Assembly Project – CSCB58 Winter 2023

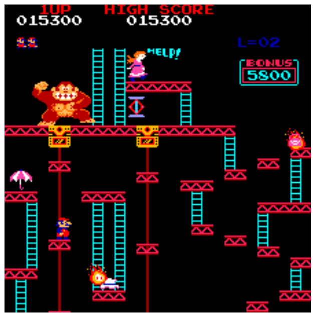
A Platform Game

Overview

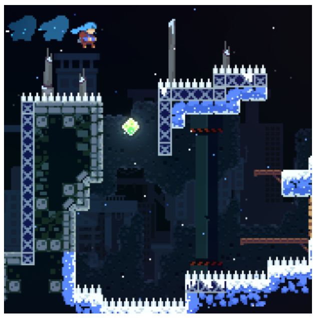
In this project, you will build a platform game using MIPS assembly. Platformers are a classic genre of games: you control a character that moves around a map ("level") by running left or right, jumping on "platforms" or falling, or climbing up and down ladders, and so on. The goal of the player might be avoiding obstacles, getting to a specific point on the screen using precise jumps, picking things up, shooting enemies, not falling off the bottom of the screen, and more. Some have other gimmicks too.

You have some level of freedom in building the game, and we encourage you to be creative in how it looks and feels. We set up the basic requirements, but it is your game! You can see several classic examples of such games for inspiration below (click links for videos). **You do not need to achieve this level of polish and sophistication!** In particular, we recommend making a "single-screen" platformer, where the screen does not scroll, but perhaps moves to the next screen once the player has finished the current level.

Pitfall!


Donkey Kong

Mega Man 2
(a.k.a Rockman 2)https://www.youtube.com/watch?v=nFYTGj1rSB0


Celeste
(PICO-8 version)

Bubble Bobble

Ori and the Blind Forest

Since we don't have access to physical computers with MIPS processors, you will develop and test your implementation in a simulated environment within MARS. We will use a simulated bitmap display and a simulated keyboard input.

Unlike in previous years where the project has two marking stages, this year we will only have a final submission. For the **final version**, you will implement the base features (milestones 1&2) and choose additional features to implement from a list of potential additions that change how the game looks and behaves (milestone 3). You will then submit the completed **assembly program** with a **video link** and TAs will later grade it. Note that projects are **individual**.

Important Info and Due Dates

- **Check the Piazza FAQ post frequently for FAQs and updates.**
- Final submission: Due Friday, April 7, 2023, 11:59pm (on Quercus).
  (life happens; we will accept late submissions without penalty if they arrive by end of Apr 10)

Version

- Mar 13, 2023: initial public version.

The Game

Basic Gameplay

The basic format of the game is simple: the player controls a character moves around horizontally (perhaps it is running left and right) and has a way to move up and down (such as jumping, dropping down, climbing on ladders, etc.). There are platforms on the screen that the player can reach. There are also other objects: perhaps enemies or spikes that the player must be careful to avoid and may end the game if touched by the player. Or perhaps pick-ups rather than enemies that the player must to collect to finish the game.

Game Controls

The player uses the keyboard to control the character. While the **a** key is pressed, the character will move left if it is not at the left edge of the screen. Similarly, the **d** key makes the character move right. For vertical movement, it can depend on your choice. A simple choice is to have the **w** key to have the character jump, after which gravity pulls it down. Alternatively, perhaps you want to have ladders or stairs, in which case it is appropriate to use **w** and **s** to move up and down. See "Technical Background" below to see how to read the status of keys.

Note: MARS does not support multiple keys well. If you prefer to allow 8 directions in your game, you can use the keyboard setup shown on the right →
Additionally, holding a key can work but is not great, and depends on the keyboard repeat delay and repeat rate set in the user's operating system.

q	w	e
a		d
z	x	c

Basic Demo

Check Quercus (or click here) for a video demonstration of a basic version of what you are supposed to implement (it also shows how to set up the MARS simulator for the project). This demo shows the features we expect for milestones 1&2 (explained below); for the final submission, you will implement additional features.

Note it is OK if your game looks and behaves somewhat differently from our demo, as long as the features are there! For example, Ryan has chosen to develop a game in the style of infinite platformer where platforms keep scrolling from right to left. You don't have to do that. You may also decide to develop a game where players are not able to "fall out of the screen" (the water in the video) – this is not mandatory, but a choice. See Milestones 1, 2 and 3 for what you'd need to do.

