6CCS3PRJ Final Year Individual Project Report Title

Final Project Report

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Abstract

Procedural generation refers to content in a medium that is produced algorithmically in lieu of by hand. Most notably, procedural generation algorithms are implemented in video games, for generating levels, terrain and other game contents programmatically. This project takes some of the more prominent algorithms for procedural generation- Lindenmayer Systems, Voronoi Points, Poisson Disk Generation and Simplex Noise- and implements them in a 3D walking simulator in the open-source Godot game engine, and compares their workings and performance. My aim with this project is to (1) increase my knowledge of procedural generation in games beyond the surface level, by going in-depth into some of the algorithms that are used, and (2) use this knowledge to implement said algorithms in a 3D walking simulator scenario in Godot, then compare how each algorithm works and performs.

Originality Avowal

I verify that I am the sole author of this report, except where explicitly stated to the contrary. I grant the right to King's College London to make paper and electronic copies of the submitted work for purposes of marking, plagiarism detection and archival, and to upload a copy of the work to Turnitin or another trusted plagiarism detection service. I confirm this report does not exceed 25,000 words.

Zishan Rahman

April 11, 2023

Acknowledgements

It is usual to thank those individuals who have provided particularly useful assistance, technical or otherwise, during
your project. Your supervisor will obviously be pleased to be acknowledged as he or she will have invested quite a lot of time overseeing your progress.
Thanks to my supervisor Senir Dinar, for providing me the guidance I so badly needed
to make this project not only the best for my mark, but also one that I enjoy.
Thanks also to Kevin Lano, who helped me up when I was down.

Contents

Chapter 1

Introduction

Procedural Content Generation, or PCG, refers to the use of algorithms and programming in lieu of human handiwork to design and implement various contents in video games, such as levels, terrains, trees and cities. A PCG algorithm is ontogenetic when it tries to produce a foreseeable end result as it goes along. For this project, I will be implementing several well-known ontogenetic algorithms in a basic 3D walking simulator game, using the open-source Godot game engine, and then comparing how each algorithm carries out the creation of levels in said game.

1.1 Report Structure

Chapter 2

Background

For my BSc individual project, I will be researching procedural content generation (PCG) algorithms and then implementing them each in a small 3D game made with the Godot Engine (and its domain-specific GDScript language).

2.1 Procedural Generation: Background

Procedural content generation (usually referred to as simply "procedural generation") refers to the creation of levels and other game objects programmatically and algorithmically, in lieu of a human being doing all the work. While procedural generation algorithms can be used to generate a myriad of things, from textures (for things like trees and clouds) to music ("generative music," as coined by legendary musician Brian Eno), by far its most common context is in automated level design, generating level layouts algorithmically in lieu of work from level designers. Game developers may opt to use procedural generation to save time and money designing levels or show off technical prowess in their games.

Procedural generation in video games has a rich history. Pioneering games such as Rogue (1980) took direct influence from tabletop role-playing games such as Dungeons and Dragons, and thus had a player navigate a randomly-generated world that expanded further as they went on. Such games spawned the *roguelike* and *roguelite* genres, which experienced immense popularity in the last decade. In the realm of first-person shooters, 2004's .kkrieger, as seen in Figure 2.1, used procedural generation to create intricate 3D levels and fit them all into a game that takes up just 96 kilobytes of space.

Figure 2.1: The game .kkrieger, which uses procedural generation to design maps while keeping the game at a 96 kilobyte file size.[5]

Other games that use procedural generation in its levels include Elite (originally published in 1984), Elite: Dangerous (2012), Minecraft (2009), No Man's Sky (2012) and Spelunky (2013). The latter game's use of procedural generation has notably been covered by video games journalist Mark Brown in a YouTube video.

Figure 2.2: The roguelike game Spelunky, which uses procedural generation to build intricate levels for the player character to explore. Source: https://store.steampowered.com/app/239350/Spelunky/

In many cases, these games end up having a **large** number of different environments that each game could generate for its players. However, by procedurally generating them upon the *loading* of the game level, in lieu of loading a layout from disk, they can save a lot of space (albeit with a considerable need for processing power, depending on the game's and algorithms' performance), as seen in Figure 2.1.

Using one or some different procedural generation algorithms, such as the use of Perlin, Simplex or other noise, Voronoï disks and also poisson disk generation, among others, games can load a seed to randomly generate a level every time it is played, meaning no two playthroughs of a game with procedurally generated content are ever the same.

2.2 Justifying My Choice of Engine: Godot

While a myriad of resources exist for procedurally generated game contents exist for Unity and Unreal, I want to implement them in Godot, for several reasons:

- It's the engine I have the most experience with, having already developed 2 published web games with it.
- It's not got as many resources on procedural generation compared to Unity, Unreal and some other popular game engines, particularly on the side of academic research (that is, there aren't as many papers on procedural generation that pertain to Godot as they do to Unity, Unreal and other engines).
  - However, it is still very powerful and feature-rich (it has its own Open Simplex noise class, for example) and I'm sure I can make procedural generation algorithms work on it.
- Compared to Unity and Unreal, Godot is a very light engine with a feature-rich editor, clocking in at under 100MB, with editors for Windows, macOS, Linux and even the web browser.

