

# CS 2110 Homework 6

## GBA

The Forefathers of CS 2110

Spring 2025

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# 1 Overview

## 1.1 Purpose

The goal of this assignment is to make a C program that will run on a Game Boy Advance (GBA) emulator. Your program can be any interactive graphical application that meets the requirements outlined below.

In writing this program, you will learn about low-level hardware programming in C. This program is similar to how you would write device drivers or parts of an operating system, which are typically written in C. The GBA devices (screen, buttons, DMA controller, etc.) are accessed via memory-mapped I/O. You will access specific hard-coded memory addresses in your C code. You will gain experience with bit masks and bitwise operators to set bits in the device registers.

The GBA is a very slow computer. You will learn tricks to optimize the performance on a resource-limited hardware device (such as DMA, integer math instead of floating point, and so forth).

## 1.2 Tasks

You will complete the items marked `TODO` in `gba.c` and `gba.h`. Then, using your now functional GBA starter methods, you will write an interactive graphical application in C that runs on the GBA emulator by completing `main.c`, `main.h`, and any other supplementary files (code or otherwise). This application can be a game or any application that meets the feature and technical requirements below. For ideas on what you could do, please see [What to Make](#) in the Appendix. This is an open-ended assignment. Just be sure that your program meets all the [requirements](#).

We have provided some [resources](#) to help you get started. You can use the outline structure of a program and fill in code to do what your application specifically does. You should have at least one `.h` header file and one `.c` file. You can have more if you wish.

Your program must use DMA, `waitForVblank()`, and Mode 3 video. You must have a title screen in addition to the other screen(s) in your program. You must use button input and include some text on the screen, as well as other images (a background image, and small image, e.g. a character that can move up, down, left, and right). You must detect collisions between two objects on the screen. You must not have any tearing (visual distortion due to drawing too many things in each screen frame on a slow computer). Please see the full list of [requirements](#) below.

## 1.3 Criteria

You will be evaluated on meeting all the [feature requirements](#) and [technical requirements](#) described below.

This assignment offers an opportunity for you to be creative if you want to. However, creativity (and artistic ability) are NOT required. Your grade will be based on meeting all the requirements outlined below.

If you write a very creative program, but do not meet all the requirements, you will lose points. On the other hand, if you write a minimal program that works and meets all the requirements, but is not exciting, you will get full credit. Please do not feel pressure to be creative if that is not your personality, or if you do not have time to do so.

## 2 Before You Start

### 2.1 Resources

To tackle this homework, we've provided:

- A `gba.h` file that contains all of the necessary GBA declarations such as DMA, `videoBuffer`, etc.
- Several other files which contain more “starter” code to get you rolling. See Section 7.2 for details.
- A Makefile which provides commands you can use to compile and run your program—most importantly, `make mgba` to compile and run the script in the Docker terminal.
- The mGBA emulator (`mGBA.app`, `mGBA`, or `mGBA.exe`), `GBAServer.jar` and `client.c`. **DO NOT TOUCH THESE FILES.**

In addition, here are some other helpful resources:

- Lab and Lecture Slides
- [TONC](#) - full documentation of the GBA, including advanced features
- Lecture Code: Canvas > Files > Source Code > `gba_`
- The [Appendix](#), including [GBA Coding Guidelines](#)

Feel free to use code from class resources as you need to, but as always, not from your friends or random sketchy Internet sites.

Your `main.c` should be something different from lecture code, since in this homework you will be creating your own program. You should keep the core setup with `videoBuffer`, `MODE 3`, `waitForVBlank`, etc., though.

Additionally, please do not rehash lecture code in your program; programs that are merely slightly modified lecture code are subject to heavy penalties. You may borrow some idea and structure from lecture code, but your code should be your own, and your idea should be distinct from lecture code in some way. For example, you are allowed to create games or programs that include bouncing squares, like Pong; however, you should attempt to add new features, like drawing an image instead of a square, or making the square change velocity whenever it bounces. If you have concerns over whether or not your idea is different enough from the s in lecture, feel free to ask a TA in office hours or on Piazza.

