, you'll need to use the **Dynamic PC**

1. Open the **Dynamic PC** window by clicking **Window -> Listing -> Dynamic - Auto PC, [...]**

1. If you do not see this option, you can alternatively open it via **Window -> Debugger -> New Dynamic Listing**

2. Next, open the **Modules** window by clicking **Window -> Debugger -> Modules**
3. Lastly, click on  in the **Modules** window.

Now, setting a breakpoint in your code view should set a breakpoint in the **Dynamic PC**

- Breakpoints will only update if the emulator has hit a breakpoint or has been paused by pressing 

You have now set up Ghidra to debug melonDS. Happy coding!

Setting Up Code Modifications

So, you're ready to dive into the code of the game? Let's get started!

In this tutorial, you will learn how to:

- Set up the NSMB DS Code Template
- Set up ARM GCC
- Set up NCPatcher
- Extract/Build your ROM

This guide will cover the "NCPatcher Standalone" method described in the code template as the steps are more synchronized between all operating systems.

Setting Up the Code Template

1. Head over to the [code template's GitHub](#)
2. Click on **Code -> Download ZIP**
3. Now extract this zip and rename the folder to what you want to call your project (this will be referred to as your **project root**)
4. **Don't put any spaces in your folder name!**

You have now set up the code template

Setting up ARM GCC

1. Head to the [Arm GNU Toolchain Download Page](#)
2. Now search (using CTRL/CMD + F) for **AArch32 bare-metal target (arm-none-eabi)** and download the correct installer for your operating system.
3. Open the installer and install the toolchain.
4. **Pick a location without spaces to install the toolchain!**

You have now set up ARM GCC

Setting Up NCPatcher

1. Head over to the [NCPatcher GitHub releases page](#)
2. Download the latest release for your operating system
3. Extract NCPatcher

Now, NCPatcher depends on **ncpatcher.json**, so lets make it!

If you'd like to learn more about this file, head over to the [NCPatcher GitHub!](#)

In your **project root**, create the following files:

- **ncpatcher.json**
 - Copy/Paste the following JSON into the file

```
{
  "$arm_flags": "-masm-syntax-unified -mno-unaligned-access -mfloat-abi=soft -mabi=aapcs",
  "$c_flags": "-Os -fomit-frame-pointer -ffast-math -fno-builtin -nostdlib -nodefaultlibs -nostartfiles -DSDK_GCC -DSDK_FINALROM",
  "$cpp_flags": "-fno-rtti -fno-exceptions -std=c++20",
  "$asm_flags": "-Os -x assembler-with-cpp -fomit-frame-pointer",
  "$ld_flags": "-lgcc -lc -lstdc++ --use-blx",

  "backup": "backup",
  "filesystem": "nsmb",
  "toolchain": "arm-none-eabi-",

  "arm7": {},
  "arm9": {
    "target": "arm9.json",
    "build": "build"
  },

  "pre-build": [],
  "post-build": [],

  "thread-count": 0
}
```

You have now set up NCPatcher

Extracting, Building, and Repackaging Your ROM

If you're on Windows

1. Download [fireflower.zip](#) and extract it.
2. Move **nds-build.exe** and **nds-extract.exe** out from the folder

If you're on macOS/Linux

1. Download [nds-extract.zip](#)
2. Download [nds-build.zip](#)
3. Extract both ZIPs

Now, you need to build the tools.

For NDS Extract:

1. Open a new **Terminal** window in the folder of the code
2. Run this command: `g++ nds-extract.cpp -o nds-extract -std=c++20`

For NDS Build:

1. Open a new **Terminal** window in the folder of the code
2. Run this command: `g++ nds-build.cpp -o nds-build -std=c++20`

From here on, the instructions will work for all operating systems. If you are on Windows 10, you can use **Command Prompt** instead of **Terminal**

Extracting Your ROM

1. Open a **Terminal** window in your **project root**
2. Run this command: `/path/to/nds-extract rom.nds nsmb`

Replace `/path/to/` with the actual file path to nds-extract. Also replace "rom" with the actual name of your .nds file

This will extract the contents of your ROM into a folder named nsmb

You have extracted your ROM

Building Your ROM

This step will compile and patch your ROM with any code files found in the **source** directory in your **project root**. The Code Template comes with a few examples included in the **source** directory.