Additional Features

The above only describes the basic gameplay. To get full marks, you will need to implement additional features from a list. There are many possible additions to the gameplay, and it depends on what kind of game you have (puzzle platformers, for example, often have no enemies). Here are a few examples:

- Additional screens once the player finishes a level.
- Moving enemies.
- Adding the ability to shoot enemies or jump on their heads to get rid of them.
- Platforms that move around, making it the timing to jump on them difficult.
- Picking up powerups that "repair" your health, freeze enemies, change enemy size and speed, and so on.
- Gimmicks such as time manipulation, turning the character into a bird that can fly for a short time, double jumping (jump in midair), etc.

See the list of additional features at the end.

Creativity and Limits

While you are not required to do so, we encourage you to be creative within the framework of the game and features we have required. Many of the features are defined generally on purpose, to allow you some freedom. Moreover, you have a lot of control in how the game looks and feels. You don't have to emulate our demo! Please see some of the project videos from previous years for inspiration.

As you consider your creativity, be aware of the limits of what we are working with. The MARS simulator is not very fast. This implies there are only so many MIPS instructions you can execute in one second, which limits the complexity of your game and graphics. You may be able to come up with interesting tricks to make things run faster, but we are not marking you based on this!

Technical Background

You will create this game using the MIPS assembly language taught in class and the MARS. However, there are a few concepts that we will need to cover in more depth here to prepare you for the project: displaying pixels, taking keyboard input and system calls (`syscall`).

Displaying Pixels Using a Framebuffer

To display things on the screen, we will use a *framebuffer*: an area in memory shown as a 2D array of "units", where each "unit" is a small box of pixels of a single colour. Figure 1 on the right shows a framebuffer of width 10 and height 8 units.

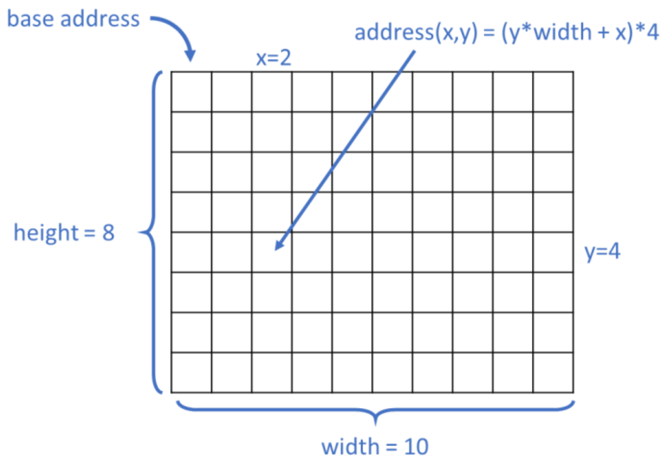


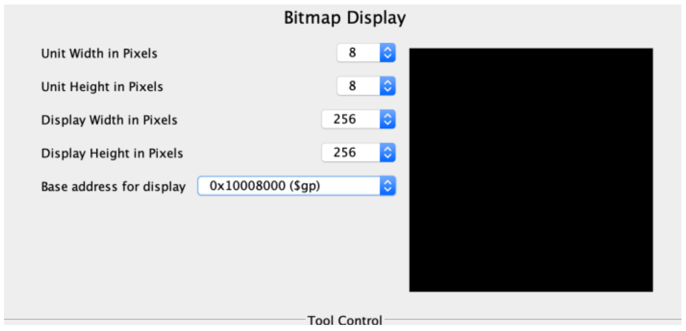
Figure 1: Framebuffer

Units are stored as an array in memory: every 4-byte word in that array is mapped to a single on-screen "unit". This is known as a *framebuffer*, because the buffer (the region of memory) controls what is shown on the display. The address of this frame buffer array is the *base address* of the display. The unit at the top-left corner of the bitmap is located at the base address, followed by the rest of the top row in the subsequent locations in memory. This is followed by the units of the second row, the third row and so on (referred to as row major order).