### 2.2 Words of Warning

- **We are not providing an autograder for this homework.** Gradescope will only confirm that your code compiles, not that it is correct. You are required to check that your program visually looks correct, as it will be manually reviewed for correctness during your demo.
- **Do not use floats or doubles in your code.** Doing so will slow your code down greatly. The ARM7 processor the GBA uses does not have a floating-point unit which means floating point operations are slow as they are done in software, not hardware. Anywhere you use floats, `gcc` has to insert assembly code to convert integers to that format. If you do need such things that you think requires floats or doubles, you should look into fixed point math.
- We strongly recommend that you do not use `malloc()` in your program. **Instead, use arrays large enough to hold all possible elements (images, game characters, etc.) that you could possibly have at one time.** You can use an array of structs, as in the lecture code example.
- Only call `waitForVBlank` once per iteration of your main loop. Each `waitForVBlank` call will stall your program for about one sixtieth of a second, so excessive calls will make your program feel slower.

- Keep your code efficient; particularly, try to do as little drawing per frame as possible. See the guide on [Reducing Tearing](#) for tips on how to make your drawing more efficient.
- If your program does have tearing, keep in mind that it will affect the top of the screen first. So, if text or images drawn at the top of the screen are disappearing for some unknown reason, it is likely that your program is attempting to draw during the VDraw period, which is often leads to tearing.
- If you choose to use more advanced GBA features like sprites or sound, making them work is your responsibility; we (the TAs) do not really know how they work, so we sadly can't help you. ([TONC](#) is useful to reference when implementing these features, if you do choose to add them.)

### 3 Requirements (75 points)

The following are requirements for you to get full credit for this assignment. These requirements will be manually reviewed (as the autograder for this assignment will not check that you have followed these requirements).

Note: the following point values may be changed, but we will not add more requirements or make requirements more strict.

#### 3.1 Feature Requirements

- Your program must compile. **This is the most important requirement, since we can't grade your feature requirements otherwise. (1 point)** *Note:* it is an automatic "0" if your program does not compile.
- You must use **3 distinct images** in your program, all drawn with DMA. **(6 points)**
  - Two full screened images sized 240x160. One of these images should be the first screen displayed when launching your program.
  - A third image which will be used during the course of your program. The width of this image must be less than 240 pixels and the height of this image must be less than 160 pixels.
  - Note: all images should be included in your submission.
  - You should use `nin10kit` (as mentioned in section 7.2.2) to convert images in standard formats like PNG and JPEG into C header files with a constant short array containing 16-bit pixel values. See the Images section in the appendix for instructions on how to create your own custom images.
- You must be able to **reset the program** to the title screen AT ANY TIME using the "select" (backspace) key. This resets the ENTIRE program, including application state. **(8 points)**
- **Button input** should visibly and clearly affect the flow of the program. Examples include pressing the start button or enter key to transition from a game's title screen into gameplay, or using the arrow keys to move an image across the screen. **(8 points)**
- You must have **2-dimensional movement** of at least one entity (an entity that moves both left/right and up/down). One entity moving up/down and another moving left/right alone does not count. **(8 points)**
- You should implement some form of **object collision**. Think of detecting collisions as determining if two on-screen items are overlapping. For example, if your player overlaps with a rectangle on the screen, then that is an example of a *collision*. Please make your collision more intricate than an object colliding with the borders of the screen; try to implement [collision between objects](#). For programs where application of this rule is more of a gray area (like Minesweeper), core functionality can take the place of this criteria, such as the numbers for Minesweeper tiles calculated correctly, accurate control, etc. When in doubt, ask a TA for clarification. **(8 points)**