1. Open a **Terminal** window in your **project root**
2. Run this command: `/path/to/ncpatcher`

Replace `/path/to/` with the actual file path to `ncpatcher`

You have built your ROM

Repackaging Your ROM

`nds-extract` depends on **buildrules.txt**, so let's create it!

- **buildrules.txt**
 - Copy/Paste the following text into the file:

```
rom_header NSNDY/header.bin
arm9_entry KEEP
arm9_load KEEP
arm7_entry KEEP
arm7_load KEEP
fnt nsmb/fnt.bin
file_mode ADJUST
arm9 nsmb/arm9.bin
arm7 nsmb/arm7.bin
arm9ovt nsmb/arm9ovt.bin
arm7ovt nsmb/arm7ovt.bin
icon nsmb/banner.bin
rsa_sig nsmb/rsasig.bin
data nsmb/root
ovt_repl_flag 0xFF
ov9 nsmb/overlay9
ov7 nsmb/overlay7
```

This step will take the files from the **nsmb** folder and repackage them into a `.nds` file

1. Open a **Terminal** window in your **project root**
2. Run this command: `/path/to/nds-build buildrules.txt NSMB.nds`

Replace /path/to/ with the actual file path to nds-build.

You have repackaged your ROM

Porting old patch syntax to NCPatcher

This page will help you understand how you can port any patching syntax to NCPatcher's.

You are searching through NSMBHD or NSMB Central and you find a shiny code patch, you rush and put it in the `source` folder of your project only to find that a code patch is not compatible with your code! That sucks.

So what can we do? For this example NSMB E3 Recreation's `PlayerAnims.cpp` code patch will be used.

Step 1 - Investigation

Let's start by taking a look at `PlayerAnims.cpp`.

```
#include <nsmb.hpp>
#include <nsmb/extra/fixedpoint.hpp>

#define NAKED __attribute__((naked))

// Slow down rotation speed
NAKED void repl_02114DFC_ov_0A() { asm("MOV R5, #0xC00\nBX LR"); }

// Walking transition delay
void repl_0211667C_ov_0A() {}

void repl_02116698_ov_0A(Player* player, int id, bool doBlend, Player::FrameMode frameMode, fx32 speed, u16
frame) {
    // 3.75fx (0x3C00) is the max walk animation speed
    if (speed > (3.75fx / 2)) {
        speed = (3.75fx / 2);
    }

    if (player->animID == 2) {
```

```

player->setBodyAnimationSpeed(speed);
} else {
    if (player->animID == 1) {
        float xvel = Math::abs(player->velocity.x);
        if (xvel >= 1.5fx) {
            player->setAnimation(2, doBlend, frameMode, speed, frame);
        } else {
            player->setBodyAnimationSpeed(speed);
        }
    } else {
        player->setAnimation(1, doBlend, frameMode, speed, frame);
    }
}

// Force jump on anim 1
NAKED void nsub_02116A14_ov_0A() { asm("CMP R0, #1\nB 0x02116A18"); }

// Use anim 1
NAKED void repl_02116A2C_ov_0A() { asm("MOV R1, #1\nBX LR"); }

```

We must now wonder, what kind of a patch is this? Is this an `NSMBe` type patch or a `Fireflower` type patch?

By comparing common traits that each patcher uses we can guess what kind of patch type we are dealing with.

`NSMBe` type patches:

- Does not use attributes to declare patches, uses the function name. `void hook_x() {}`
- Patches always follow the format `<PATCH TYPE>_<ADDRESS HEX>_ov_<OVERLAY HEX>` or `<PATCH TYPE>_<ADDRESS HEX>` if you don't need to specify an overlay.
- `PATCH TYPE` can only be `hook`, `repl` or `nsub`.

`Fireflower` type patches:

- Uses attributes to declare patches. `hook(X) void func() {}`
- Patches always follow the format `<PATCH TYPE>(0x<ADDRESS HEX>, 0x<OVERLAY HEX>)` or `<PATCH TYPE>(0x<ADDRESS HEX>)` if you don't need to specify an overlay.
- `PATCH TYPE` can only be `hook`, `rlnk`, `safe` or `over`.

Did you guess correctly what kind of patch we are working with?