By the end of my allotted time, I plan to have implemented several procedurally generated environments in small Godot games, using a myriad of methods (such as Voronoï cell and poisson disk generation) in a myriad of contexts (anything from platformers to first-person games). With these games, I plan for the final report to be the centrepiece of my project, with it containing my research on how each environment was implemented, as well as my findings on the algorithms themselves and how they work.

This is more a research-oriented project than an implementation-oriented project, but the implementations will nonetheless prove that Godot is just as adept at procedural content generation as the other major players in the game engine space, and I will have gained immense knowledge on PCG in the process.

2.2.1 Note on Differing Versions of Godot

Godot currently is at version 3, but concurrently there is also Godot 4, which is nearing its release and is in working condition. The latter version of Godot contains several new features and breaking changes, so any project made in Godot 3 won't readily be compatible with Godot 4 (and vice-versa) without making the necessary changes and conversions. I have access to both versions of Godot and, for all the Godot projects I create, which version I'm using will be clearly denoted and clarified.

2.3 Justifying My Choice of Scenario: A 2D tile-map RPG-style roaming game

Here, I will justify why I chose this particular scenario for all my algorithm implementations.

Chapter 3

Report Body

3.1 Algorithms

3.1.1 Lindenmayer Systems

Hungarian academic Aristid Lindenmayer devised a mathematical model for the reproduction of fungi in 1967.[6] His model involved a string of symbols, each unique symbol denoting a specific action and/or branch. Essentially, running that initial string, called the *axiom*, through a set of rules (called a *grammar*) gives us an ever-expanding string that is then taken as instructions to draw something from. Lindenmayer Systems, or L-Systems, have since been used in several scenarios beyond its initial purpose of modelling fungi, from trees to fractals. In video games, they are frequently used to aid in the creation of foliage in several environments, as well as buildings and, here, level layouts.

A Basic 0L-System

The most basic form of L-System is a *0L*-System, 0 in this case referring to the fact that the grammar is *context-free*.

For this example[1], consider an alphabet V, which consists of the following symbols:

$$\mathrm{F}, +, -$$

where F means "to go forward", and $+$ and $-$ denote turning right or left (respectively) a set number of degrees .

Take an axiom ω, for example:

$$\mathrm{F+F+F+F}$$

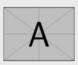
And a set of rules P which, in this case, is of size 1:

$$\mathrm{F \rightarrow F+F-F-FF+F+F-F}$$

We can represent this *parametric* L-system in the following form:[8]

$$G = (V, \omega, P)$$

To implement G in Godot, we can take each rule and replace each string in accordance to our one rule, using the replace method, like so:



Simple String Replacement for an L-System with 1 rule

```
string = string.replace(rule["from"], rule["to"]) #Here the
    rules were stored in dictionaries.
```

Code 3.1: Simple String Replacement for an L-System with 1 rule

The first 3 iterations of this operation are shown here:

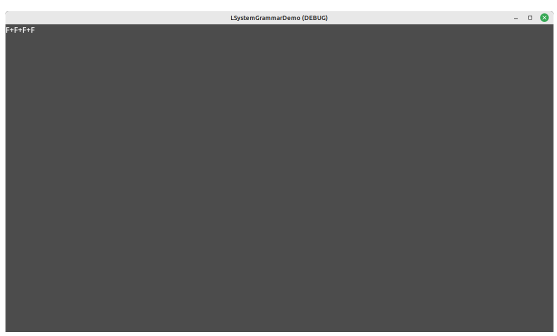


Figure 3.1: The axiom of the aforementioned simple L-System with just one rule. String size: 8. Source: Own work.

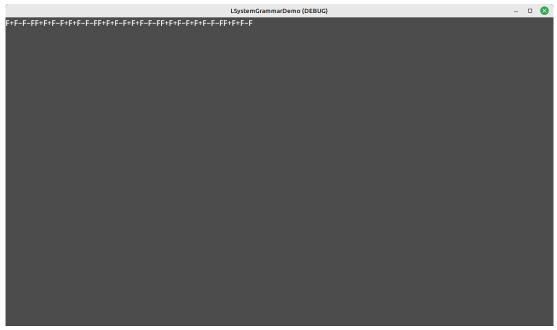


Figure 3.2: The first iteration of the aforementioned simple L-System with just one rule. String size: 59. Source: Own work.