- Use **text** to show progression in your program. **(8 points)**
  - Examples of text progression include on-screen timers, score counters, or any other text that displays useful information to the user.
  - Several functions for drawing strings are already implemented in `gba.h` and `gba.c`. To use these, you must implement `drawPixel` in `gba.c`.
  - You may find the `snprintf` function to be useful when displaying numerical values. This function works like `printf`, except it fills a character array instead of printing to console.
  - See the lecture code for an example of how to implement text progression.
  - If you choose to implement a timer, think about how you can keep track of time. (Hint: the GBA runs at 60 FPS, so how can you turn the `vBlankCounter` into “time elapsed”?)
- There must be **no tearing** in your program. Make your code as efficient as possible! Check out the appendix for tips on how to reduce tearing. **(14 points)**

## 3.2 Technical Requirements

- Include a **README.txt** or **README.md** file with your submission that briefly explains the program and the controls. **Don’t forget to put this in your Gradescope submission! (2 points)**
- Your program is strongly encouraged to be in **Mode 3!** – Mode 3 should be the very first thing set in the main method. The examples provided as well as the knowledge of the TAs are in mode 3 so choosing to implement any other mode will be at your own risk (no points just a warning).
- You must also implement `drawImageDMA()` with **DMA**. The prototype and explanation are later in the assignment. Depending on when you are reading this, DMA may not have been covered in lecture yet. If this is the case, you should implement this function with `setPixel` first, and reimplement it with DMA once it’s been covered in lecture. **(3 points)**
- You must implement `waitforVBlank()` **(3 points)**
- You must use at least one **struct**. The struct must be defined in a header (`.h`) file, not a source (`.c`) file. If your program has an object that moves around the screen, you may find it useful to create a struct that stores the object’s position. **(3 points)**
- You can create your own **header file** or use the `main.h` header already available. You must move any `#defines`, function prototypes, and typedefs to this file from your code, along with your extern `videoBuffer` statement if you wish to use `videoBuffer` in other files. Remember that function and variable definitions should not go in header files, just prototypes, extern variable declarations, and struct declarations. **(3 points)**
  - As always, do not include `.c` files into other files. Only `.h` files should be included and `.h` files should contain no functional code.
  - It is optional for you to use other `.c/.h` files to organize your logic if you wish. Just make sure you include them in your submission.

## 4 Bonus (10 points)

Additionally, you can also gain up to 10 points of ★ extra credit ★ for this assignment by completing the following tasks:

1. **Animation of a sprite or text in the title screen. The animations should keep looping as long as I’m on the title/intro screen. (5 points)**

- If you choose to animate text, then, you need to make the text move around in some time interval. The text needs to contain at least five characters.
- If you choose to animate sprite, then you need to make the sprite move around in some time interval. The animated sprite needs to be a custom sprite/image (so no basic shapes (i.e. square, rectangle, circle etc)).

**2. Additional state/screen that contains some dynamic text or records user input or allows for user interaction. If you choose to select this extra credit, you need to make this state/screen follow the context of your application. (5 points)**

If you are unsure about this, make an Piazza post and ask your TAs. For example...

- If you are making a game, then maybe this state can be additional level. Or a leaderboard screen with personal best score.
- If you are working on an application, then maybe this state can be an options menu or some additional settings etc.

**Specific requirements (Choose one of the following)**

- Standard user interaction could be clicking a button that causes some persistent change in the game.
- user input can be implementing some text box that records typed text.
- Screen containing dynamic text can be data that is carried over from another state. This data should be recorded at run-time (or gathered from some screen while running the application). Ex: Leaderboard data, player name (typed before game) etc.

**NOTE:** Each bonus is an ALL or Nothing. Standard compilation and tearing requirements apply (See previous section for more details)

## 5 Assignment Details

### 5.1 What to Make?

You may either create your own interactive graphical application the way you wish it to be as long as it fulfills the requirements, or you can make applications that have been made before using your own code. However, your assignment must be yours entirely and not based on anyone else's code. This also means that you are not allowed to base your program off the code posted from lecture. Programs that are merely slightly modified lecture code are subject to heavy penalties. You may borrow some ideas and structure from lecture code, but you should write your own code, and your application should be distinct in some major way. If you have concerns about whether or not your idea is different enough from lecture code or if your idea would satisfy requirements, feel free to ask a TA. Below are some previous programs that you can create or use as inspiration:

#### 5.1.1 Example Program Ideas

##### Minimum Viable Product:

- As stated in the Overview, you do not need to make a complex or creative program; it must only fulfill the minimum requirements
- Create a start screen and a win screen that use the two required full-screen DMA images
- Use the arrow keys to move a small DMA image around the screen; store this image's position using a struct
- Transition to the win screen when the player-controlled image touches a goal zone (represented via a colored rectangle or image)
- Use text to show an on-screen timer, and display the total time taken on the win screen

##### Interactive Storybook:

- Recreate a story from a movie or a book using the GBA
- Use text to narrate what is currently happening in the scene
- Use the controls to advance to the next scene or control a character within the scene
- Smooth movement (for any moving characters or objects)
- Start off with a full screen title image and end with a full screen credits image
- Characters represented by structs

##### Galaga:

- Use text to show lives
- Game ends when all lives are lost. Level ends when all aliens are gone.
- Different types of aliens: there should be one type of alien that rushes towards the ship and attacks it
- Smooth movement (aliens and player)
- Aliens and the ship represented by structs



### **The World's Hardest Game:**

- Smooth motion for enemies and player (no jumping around)
- Confined to the boundaries of the level
- Enemies moving at different speeds and in different directions
- Sensible, repeating patterns of enemy motion
- Enemies and the player represented by structs

### **Flyswatter:**

- Images of flies moving smoothly across the screen
- Player controlled flyswatter to swat the flies
- Score counter to keep track of how many flies have been swatted
- Fullscreen image for title screen and game background
- Enemies and the player represented by structs

### **Text Editor:**

- Pick some sample pre-rendered text, and display it in a window on the screen.
- Use the up/down/left/right buttons to move a cursor through the text. (Display the cursor somehow. Advanced: use time to make it blink over the current position.)
- Pick another button to be the mouse down button. When the mouse is down, the arrow keys will select the text you mouse over. (Highlight the selected text. Perhaps reverse foreground and background colors.)
- Choose three more buttons to be cut (ctrl-X), copy (ctrl-C), and paste (ctrl-V). Paste will insert text (from your clipboard) at the current cursor position.
- Collision detection (feature requirement) involves determining which character the cursor is pointed at.
- Find a way to include the three required images.

### **Color Picker:**

- There are 32,768 unique colors on the GBA. Draw a two-dimensional color palette rectangle, including all the possible colors.
- Use the arrow keys as a mouse to move a crosshairs cursor around the color palette.
- Choose a key to select a color. Display that color in a solid box somewhere else on the screen.
- Optionally choose a separate background color, and display that. (Find a way to choose if you are selecting foreground or background color.)
- Collision detection - which color am I currently pointing the mouse at?
- Find a way to implement the three required images.
- Variation (or extension of this): Implement part of Microsoft Paint - a simple drawing program. Use the arrow keys as a cursor. Use another key to select draw or erase (or other tools).

### 5.1.2 Example Programs To Run

Included in the homework are some programs made by TAs from when they were in the class. These programs are provided to give you an idea of what type of program will get full credit for this assignment and to give some inspiration for your own program.

You will be able to find these in the **examples** directory, which include the `.gba` file as well as the `README.txt` for each program, so you can understand how they work while running them.

To run these programs in the emulator, run:

```
# Run "Rescue Princess Peach"
$ make mario

# Run "Maze"
$ make maze

# Run "Pong"
$ make pong

# Run "Sandtris"
# You are not expected to make something this high-quality,
# but if you want to, we would not be opposed!
$ make sandtris
```

## 5.2 GBA Coding Guidelines

### 5.2.1 Building and Running your Code

For this homework, we have provided an augmented version of our usual Docker scripts, which does some magic to open up mGBA natively on your computer. You should be able to see them in the same directory as the rest of the HW06 files, named `cs2110docker-gba.sh` or `cs2110docker-gba.bat` based on your OS. Please run this script instead when developing for this homework. **NOTE: These scripts require Java 11+ to run properly.** You can run these scripts just like you do with the normal scripts we had provided in the past:

```
# macOS and Linux
$ ./cs2110docker-gba.sh

# Windows
$ cs2110docker-gba
```

**Make sure you've cd'd into your HW06 directory before running the above command!**

Once you are in the Docker container using the above scripts, to build your code and run the emulator, run:

```
$ make mgba
```

A mGBA window that is running your game should now appear. If this does not happen, please come to office hours or reach out on Ed Discussion and provide info about your OS, computer, and any modified homework files!

