High-performance real-time 3D graphics with Vulkan (and Ruby)

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The Ruby language

Ruby is simple in appearance, but is very complex inside, just like our human body.

Yukihiro Matsumoto

The Ruby way of doing 3D graphics

```ruby
def init
  texture = CandyGear::Texture.from_image("texture.qoi")
  mesh = CandyGear::Mesh.new("meshe.cgmesh")
  $model = CandyGear::Model.new(mesh, texture)
  $instance = {
    position: CandyGear::Vector3D.new(0.0, 0.0, 0.0),
    rotation: CandyGear::Rotation3D.new(0.0, 0.0, 0.0)}
  view = CandyGear::View3D.new(
    CandyGear::Vector4D.new(0, 0, 1280, 720), 640, 360);
  view.camera_position =
    CandyGear::Vector3D.new(0.0, 0.0, 0.0)
end

def tick = $model.draw(
      $instance[:position], $instance[:rotation])
```

Why Candy Gear is valuable for game developers

- Unreal and Unity are bloated; Candy Gear aims to be a thinner alternative.
- Ruby is multi-purpose, while Blueprint Visual Scripting and Godot Script are ad-hoc.
- It is hard to use Blueprint Visual Scripting with version control.

Why Candy Gear is suitable for the Ruby community

- Expand Ruby beyond the web industry.
- Test the Ruby language outside of web development.
- Attract game developers to the Ruby community, making the language more popular.

Engine implementation

YARV vs mruby

YARV	the Ruby code calls the C/C++ code (the engine); therefore, every internal state in the framework is attached to Ruby objects.
mruby	the C/C++ code (the engine) calls the Ruby code; therefore, it is easier to decouple the internal states of the framework from the Ruby environment.

Hollywood principle

a.k.a.: “Inversion of control”

Don’t call us, we’ll call you.

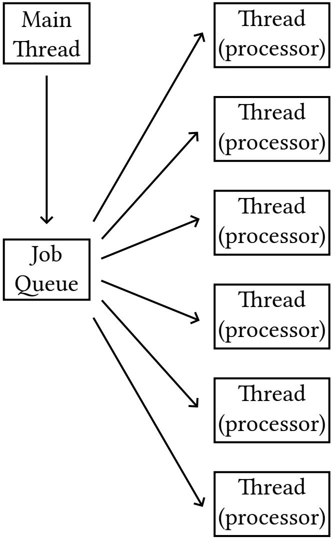
Hollywood principle

How Candy Gear executes a game

```
# Called once before the graphics engine is loaded
def config; end

# Called once after the engine is fully loaded
def init; end

# When you press a key
def key_down key; end

# When you release a key
def key_up key; end

# When you quit the game
def quit; end

# At the beginning of each frame
def tick; end
```

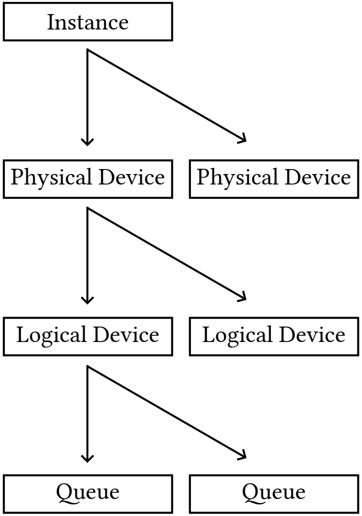
Multithreading and multiprocessing
at CPU level

- Starting and finishing threads are expensive operations.
- Create all threads at startup.
- Destroy all threads at finalization.
- Each thread gets and executes jobs from a job queue.
- If there are no jobs, the thread waits for new ones.
- There should not be more threads than processors.



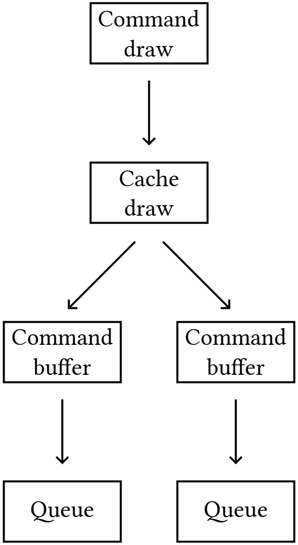
Vulkan initialization

- Vulkan instances
- logical devices
- queues (for GPU multiprocessing)
- swap chain
- graphics pipelines



Command buffers

- Queues execute work.
- Work must be inside command buffers.
- Candy Gears caches drawing commands.
- Queues work in parallel.