To set the colour of a single unit, you will write a 4-byte colour value to the corresponding location in memory. Each 4-byte value has the following structure: **`0x00RRGGBB`** , where 00 are just zeros, RR is an 8-bit colour value for the red component, GG are the 8-bits for the green components, and BB are the 8-bits for the blue component. For example, `0x00000000` is black, `0x00ff0000` is bright red, `0x0000ff00` is green, and `0x00ffff00` is yellow. To paint a specific spot on the display with a specific colour, you need to calculate the correct colour code and store it at the right memory address (perhaps using the `sw` instruction).

The MARS Bitmap Display

MARS allows us to map a framebuffer in memory to pixels on the screen using the **Bitmap Display** tool, which you launch by selecting it in the MARS menu: **Tools → Bitmap Display**. The Bitmap Display window is shown in Figure 2.



Unit Width in Pixels: 8
Unit Height in Pixels: 8
Display Width in Pixels: 256
Display Height in Pixels: 256
Base address for display: 0x10008000 ($gp)

Figure 2: The MARS Bitmap Display

To use the Bitmap Display, you need to:

- Specify the actual on-screen width and height of each unit. The screenshot is configured to show each framebuffer unit as 8x8 block on your screen.
- Set the dimensions of the overall display: in the example above the framebuffer is of size 32x32 units, since we configured the bitmap display to have width and height of 256 pixels, and units of 8x8 pixels. Make sure the sizes match your assembly code.
- Tell MARS the base address for the framebuffer in hexadecimal. In screenshot above, this is memory location `0x10008000` in the screenshot. This means that the unit in the top-left corner is at address `0x10008000`, the first unit in the second row is at address `0x10008080` and the unit in the bottom-right corner is at address `0x10008ffc`.
- Remember to click “Connect to MIPS” so that the tool connects to the simulated CPU.

Tip: We recommend using `0x10008000` as the base address for your framebuffer, but only if your framebuffer has 8192 cells or fewer, which is enough for 128x64 or 64x128 (if you want a larger framebuffer, ask us on Piazza; you’ll have to add a variable at the beginning of the .data section). When using the Bitmap Display, make sure to change the “base location of display” field. If you set it to the default value *(`static data`)* provided by the Bitmap Display dialog, this will refer to the "*`.data`*" section of memory and may cause the display data you write to overlap with instructions that define your program, leading to unexpected bugs.

Bitmap Display Starter Code

To get you started, the code below provides a short demo, painting three units at different locations with different colours. Understand this demo and make it work in MARS.

The assembly directive `.eqv` defines a numeric constant which you can use instead of writing the number manually (similar to `#define` in C, but much more primitive) You can use it to define common useful constants such as fixed addresses, colours, number of enemies, etc.

```
# Bitmap display starter code
#
# Bitmap Display Configuration:
# - Unit width in pixels: 4
# - Unit height in pixels: 4
# - Display width in pixels: 256
# - Display height in pixels: 256
# - Base Address for Display: 0x10008000 ($gp)
#
.eqv  BASE_ADDRESS            0x10008000

.text
      li $t0, BASE_ADDRESS    # $t0 stores the base address for display
      li $t1, 0xff0000        # $t1 stores the red colour code
      li $t2, 0x00ff00        # $t2 stores the green colour code
      li $t3, 0x0000ff        # $t3 stores the blue colour code

      sw $t1, 0($t0)     # paint the first (top-left) unit red.
      sw $t2, 4($t0)     # paint the second unit on the first row green. Why $t0+4?
```

```
    sw $t3, 256($t0)    # paint the first unit on the second row blue. Why +256?

    li $v0, 10 # terminate the program gracefully
    syscall
```

Keyboard

This project will use the MARS **Keyboard and MMIO Simulator** to take in these keyboard inputs (**Tools → Keyboard and MMIO Simulator**). To use it when playing, make sure to click inside the lower window titled "KEYBOARD". As with the bitmap display, remember to "Connect to MIPS".

Note we cannot use system calls to read the keyboard input, because syscalls will block your program from executing (they are also slower).

Note the MARS simulator does not support pressing multiple keys at the same time, which you may need to think about when implementing jumps to left and right.