### 5.2.2 Images

As a requirement, you must use at least 3 images in your program. To use images in GBA, you will first have to convert them into the suitable format. We recommend using a tool called `nin10kit`, which is pre-installed on the Docker image, or you just installed using the command above.

You can read about `nin10kit` in the `nin10kit` documentation (there are pictures!):

<https://github.com/TricksterGuy/nin10kit/raw/master/readme.pdf>

`nin10kit` reads in, converts, and exports image files into C arrays in `.c/.h` files ready to be copied to the GBA video buffer by your implementation of `drawImageDMA()`! It also supports resizing images before they are exported.

You want to use Mode 3 since this assignment requires it, so to convert a picture of smelly festering garbage into GBA pixel format in `garbage.c` and `garbage.h`, resizing it to 50 horizontal by 37 vertical pixels, you would run `nin10kit` from the same directory as your images using:

```
$ nin10kit --mode=3 --resize=50x37 garbage garbage.png
```

This creates a `garbage.h` file containing

```
extern const unsigned short garbage[1850];
#define GARBAGE_SIZE 3700
#define GARBAGE_LENGTH 1850
#define GARBAGE_WIDTH 50
#define GARBAGE_HEIGHT 37
```

which you can use in your program by saying `#include "garbage.h"`.

The `garbage.c` generated, which you should add to the Makefile under `OFILES` as `garbage.o` if you plan to use it, contains all of the pixel data in a huge array:

```
const unsigned short garbage[1850] =
{
    0x7fff,0x7fff,0x7fff,0x7fff,0x7fff, // ...
    0x7fff,0x7fff,0x7fff,0x7fff,0x7fff, // ...
    // ...
    0x7fff,0x7fff,0x7fff,0x7fff,0x7fff, // ...
    0x7fff,0x7fff,0x7fff,0x7fff,0x7fff, // ...
};
```

We've included `garbage.png`, `garbage.c`, and `garbage.h` in the homework zip so you can check them out yourself. To draw the garbage in your own program, you can pass the array, width, height to your `drawImageDMA()` like `drawImageDMA(10, 20, GARBAGE_WIDTH, GARBAGE_HEIGHT, garbage)` (to draw at row 10 and col 20). (Keep in mind that this image will only work with `drawImageDMA`; it is not a fullscreen image.) The next section will cover `drawImageDMA()` in more detail.

### 5.2.3 DMA / drawImageDMA

In your program, you must use DMA to code `drawImageDMA`.

The GBA screen is represented with a `short` pointer declared as `videoBuffer` in the `gba.h` file. The pointer represents the first pixel in a 240 by 160 screen that has been flattened into a one dimensional array. Each pixel is a `short` and has red, green, and blue channels.

DMA stands for Direct Memory Access and should be used to make your rendering code run much faster. If you want to read up on DMA before it is covered in lecture, you may read these pages from Tonc. <http://www.coranac.com/tonc/text/dma.htm> (Up until 14.3.2).

If you want to wait, then you can choose to implement `drawImageDMA` without DMA and then when you learn DMA rewrite it using DMA. Your final answer for `drawImageDMA` must use DMA.

You must not use DMA to do single-pixel copies (doing so defeats the purpose of DMA and is actually slower than just using `setPixel`!). Solutions that do this will receive no credit for that function. The prototype and parameters for `drawImageDMA` are as follows.

```
/* drawImageDMA

* A function that will draw an arbitrary sized image
* onto the screen (with DMA).
* @param row the row coordinate to start drawing the image at
* @param col the col coordinate to start drawing the image at
* @param width width of the image
* @param height height of the image
* @param image pointer to the first element of the image
*/
void drawImageDMA (int row, int col, int width, int height, const u16 *image) {
    // TODO: implement :)
}
```

#### 5.2.4 Other DMA functions

Stubs and comments for other DMA functions are provided in `gba.c`. You are not required to implement them, as they are not graded. However, it is likely that you will need to use at least some of them while developing your application.