Graphics pipelines

Commonly, a 3D engine has pipelines for:

- 3D models (can be split into several pipelines);
- 2D sprites;
- sky;
- (sea, pool, or river) water.

3D graphics pipeline
(for 3D models)

Vertex

textured model coordinates x, y, z, u, v

wireframe model coordinates x, y, z

Polygon

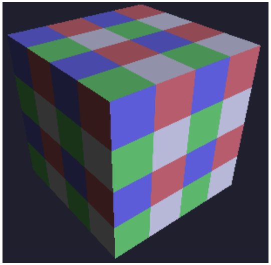
A polygon consists of a sequence of 3 vertexes.

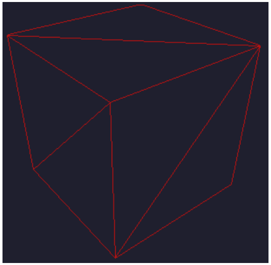
Mesh

A mesh consists of a sequence of one or more vertexes.

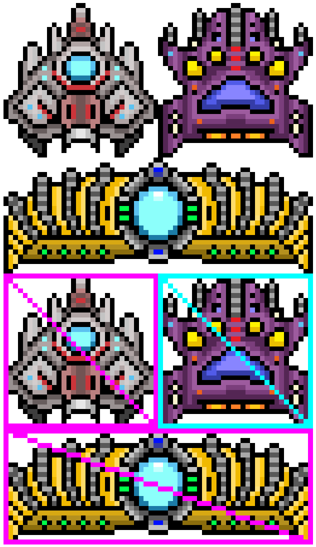
Vertex index

Create an index for each vertex to reuse the vertexes.





2D graphics pipeline



Sprite

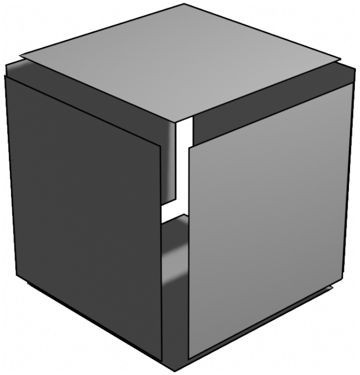
- A sprite is a rectangular region from a texture.
- A graphic card renders a sprite as 2 polygons.
- It is cheaper to render 2D polygons.

Sky graphics pipeline

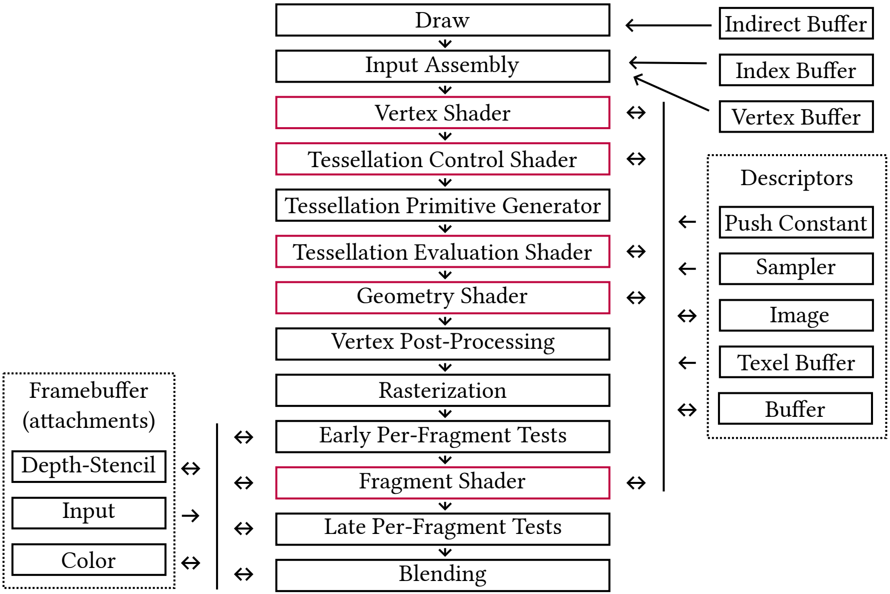
(cube maps and skyboxes)

Cube map

- It uses six different textures as one cube.
- It samples all images sampled as one.
- It uses a 3D vector to calculate which cube regions to display.