[Click here to reveal the answer](#)

NSMBe

Step 2 - Porting

This is a fairly simple process. Here is a list that shows the different patch syntax between the patchers:

NSMBe	Fireflower	NCPatcher
hook	safe	ncp_hook
repl	rlnk	ncp_call
nsub	hook	ncp_jump
	over	ncp_over
		ncp_repl

And here is an example comparing some of them:

```
// NSMBe
void hook_02000000() {} // doSomethingPatch
void repl_0200A000() {} // doUnspecifiedPatch
void repl_02010000_ov_0A() {} // doWhateverOverlayPatch
// over does not exist in NSMBe

// Fireflower
safe(0x02000000) void doSomethingPatch() {}
rlnk(0x0200A000) void doUnspecifiedPatch() {}
rlnk(0x02010000, 10) void doWhateverOverlayPatch() {}
over(0x02159348, 52) static int stupidVar = 0x0215CA6C;

// NCPatcher
ncp_hook(0x02000000) void doSomethingPatch() {}
ncp_call(0x0200A000) void doUnspecifiedPatch() {}
ncp_call(0x02010000, 10) void doWhateverOverlayPatch() {}
ncp_over(0x02159348, 52) static int stupidVar = 0x0215CA6C;
```

These addresses are fictitious and purely for demonstration!

An important thing to remember is that all values in `NSMBe` patches are always written in hexadecimal without `0x` prepended to them. In `NCPatcher` if you want to specify an hexadecimal value you need to prepend `0x`, otherwise the value will be interpreted as a decimal value!

Let's go back to `PlayerAnims.cpp` and try to apply these changes.

```
#include <nsmb.hpp>
#include <nsmb/extra/fixedpoint.hpp>

#define NAKED __attribute__((naked))

NAKED ncp_call(0x02114DFC, 10)
void slowDownRotationSpeed() { asm("MOV R5, #0xC00\nBX LR"); }

// Walking transition delay
ncp_call(0x0211667C, 10) void doNotJumpOnAnim2() {}

ncp_call(0x02116698, 10)
void customPlayerAnimator(Player* player, int id, bool doBlend, Player::FrameMode frameMode, fx32 speed, u16
frame) {
    // 3.75fx (0x3C00) is the max walk animation speed
    if (speed > (3.75fx / 2)) {
        speed = (3.75fx / 2);
    }

    if (player->animID == 2) {
        player->setBodyAnimationSpeed(speed);
    } else {
        if (player->animID == 1) {
            fx32 xvel = Math::abs(player->velocity.x);
            if (xvel >= 1.5fx) {
                player->setAnimation(2, doBlend, frameMode, speed, frame);
            } else {
                player->setBodyAnimationSpeed(speed);
            }
        } else {
            player->setAnimation(1, doBlend, frameMode, speed, frame);
        }
    }
}
```

```
NAKED ncp_jump(0x02116A14, 10)
void forceJumpOnAnim1() { asm("CMP R0, #1\nB 0x02116A18"); }

NAKED ncp_call(0x02116A2C, 10)
void useAnim1() { asm("MOV R1, #1\nBX LR"); }
```

The code should now compile!

If your code still doesn't work because it complains about some functions not being defined or not existing then you might want to check this out as well: [Porting old patches to the NSMB Code Reference](#)

What if the patch was an assembly `.s` file instead of C `.c` or C++ `.cpp`? The process is the same.

```
hook_....:
    BX LR
```

Becomes

```
ncp_hook(...)
    BX LR
```

Step 4 - Tidying up

Even though the code should now be able to execute, it is still not in its optimal state. This part is slightly more complicated because it requires understanding the code.

NCPatcher includes its own definition of `__attribute__((naked))` which is `ncp_asmfunc` so we remove that macro definition and use `ncp_asmfunc` instead.

```
#include <nsmb.hpp>
#include <nsmb/extra/fixedpoint.hpp>

ncp_asmfunc ncp_call(0x02114DFC, 10)
void slowDownRotationSpeed() { asm("MOV R5, #0xC00\nBX LR"); }

// Walking transition delay
ncp_call(0x0211667C, 10) void doNotJumpOnAnim2() {}

ncp_call(0x02116698, 10)
```

```

void customPlayerAnimator(Player* player, int id, bool doBlend, Player::FrameMode frameMode, fx32 speed, u16
frame) {
    // 3.75fx (0x3C00) is the max walk animation speed
    if (speed > (3.75fx / 2)) {
        speed = (3.75fx / 2);
    }

    if (player->animID == 2) {
        player->setBodyAnimationSpeed(speed);
    } else {
        if (player->animID == 1) {
            fx32 xvel = Math::abs(player->velocity.x);
            if (xvel >= 1.5fx) {
                player->setAnimation(2, doBlend, frameMode, speed, frame);
            } else {
                player->setBodyAnimationSpeed(speed);
            }
        } else {
            player->setAnimation(1, doBlend, frameMode, speed, frame);
        }
    }
}

ncp_asmfunc ncp_jump(0x02116A14, 10)
void forceJumpOnAnim1() { asm("CMP R0, #1\nB 0x02116A18"); }

ncp_asmfunc ncp_call(0x02116A2C, 10)
void useAnim1() { asm("MOV R1, #1\nBX LR"); }