Tip #1: if your implementation of a DMA function does not use all the parameters that are passed in then you are not implementing the function correctly.

Tip #2: For implementing DMA functions, you should know that DMA acts as a for loop, but it is done in hardware.

Tip #3: The number of DMA calls needed to implement

#### 5.2.5 GBA Controls

Here is the mapping between GameBoy buttons and keyboard keys in our configuration of the `mgba` emulator:

| GameBoy | Keyboard  |
|---------|-----------|
| Start   | Enter     |
| Select  | Backspace |
| A       | Z         |
| B       | X         |
| L       | A         |
| R       | S         |

The directional arrows are mapped to the same directional arrows on the keyboard.

#### 5.2.6 C Coding Conventions

- Do not jam all your code into one function (i.e. the main function)
- Split your code into multiple files (for example, you can have your main logic in your main files, but other helper functions for drawing or assessing the application state in external files)

- Do not include .c files into other files. Only .h files should be included.
- .h files should contain no functional code.
- Comment your code, and comment what each function does.

### 5.2.7 Reducing Tearing

- If you see images at the top of the screen start to flicker, you are likely experiencing tearing. This typically happens because you are drawing during the VDraw phase of the GBA's drawing cycle, which means there is a possibility that any pixels that you write to the video buffer will not be drawn until the next VDraw cycle.
- To reduce tearing, it is first necessary to understand how much you can draw in a single VBlank cycle (the following stats were measured by Brandon Whitehead, a former 2110 TA):
  - Drawing a fullscreen image without DMA will take over three full VBlank cycles. You should never, ever draw this many pixels without using DMA.
  - Drawing a fullscreen image with DMA will take 124 scanlines, which is more than a single VBlank phase! So, even if you start at the very beginning of a VBlank phase, you can never draw an entire fullscreen image without entering VDraw. This is not necessarily bad, since DMA typically starts at the top of the screen, so the top portion of the full screen image is drawn before there is any risk of tearing; however, this also means that any text or images drawn at the top of the screen after the full-screen image will not be drawn until the VBlank period is over.
  - The maximum amount of pixels drawable during a VBlank phase **WITHOUT** DMA is approximately 1610. Remember this when drawing text, since text does not use DMA.
  - The maximum amount of image pixels drawable during a VBlank phase **WITH** DMA is approximately 20690. Remember this if you plan to draw many images on-screen.
  - Clearing the screen with a constant color using DMA is barely possible inside a single VBlank phase (63 scanlines). 32-bit DMA can be used to fill the screen in 47 scanlines (approximately 70 percent of the VBlank phase).
- The best way to reduce tearing is to simply draw less. As explained above, using a solid color background is more efficient than an image background. You should also minimize the number of images on-screen, and use text sparingly.
- However, it is possible to use an image as a background by using an **undraw function**. This is a function that takes a full-screen image and draws only a portion of the image to the screen. By using this function, you can skip having to redraw the entire background whenever the player moves; instead, you only need to redraw the portion near the player.
- It may also help to be efficient when "undrawing" images. For example, if the player is a 16x16 image and the player moves one pixel to the right, it is tempting to either redraw the entire background, or at the very least redraw a 16x16 portion of the background where the player used to be. However, you only really need to redraw the 16x1 rectangle sliver that player evacuated when it moved one pixel to the right.
- If you simply must draw a fullscreen image and other small images and text in a single frame, there are a few workarounds. One easy option is to create a second buffer (a 38400-element **short** array) that you will "draw" to during VDraw; then, as soon as VBlank begins, you can DMA the second buffer's data to the main video buffer. A more difficult option is to draw everything at the top of the screen first, then everything at the bottom of the screen; this avoids tearing by taking advantage of the fact that scanlines go from the top of the screen downwards.