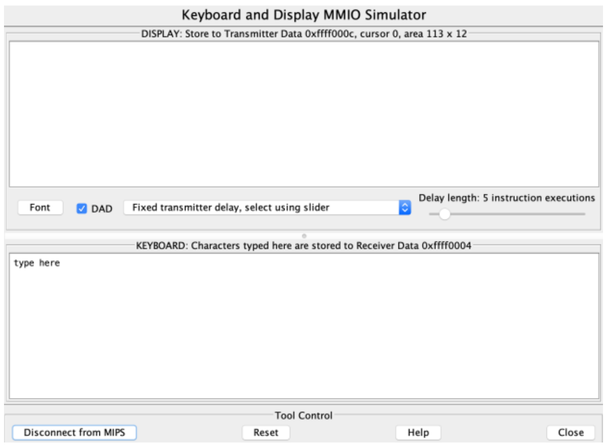

Keyboard and Display MMIO Simulator
DISPLAY: Store to Transmitter Data 0xffff000c, cursor 0, area 113 x 12
[✓ DAD] Fixed transmitter delay, select using slider
Delay length: 5 instruction executions
KEYBOARD: Characters typed here are stored to Receiver Data 0xffff0004
type here

Figure 3: MARS Keyboard and MMIO Simulator

Fetching Keyboard Input

MARS uses *memory-mapped I/O* (MMIO) for keyboard. If a key has been pressed (called a *keystroke event*), the processor will tell you by setting a word in memory (at address `0xffff0000`) to a value of `1`. To check for a new key press, you first need to check the contents of that memory location:

```
li $t9, 0xffff0000
lw $t8, 0($t9)
beq $t8, 1, keypress_happened
```

If that memory location has a value of 1, the ASCII value of the key that was pressed will be found in the next word in memory. The code below is checking to see if the lowercase '`a`' was just pressed:

```
lw $t2, 4($t9) # this assumes $t9 is set to 0xfff0000 from before
beq $t2, 0x61, respond_to_a    # ASCII code of 'a' is 0x61 or 97 in decimal
```

Useful Syscalls

In addition to writing the bitmap display through memory, the `syscall` instruction will be needed to perform special built-in operations, namely invoking the random number generator and the sleep function.

To invoke the **random number generator**, you can use service 41 to produce a random integer with no range limit, or service 42 to produce a random integer within a given range.

To do this, put the value 41 or 42 into register `$v0`, then put the ID of the random number generator you want to use into `$a0` (since we're only using one random number generator, just use the value `0` here). If you selected service 42, you also have to enter the maximum value for this random integer into `$a1`. Once the syscall instruction is complete, the pseudo-random number will be in `$a0`.

```
li $v0, 42
li $a0, 0
li $a1, 28
syscall
```

The other syscall service you will want to use is the **sleep operation**, which suspends the program for a given number of milliseconds. To invoke this service, the value `32` is placed in `$v0` and the number of milliseconds to wait is placed in `$a0`:

```
li $v0, 32
li $a0, 1000   # Wait one second (1000 milliseconds)
syscall
```

More details about these and other syscall functions can be found here.

Your Code

Getting Started

This project must be completed individually, but you are encouraged to work with others when exploring approaches to your game. Keep in mind that you will be called upon to explain your implementation to your TAs when you demo your final game.

You will create an assembly program named `game.asm`. You'll design your program from scratch, but you must begin your file with the preamble starter code we include below.

1. Open a new file in MARS, call it `game.asm` and copy the preamble (listed below) into it.
2. Set up display: Tools > Bitmap display (the demo shows how to do this)
   - Set parameters like unit width and height (we recommend 8) and base address for display (we recommend `0x10008000`).
   - Click “Connect to MIPS” once these are set.
3. Set up keyboard: Tools > Keyboard and Display MMIO Simulator (see demo)
   - Click “Connect to MIPS”

...and then, to run and test your program:

4. Run > Assemble (see the memory addresses and values, check for bugs)
5. Run > Go (to start the run)
6. Input the character `a` or `d` or `w` or `s` in Keyboard area (bottom white box) in Keyboard and Display MMIO Simulator window.

Code Structure

Your code should store the location of the player character and other entities (and any other information you need) in memory or registers. We particularly recommend arrays for storing things like enemies. Make sure to determine what values you need to store and label the locations in memory where you'll be storing them (in the `.data` section)

At the beginning of your program, **clear the screen** and **initialize the state of the game**. You will then switch to a central processing loop of the game (the "**main loop**"). Everyone's main loop looks a little different, but in general your loop will eventually need to do most if not all of the following operations (**not necessarily in this order!**):

- Check for keyboard input.
- Figure out if the player character is standing on a platform.
- Update player location, enemies, platforms, power ups, etc.
- Check for various collisions (e.g., between player and enemies).
- Update other game state and end of game.
- Erase objects from the old position on the screen.
- Redraw objects in the new position on the screen.