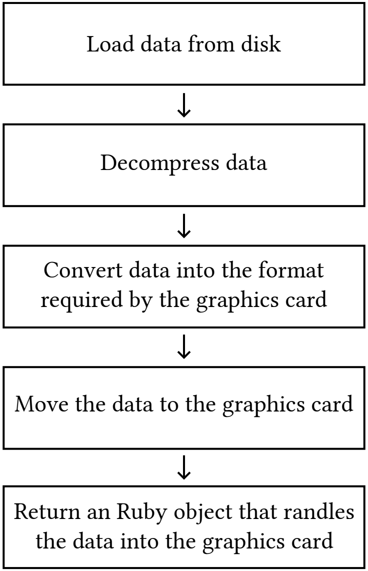


Graphics pipeline overview



Loading data into a graphics card

```
image =
  CandyGear::Texture.from_image(
    "image.qoi")
mesh = CandyGear::Mesh.new(
  "object.cgmesh")
font = CandyGear::Font.new(
  "font.ttf", 16)
```


Load data from disk
Decompress data
Convert data into the format required by the graphics card
Move the data to the graphics card
Return an Ruby object that randles the data into the graphics card

Descriptor sets

World:

- ambient light (vertex shader);
- and directional light (fragment shader).

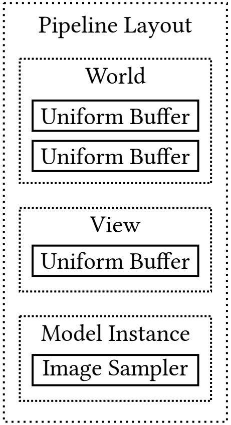
View:

- camera position;
- camera rotation;
- and projection.

Model Instance:

- instace position;
- and instance rotation;

```
model.draw(
  instance_position, instance_rotation)
```



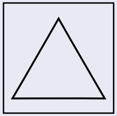
Graphics pipeline stages

Draw

This stage receives the commands for the graphics pipeline.

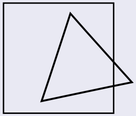
Input Assembly

Assemble vertices from Vertex Buffer and (optionally) Index Buffer into geometric primitives based on topology.



Vertex Shader

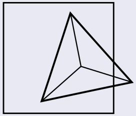
Converts vertex position to screen position.



Graphics pipeline stages

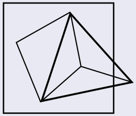
Tessellation (three stages)

Subdivide polygons into smaller polygons and apply transformations to the new generated polygons.



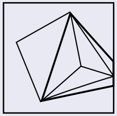
Geometry Shader

Can subdivide, reduce and modify polygons. Similar to tessellation but with a different finality.



Vertex Post-Processing

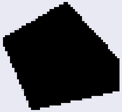
Assembly primitives produced by the previous stage (vertex shader, tessellation, or geometry shader). Clip and cull; discard parts of primitives that the rasterization will not use.



Graphics pipeline stages

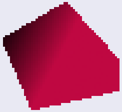
Rasterizer

Converts 3D coordinates into rasterized fragments.



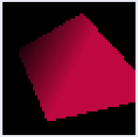
Fragment shader (three stages)

Adds colors and depth to the fragments produced by the Rasterizer.



Color Blending

Mix all the fragments according to their transparency level and depth into one image, generating the frame displayed on the screen.



To-do

Graphics:

1. Finish multithread system (CPU).
2. Finish the graphical engine.
3. Create default file formats.

Audio:

- Create an audio engine.
- Create a MIDI synthesizer.

Ports:

1. Windows (with Vulkan)
2. Nintendo
3. PlayStation

Cleanup:

- Remove libSDL (it adds unnecessary indirections to the engine).

References

Vulkan Tutorial

It is a tutorial for absolute beginners in 3D graphics.
`https://vulkan-tutorial.com/`

Vulkan Programming Guide

This book presumes that the reader has some basic knowledge of 3D graphics. If you are entirely new, read the tutorial first.
`https://www.vulkanprogrammingguide.com/`

Kohi Game Engine

It is a series of videos teaching how to make a game engine from scratch in C.
`https://www.youtube.com/watch?v=dHPuU-DJoBM&list=PLv8Ddw9K0JPg1BEO-RS-0MYs423cvLVtj`

Candy Gear Game Engine

It is my game engine. It is written in C++ and uses Vulkan and mruby.
`https://bitbucket.org/fredlinhares/candygear`