```

Now, take a look at the original purpose of `repl_0211667C_ov_0A` (now named `doNotJumpOnAnim2`) and the code it targeted.

```

ov10:02116678  CMP R0, #2
ov10:0211667C  BEQ 0x021166A0
ov10:02116680  MOV R0, R5

```

We can see that what we are doing is the following:

```

ov10:02116678  CMP R0, #2
ov10:0211667C  BL repl_0211667C_ov_0A

```

```

ov10:02116680  MOV R0, R5
//...
repl_0211667C_ov_0A:
    BX LR // return generated by the compiler

```

Essentially we are just making it so `BEQ 0x021166A0` will never jump to `0x021166A0`, but we are not doing this efficiently because we jump from `0x0211667C` to `repl_0211667C_ov_0A` and then back to `0x02116680` instead of just continuing. This wastes memory and CPU cycles, but it was the only way of doing so in `NSMBe`. Instead we can write it like `ncp_repl(0x0211667C, 10, "NOP")` in `NCPatcher`, making the instruction do nothing and just skip to the next one without using any more memory.

```

ov10:02116678  CMP R0, #2
ov10:0211667C  NOP      // Skips to the next instruction
ov10:02116680  MOV R0, R5

```

After evaluating all these different cases, our optimal code should look like this:

```

#include <nsmb.hpp>
#include <nsmb/extra/fixedpoint.hpp>

// Slow down rotation speed
ncp_repl(0x02114DFC, 10, "MOV R5, #0xC00")

// Walking transition delay
ncp_repl(0x0211667C, 10, "NOP")

ncp_call(0x02116698, 10)
void customPlayerAnimator(Player* player, int id, bool doBlend, Player::FrameMode frameMode, fx32 speed, u16 frame) {
    // 3.75fx (0x3C00) is the max walk animation speed
    if (speed > (3.75fx / 2)) {
        speed = (3.75fx / 2);
    }

    if (player->animID == 2) {
        player->setBodyAnimationSpeed(speed);
    } else {
        if (player->animID == 1) {
            fx32 xvel = Math::abs(player->velocity.x);
            if (xvel >= 1.5fx) {
                player->setAnimation(2, doBlend, frameMode, speed, frame);
            }
        }
    }
}

```

```
    } else {  
        player->setBodyAnimationSpeed(speed);  
    }  
} else {  
    player->setAnimation(1, doBlend, frameMode, speed, frame);  
}  
}  
}
```

```
// Force jump on anim 1
```

```
ncp_repl(0x02116A14, 10, "CMP R0, #1")
```

```
// Use anim 1
```

```
ncp_repl(0x02116A2C, 10, "MOV R1, #1")
```

Porting old patches to the NSMB Code Reference

Custom Actors

Sometimes the base game doesn't offer exactly what you need for your level. That's when you should turn to custom actors!

This guide provides a basic overview of how to create custom actors. A decent understanding of C++ along with some prior NSMB code modding knowledge are recommended for this tutorial.

Section 1 - The Boiler Plate

This is code you will be writing basically every time you go to create a custom actor. It is standard practice to split your actor into two files `myActor.cpp` and `myActor.hpp`

`myActor.cpp`

```
#include "nsmc.hpp"
#include "myActor.hpp"

ncp_over(0x020c560c, 0) const ObjectInfo objectInfo = MyActor::objectInfo; //Stage Object ID 44 (use this in the editor)
ncp_over(0x02039a34) static constexpr const ActorProfile* profile = &MyActor::profile; //objectID 46

s32 MyActor::onCreate(){
    return true;
}

bool MyActor::loadResources() {
    return true;
}

s32 MyActor::onDestroy(){
    return true;
}

s32 MyActor::onRender(){
    return true;
}
```

```

}

bool MyActor::updateMain(){
    return true;
}

```

This file is where you program your actor.