At the end of each iteration, your main loop should sleep for a short time and go back to step 1.

Sleep and Display Refresh Rate

For animations, we generally need to update the display between 20 to 60 times per second (we recommend sleeping for 40ms, at least initially, which is a 25Hz update rate). When developing your game, you may find it occasionally useful to set it to a very high number to help debugging. We recommend using a constant (`.eqv`) to make it easy to change the wait time.

Make sure to choose your display size and frame rate pragmatically. The simulated MIPS processor isn't very fast. If you have too many pixels on the display and too high a frame rate, the processor will have trouble keeping up with the computation. If you want to have a large display and fancy graphics in your game, you might consider optimizing your way of repainting the screen so that it does incremental updates instead of redrawing the whole screen; however, that may be quite a challenge! Moreover, sleep time can affect the speed and difficulty of your game.

Tip: Your display may flicker (blink on and off) because it takes some time between erasing an object and redrawing it at the new position. There are all kinds of ways to prevent this, but some of them require special hardware. You can prevent flicker by carefully erasing and/or redrawing only the parts to the frame buffer that have changed but this requires some effort. **We are not marking you based on the smoothness of the display, as long as the game is reasonably playable, so don't worry about it.** See Marking below.

General Tips for Success

1. **Prototype and build in stages**. Start with drawing a square on the screen. Then animate it moving move across the screen by adjusting its position every frame and redrawing in a loop. Then add keyboard controls for the position, and perhaps simple rules about not moving across the edges or through platforms. Then add gravity, and so on.
2. **Choose storage wisely**. Most of your variable will be stored in memory (`.data`), because you only have a few registers, and they are not going to be enough for allocating all the different variables that you'll need for keeping track of the state of the game. Use the ".data" section (static data) of your code to declare as many variables as you need. In particular, arrays are very useful. Nevertheless, it might make sense to devote a few registers to very common variables or values that you need! Calling conventions can help you there.
3. **Create reusable functions for code that you reuse frequently.** Instead of copy-pasting, write a function. Design the interface of your function (input arguments and return values) so that the function can be reused in a simple way.
4. **…but pay attention to performance.** Calling functions comes at a cost. Use functions when you need to (using the same code many times), but not when you don't. Think about calling conventions that make sense for you and are efficient. For example, you may be able to avoid using the stack entirely!
5. **Flicker and clearing the screen**. It is usually best to avoid erasing and redrawing the entire screen every frame. It is a slow process and will cause lots of flickering. It is better to just erase the part you need to erase. The more time that passes between erase and redraw, the more flickering you will have.
6. **Create meaningful labels.** Meaningful labels for variables, functions and branch targets will make your code much easier to debug.
7. **Write comments.** Without proper comments, assembly programs tend to become incomprehensible spaghetti alarmingly quickly, even for the author of the program. It would be in your best interest to keep track of registers, variables, and stack pointers (if you use it) relevant to different components of your game.
8. **Start small and build upwards.** Don't try to implement your whole game at once. Assembly programs are notoriously hard to debug, so add each feature one at a time and test them. Always save the previous working version before adding the next feature. Use source control (Git, SVN, etc.).
9. **Debug.** Debug your code cleverly. For example, you may find it useful to change the sleep time between frames to 1000ms so you can see things advance slowly, or even to wait for a key. It makes sense to sometimes add code just for debugging, and then remove it later.
10. **State of player and enemies.** The player can behave differently in different situations such as when jumping, falling, standing on platform, etc. Enemies might be moving left until the reach the end of the platform, and then move right. How can you implement such behaviour? You

already know one way – it's called a state machine. Store the state somewhere and jump to difference handling code based on the state.

11. **Play your game**. Take some time to make conscious decisions about movement speed, gravity, enemy movement, difficulty, sleep time, etc.
12. **Have fun with programming.** Try to do new things and make the game yours! Writing a game purely in assembly language is an accomplishment you should be proud of.