### 5.2.8 Debugging

The GBA does not have a console to print to, so you cannot rely on traditional `printf` debugging. In fact, the GBA doesn't even have an operating system that can handle any calls to `printf`. You should instead use the GNU debugger (`gdb`) to debug your program.

To launch your application in mGBA and start an attached GDB session in your terminal, run the command `make gdb` from the terminal within the Docker container. To exit GDB, use the `quit` command. If you run this command or manually enable GDB from inside mGBA, **you will need to stop the GDB server from mGBA or close the mGBA instance you opened before you can run it again.**

Learning how to use GDB will be covered in lab. There is also a supplemental video on the topic [here](#). Additionally, there is a GDB cheat sheet [here](#) which describes more than enough commands to be able to effectively debug this homework.

### 5.2.9 Making Sense of the Files

As mentioned in the C Coding Conventions section, it's often a good idea to split up functionality into multiple files. In fact, this is exactly what we've done with the "starter" code we've given you. The pure volume of files may be a bit daunting, so here's a brief breakdown of what each file is used for.

- `cs2110docker-gba.sh` (or `cs2110docker-gba.bat` for Windows folks)

For HW06, use this script/batch file to spin up our Docker container instead of the usual one we provided in the past. This enables us to open mGBA natively in your machine!

- `Makefile`

This Makefile contains all of the tasks you can run to build and test your program. You do not need to modify this file, as bad things may happen. Feel free to look through it in order to see all of the tasks at your disposal.

- `main.c`

This file contains a **state machine** which ultimately calls all other functionality in the program. It is also the main entry point to the entire application.

- `main.h`

This file should contain any function prototypes and structs that you create.

- `gba.h`

This file contains a large collection of useful macros and constants which will help primarily with GBA-specific tasks. These include macros for handling GBA input, DMA graphics, and general GBA graphics.

The file also contains an extern declaration of the font data found in `font.c`, which is necessary for drawing text.

This file also contains some prototypes for functions in `gba.c`.

There is one macro to be completed in this file.

- `gba.c`

The functions you will write in this file do the "dirty" work, executing graphics updates with both DMA and non-DMA strategies. All of this code will be very specific to the GBA platform and the way it handles graphics.

The file also comes with some prepackaged functions for drawing text.

- `font.c`

Simply exists to store a large amount of font data. No real need to mess around with this file.

- The mGBA application & `client.c` & `GBAServer.jar`

Files behind the magic of opening mGBA natively from within the Docker container.

If you are curious, here are the technical details of what these items do. The mGBA application, is of course, a GBA emulator used to run your program. The `GBAServer.jar` is a program on the host which listens to whenever `make mgba` is called. This `make` target runs the code within `client.c` which alerts the server to run a command locally and open up mGBA for you! No need to touch these files either. If you are curious about the source for these files, refer to:

- The mGBA emulator webpage: <https://mgba.io>
- The `GBAServer.jar` repository: <https://github.com/gt-cs2110/GBAServer>

- Various Image Files

When you create your own image files, you will need to include the relevant header files in any file you'd like to reference these images from. The data stored in each of these files (and how to create them) is pretty well explained in section 5.3.

- Personal `.c` files and `.h` files

You are heavily encouraged to split your code up into separate `.c` and `.h` files! Do not put everything in your main method. Keep your code organized and readable.

## 6 Deliverables

Please run `make clean` followed by `make submit` to create a tar archive `submission.tar.gz` and upload this to Gradescope under the “Homework 6: GBA” assignment. Do not submit any compiled (`.o`) files. This tar archive should also contain your README.