At the beginning of the file is where you define:

- Where in the object bank table your actor's object info is stored. The array index is what you place in the editor to "place" your object. In the sample above, it is replacing ID 44. The beginning of this array is located at `0x020c529c`
- Where in the main process table your actor's profile is stored. The beginning of this array is located at `0x0203997c`

Here's an overview of what these functions are usually used for:

Function	Purpose
<code>onCreate()</code>	This function is ran when your actor is first created. This function is used for initalizing variables and anything that should be done once.
<code>loadResources()</code>	This function is called when the game is setting up your actor. [Todo]: Find the normal use case for this function.
<code>onDestroy()</code>	This function is called when your Actor is being removed from the stage. This function is used for cleaning up after the actor (i.e. freeing resources).
<code>onRender()</code>	This function is called every game tick while your actor is in view of the camera. This is typically used for graphics related code (for example, changing what texture an NSBTX is currently drawing).
<code>updateMain()</code>	This function is called every game tick while your actor is loaded. This function is used for the main functionality of your code (i.e. calculating positions, updating variables, etc).

TODO: Expand this table with more functions you can override in a `StageEntity`

`myActor.hpp`

```

#pragma once

#include "nsmc.hpp"

```

```

class MyActor: public StageEntity {
public:
    virtual s32 onCreate() override;

    static bool loadResources();

    virtual bool updateMain() override;

    virtual s32 onRender() override;

    virtual s32 onDestroy() override;

    static constexpr u16 objectID = 46;

    static constexpr ObjectInfo objectInfo = {
        0, 0,
        0, 0,
        0, 0,
        0, 0,
        CollisionSwitch::None,
    };

    static constexpr u16 updatePriority = objectID;
    static constexpr u16 renderPriority = objectID;
    static constexpr ActorProfile profile = {&constructObject<MyActor>, updatePriority, renderPriority,
loadResources};
};

```

This file is where you store your instance variables and declare your functions.

Section 2 - State Machines

While not all Actors *need* to have a state machine, it can often times greatly improve the readability and reliability of your code (state machines are also a strategy Nintendo used when writing actors for the game).

Defining the State Machine

In your `.hpp`, you need to add the following:

```

class MyActor: public StageEntity {
    /* ... */

    // Functions for the state machine. Add more as needed.
    void exampleState();
    void anotherExampleState();

    void (*updateFunc)(MyActor*);
    int updateStep;

    void switchState(void (MyActor::*updateFunc)());

    /* ... */
}

```

In your `.cpp`, here's what you need:

```

s32 MyActor::onCreate(){
    /* ... */

    // Initialize the current state
    switchState(&MyActor::exampleState);

    /* ... */
}

bool MyActor::updateMain(){
    /* ... */

    // Make sure to call the update function every tick
    updateFunc(this);

    /* ... */
}

bool MyActor::exampleState(){
    if (updateStep == Func::Init) {
        updateStep++;
        return;
    }
}

```

```

    if (updateStep == Func::Exit) {
        return;
    }
}

bool MyActor::anotherExampleState(){
    if (updateStep == Func::Init) {
        updateStep++;
        return;
    }

    if (updateStep == Func::Exit) {
        return;
    }
}

void MyActor::switchState(void (MyActor::*updateFunc)()) {
    auto updateFuncRaw = ptmf_cast(updateFunc);

    if (this->updateFunc != updateFuncRaw) {
        if (this->updateFunc) {
            this->updateStep = Func::Exit;
            this->updateFunc(this);
        }

        this->updateFunc = updateFuncRaw;

        this->updateStep = Func::Init;
        this->updateFunc(this);
    }
}

```

Using the State Machine

While the code may look intimidating, state machines are very intuitive once you start working with them.

Function/Variable	Purpose
-------------------	---------

<code>updateStep</code>	<p>This variable keeps track of what update step the current state is in.</p> <p>1 (or <code>Func::Init</code>) is used for when a state function is entered for the first time. Useful for setting variables related to the current state.</p> <p>-1 (or <code>Func::Exit</code>) is used for when a state function is being exited. Used for cleaning up any state specific code before the code changes to the next state.</p> <p>All other update step values can be used inside a step to create "sub steps" via conditional code.</p>
<code>switchState()</code>	<p>This function will swap the current state to the function passed as a parameter. Call this function when you want to change what state you are in.</p>

TODO: Expand this page with more actor components (for example, colliders)