Required Preamble

The code you submit (`game.asm`) ***must*** include at the beginning of the file the lines shown below, in the same format. This preamble includes information on the submitter, the configuration of the bitmap display, and the features that are implemented, and a link to your video demonstration (more on this later). **This is necessary information for the TA to be able to mark your submission.**

```
#####################################################################
#
# CSCB58 Winter 2023 Assembly Final Project
# University of Toronto, Scarborough
#
# Student: Name, Student Number, UTorID, official email
#
# Bitmap Display Configuration:
# - Unit width in pixels: 4 (update this as needed)
# - Unit height in pixels: 4 (update this as needed)
# - Display width in pixels: 256 (update this as needed)
# - Display height in pixels: 256 (update this as needed)
# - Base Address for Display: 0x10008000 ($gp)
#
# Which milestones have been reached in this submission?
# (See the assignment handout for descriptions of the milestones)
# - Milestone 1/2/3 (choose the one the applies)
#
# Which approved features have been implemented for milestone 3?
# (See the assignment handout for the list of additional features)
# 1. (fill in the feature, if any)
# 2. (fill in the feature, if any)
# 3. (fill in the feature, if any)
# ... (add more if necessary)
#
# Link to video demonstration for final submission:
# - (insert YouTube / MyMedia / other URL here). Make sure we can view it!
#
# Are you OK with us sharing the video with people outside course staff?
# - yes / no / yes, and please share this project github link as well!
#
# Any additional information that the TA needs to know:
# - (write here, if any)
#
#####################################################################
```

Features, Milestones, and Marking

Projects are **individual**. This assignment is worth **17** points. To better give you a sense of progress, the project is broken down into 3 milestones as follows. For milestones 1 and 2 you need to implement **all** features; for milestone 3 you choose a set of features to implement.

1. **Milestone 1: basic graphics [3 marks]**
   A. **Draw the level** (platforms, ladders if you have them, etc.). Your game's display resolution (framebuffer size) should be **at least 64 units high and 64 units wide**. Make sure to **include at least 3 platforms** the player would be able to stand on (that could for example mean 2 floating platforms plus a floor).
   B. **Draw the player character**: it needs to be **at least 3 framebuffer units big** (more is allowed).
   C. Draw **at least 2 additional objects** that are not platforms other than the player and the level itself (more is allowed!). These can be enemies, pickups, a mixture of both, or anything similar that makes sense. Each object needs to be **at least 3 framebuffer units big** (more is allowed).
2. **Milestone 2: basic controls [5 marks]**
   A. **Player can move** the player character left/right around the platform using the movement keys. Make sure the player cannot move past the edges of the screen! Optional exception: you may choose to allow the player to momentarily be above the top of the screen during a jump. You will need to account for this when drawing the player character (it should be clipped by the top of the screen, meaning drawn partially).
   B. **Platform collision and gravity**: the player can stand on a platform but will fall down if moving off a platform. If the player falls down on another platform, they will **not** go through; you need to detect and handle "collision" between player and platforms. You also need to handle the case where a player falls off the edge of the screen (unless you add a "floor"). This can be handles as an "end game" condition (see Milestone 3).
   C. Vertical movement: the player can navigate to (then move around on) **at least 3 different platforms** (including the one they are standing on initially). This can be done by jumping up to platforms and dropping down from them. You may choose instead alternative mechanisms such as going up and down ladders for navigation, and that's ok (see Donkey Kong example). Again, make sure the player is actually able to get to at least 3 platforms.
   D. **Collision with objects**: the game must detect when a moving object touches the player (or vice versa). There are several ways to do this, and you don't have to be 100% accurate as long as they are very close. You also need to handle collisions appropriately and give some feedback to the player. For example, if it's an enemy you could change

the player character color to indicate the collision, and also reduce the player's health or end the game. If it's a pick-up, you could make it vanish and perhaps increase the score.

E. **Allow restarting the game at any point** by pressing the `p` key on the keyboard.

3. **Milestone 3: additional features and polish**

Choose and implement enough features from the list below, each is worth some marks. Your preamble and video should list specifically what features you implemented, and you need to demonstrate them in the video. To get full marks on this milestone, you will need to implement features with a total of at least **9 marks** (assuming you got all the marks for milestones 1 and 2). Note you cannot "make up" for missing features of previous milestones. In other words, you can only make at most 9 marks from milestone 3.