## 7 Demos (25 points)

**This homework will be demoed.** The demos will be ten minutes long. Stay tuned for details as the due date approaches.

- Sign up for a demo time slot via Canvas **before** the beginning of the first demo slot. This is the only way you can ensure you will have a slot.
- If you cannot attend any of the predetermined demo time slots, e-mail the head TAs Sara Enright ([senright6@gatech.edu](mailto:senright6@gatech.edu)) and Annelise Lloyd ([alloyd42@gatech.edu](mailto:alloyd42@gatech.edu)) **before** the week of demos.
- If you know you are going to miss your demo, you may cancel your slot on Canvas with no penalty, as long as you cancel before demo sign-ups close. However, you are **not** guaranteed another time slot. If you cancel after demo sign-ups close, it will be counted as a missed demo.
- Your overall homework score will be  $((\text{homework\_score} * 0.75) + (\text{demo\_score} * 0.25))$ , meaning if you received a 90% on your homework, but a 50% on the demo, you would receive an overall score of 80%. **If you miss your demo you will not receive any of these points, and the maximum you can receive on the homework is 75%.**

## 8 Rules and Regulations

1. Please read the assignment in its entirety before asking questions.

2. Please start assignments early, and ask for help early. Do not email us the night the assignment is due with questions.
3. If you find any problems with the assignment, please report them to the TA team. Announcements will be posted if the assignment changes.
4. You are responsible for turning in assignments on time. This includes allowing for unforeseen circumstances. If you have an emergency please reach out to your instructor and the head TAs **IN ADVANCE** of the due date with documentation (i.e. note from the dean, doctor's note, etc).
5. You are responsible for ensuring that what you turned in is what you meant to turn in. No excuses if you submit the wrong files, what you turn in is what we grade. In addition, your assignment must be turned in via Gradescope. Email submissions will not be accepted.
6. See the syllabus for information regarding late submissions; any penalties associated with unexcused late submissions are non-negotiable.

## 8.1 Academic Misconduct

Academic misconduct is taken very seriously in this class. Quizzes, timed labs and the final examination are individual work. Homework assignments will be examined using cheat detection programs to find evidence of unauthorized collaboration.

**You are expressly forbidden to supply a copy of your homework to another student. If you supply a copy of your homework to another student and they are charged with copying, you will also be charged. This includes storing your code on any platform which would allow other parties to it (public repositories, pastebin, etc). If you would like to use version control, use a private repository on github.gatech.edu**

Homework collaboration is limited to high-level collaboration. Each individual programming assignment should be coded by you. You may work with others, but each student should be turning in their own version of the assignment.

High-level collaboration means that you may discuss design points and concepts relevant to the homework with your peers, share algorithms and pseudo-code, as well as help each other debug code. What you shouldn't be doing, however, is pair programming where you collaborate with each other on a single instance of the code, or providing other students any part of your code.

Submissions that are essentially identical will receive a zero and will be sent to the Dean of Students' Office of Academic Integrity. Submissions that are copies that have been superficially modified to conceal that they are copies are also considered unauthorized collaboration.



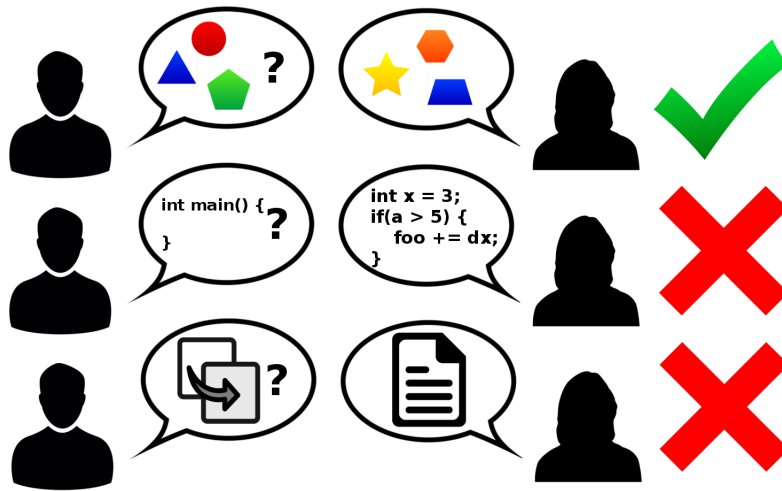


Figure 1: Collaboration rules, explained colorfully