A. **Health/score [2 marks]**: track and show the player's health and/or score on screen during the game. You **must** show the score on the screen during play and on the game-over screen for this to count. You can do this in many ways: a numeric score, a bar, or hearts that disappear when the player gets hurt. Score can be based on pick-ups, jumping on top of enemies, or any idea you may have.

B. **Fail condition [1 mark]:** the player should be able to fail the game, and you then show an appropriate game over screen (awesome music optional). Failure could be caused by the player health dropping to zero, falling off the edge of the screen, or failing to meet a time limit – up to you. Don't make the game too hard!

C. **Win condition [1 mark]**: the player can win the game and there is a "you won!" screen when the goal is achieved. For example, collecting all the floating coins, or getting a specific pick-up. It's OK to make the game easy if you want, but try not making it so easy that you can't demonstrate important features.

D. **Moving objects [2 mark]:** have the enemies/pickups move around the level. This entails continually redrawing the relevant parts of the screen with the appropriate assets. For example, perhaps enemies patrol left and right across on the platform they are on, or object pickups hovering gently up and down, or annoying, flying bats trying to hit the player.

E. **Moving platforms [2 marks]**: some of the platforms might be moving around, making it more challenging for the player to reach them.

F. **Disappearing platforms [1 mark]**: some of the platforms disappear and reappear over time. Note this is considered similar to moving platform, so if you implement both features you will only get 2 marks. A variation of this is **bubble platforms:** when the player touches the bubble, the bubble pops and player gets a boost up. The bubble will reappear after some time

G. **Different levels [2 marks]**: once the player has finished a level, the player moves to the next level which can include a different (perhaps more challenging?) configuration of platforms, enemies, and pickups. You need to show you have at least 3 different levels for this to count. “Finishing a level” depends on your game design – for example collecting all pick-ups, killing all enemies, or reaching a specific platform.

H. **Shoot enemies [2 marks]:** add ability to shoot enemies using a key on the keyboard. They have to respond to being hit (for example, they might disappear).

I. **Enemies shoot back! [2 marks]:** what, you think they are just going to stand there? Add enemies that shoot the player. If they hit the player, you can reduce health, kill the player, reduce score, or something similar (depending on what other features you implemented)

J. **Pick-up effects [2 marks]:** slow down time? Make the player jump higher? Make enemies bigger? Restore player health? Turn the player into a frog? Anything goes as long as you have at least 3 different kinds of pickups with different effects.

K. **Double jump [1 mark]:** allow the player to jump when in mid-air, but only once! If you ask me, every game should have it.

L. **Animated sprites [2 marks]**: the images you use for player or other objects are animated when walking, moving, and jumping. If we see a serious effort for polish, we may award more than 2 marks. See Useful Resources below for links to sprite editing tools.

M. **Start menu [1 mark]**: at the beginning, the user can choose to start the game or exit (you may add more options if you want). Note this feature is quite minimal, and so we expect a decent level of polish visually and in the user interace. Operating should be clear. Example of acceptable implementation: write "start" and "exit" with a cursor that can be moved with WASD and selected somehow. Example of **unacceptable** implementation: green blob and purple blob. If you press W then the game quits (???).

N. **Jet Pack [2 marks].** Instead of double jump, the player can activate a jetpack, which flies as long as there is fuel. The jetpack’s effect may be to slow falling or even allow hovering/flying around for a limited time. Make sure fuel is limited so player can’t fly indefinitely. Fuel is replenished by landing on the ground, or by booster pickups, or any other method (booster pickups can count towards the 3 required effects of for the pickup feature). There should be some visual indication on whether the jetpack is active or not: it can be as simple as changing player color or as complicated as a trail of "smoke" (pixels). Adding mimigas and exhilarating music is optional.

O. **Player clones [3 marks].** Something can cause a clone of the player to appear and interact with the environment. There must be at least one clone in addition to the original player character for the feature to count. Clones exists alongside the player character. They affect and are affected by the environment similar to the player: they stand on platforms, could fall off, cannot go through walls/edges of the screen, etc. You can also choose to allow clones to die from enemies and do pickups -- up to you. Clones are controlled by the player in some way: either repeating past actions, or they might mirror the player's current actions, or maybe there is a way to switch which clone is controlled. Whichever way you can think of.

P. **Gimmicks and features [0-3 marks]:** Be creative and invent your own feature or gimmick. We will award points taking in consideration ambition (coolness factor) and achievement (implementation difficulty and quality). Note that super-trivial ideas like "my player becomes red when I press X" will get 0 marks. If you have a feature in mind that you want to discuss with us in advance, ask us on Piazza.

⇨ If you would like to request a feature not on the list or have an idea for a gimmick and want to know the score, post on Piazza by March 30.

Final Submission

The deadline for final submission is going to the last day of classes; see "Important Info and Due Dates" on page 2 for details. As such, we won't have an opportunity to meet to discuss your project. To help us evaluate your final project (so we don't miss anything), you need to submit a short video walking us through your project. ***Any final submission that does not include a video will not be marked***. If you have concerns with this, please get in touch with us *immediately*.

You will submit your `game.asm` (and only this one file) to Quercus. You will host the videos externally (on your OneDrive, YouTube, Google Drive, etc.) and add a link to it in your submission. Look below for additional details on what to include in the file and the video. You can submit the same file multiple times and only the latest version before the deadline will be marked. It is also a good idea to backup your code after completing each milestone or additional feature (e.g., using Git), to avoid the possibility that the completed work gets broken by later work. Again, make sure your code has the required preamble as specified above.

As detailed in the term work policy, late submissions are not allowed for this project, except in documented and unusual circumstances.

Required Video Demonstration

You will need to include a short video (aim for 5 minutes, and no more than 7) walking us through your project. This is to help us properly evaluate you and not miss any features you might have implemented. In the video, you should:

1. Demonstrate that the basic functionality works (movement, jumping, enemy collision, ...) and all the features in milestones #1 and #2.
2. Demonstrate the functionality of the additional features implemented for milestone #3 (remember to also list them in the preamble).
3. If you were unable to complete all milestones, explain what difficulties you encountered and show what progress you had on those features.
4. Tell us any other information you think you would be useful to us while we are evaluating your work.

Use screen-recording software for the demo instead of taking a video of your screen with your phone, if possible.
For sharing the video with us you will send use a URL (in the preamble). U of T provides a media sharing service you can use to host the video, or you can use YouTube and similar services of your choice. Another option is Office 365, provided by the university, also includes OneDrive which allows sharing videos as well. It's up to you! Regardless of what service you use, make sure to include the URL in the preamble of the submitted file, and **make sure the video is viewable by the course staff**.

Publicly sharing videos: do let us know in your preamble if you are OK with us sharing the video link with people outside course staff (e.g., future students). **It's up to you and won't affect your grade!**

For those using MyMedia to share videos: by default, MyMedia requires UTorID login to access the video, even "published" videos. Consider configuring your video to allow access to those outside U of T, which allows for wider sharing. I stress that the choice is 100% yours, and you can always change this setting later.

Marking

Marking is based on completing features and answering oral questions. Your game does not need to be very smooth, polished, complex, or even fun, to get full marks. If the game is playable and working, that's fine! However, your game needs to playable, which means (for example) we need to be able to see where things are, animations cannot be so slow or so flickering that we cannot see where things are, and the game cannot be so hard that it ends in 5 seconds. **Again, we are going to be very lenient on this, but your game does need to be playable.**

Bonus for Polish

We may decide to give an additional small bonus to students whose projects exceeded our expectations. **You do not need this bonus to get full marks!** This bonus will be decided on a case-by-case basis and will depend on how well you have executed features you have implemented and how polished your overall game is. For example, you may have made tangible, visible improvement to the graphics using bigger resolution, smooth animations, and nice UI.

Academic Integrity

It is fine and even encouraged to discuss ideas, but sharing code between you is forbidden. **All the code you submit must be your own.**

Please note that all submissions will be checked for plagiarism. Make sure to maintain your academic integrity carefully and protect your own work. It is much better to take the hit on a lower assignment mark (just submit something functional, even if incomplete), than risking much worse consequences by committing an academic offence.

Remember that **sharing your code with others before the end of the term is also a violation**, not just using someone else's. If you are using web-based version control such as Github, ensure your repositories are private, and do not otherwise let anyone else see your code**. After the final exam you can go ahead and make it public.**

See the policy on the course info sheet for more details.

Useful Resources

- Assembly slides on Quercus
- MIPS System Calls Table
- Notable projects from previous years (it was a different game with different requirements).
- Tools for editing sprites and pixel art.