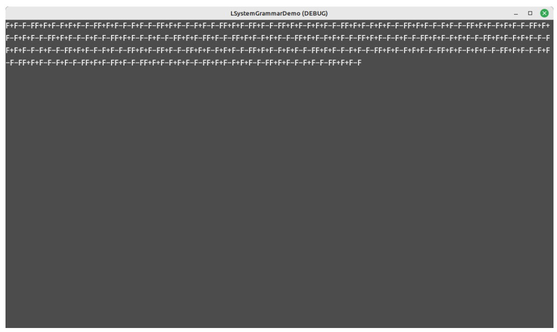


Figure 3.3: The second iteration of the aforementioned simple L-System with just one rule. String size: 475. Source: Own work.

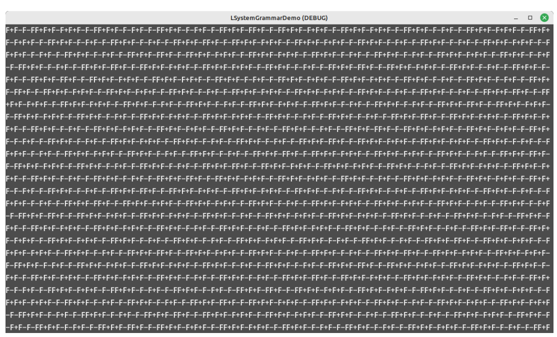


Figure 3.4: The third iteration of the aforementioned simple L-System with just one rule. String size: 3803. The string is too large to show in the window, as you can see here. Source: Own work.

The resulting string can be used to draw a lattice.[1] Examples of the above grammar in action are below.

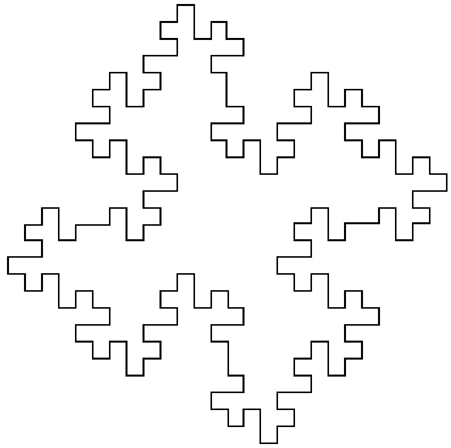


Figure 3.5: A lattice generated with the example grammar on a custom-written Classic Mac OS application specifically written for working with L-Systems.[1]

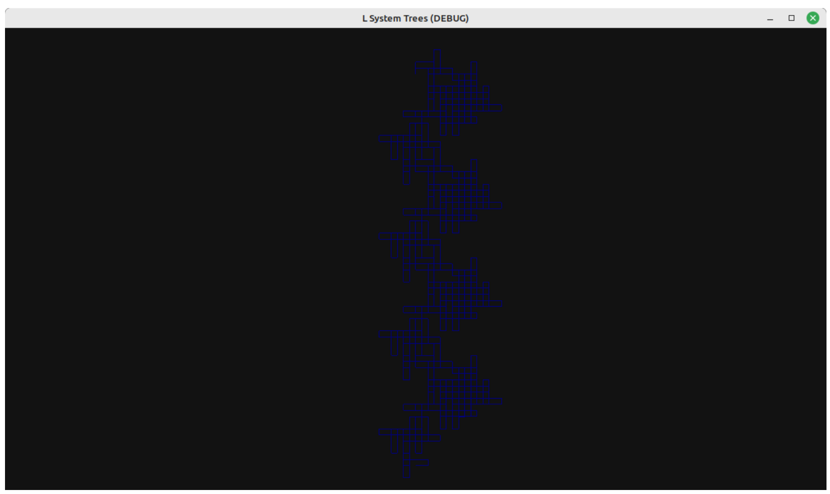
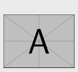


Figure 3.6: A lattice generated with the example grammar on a Godot project for drawing from L-Systems. Source: Initial project written by YouTuber Codat[2][3], and converted to Godot 4 (with the addition of the lattice grammar) by me.[4]

A More Complex D0L-System With More Than One Rule

For handling more than one rule, we can instead use a new string buffer variable where, for each character in our string, we can attain a new string and append it to our string buffer. The resulting string is then returned and interpreted. This can be represented in Godot like so:



String replacement for an L-System with 2 rules

```
func get_new_replacement(character: String) -> String:
^^Ifor rule in rules:
```

Code 3.2 – continued

```
^^I^^Iif rule["from"] == character:
^^I^^I^^Ireturn rule["to"]
^^Ireturn ""

func replace_string(string: String) -> String:
^^Ivar new_string = ""
^^Ifor character in string:
^^I^^Inew_string += get_new_replacement(character)
^^Ireturn new_string
```

Code 3.2: String replacement for an L-System with 2 rules

This can *then* be used to handle more complex grammars that can handle more than one rule in which characters in strings are replaced by other strings of variable length, as before.

The grammar in the following example represents a D0L-System[7], a **deterministic** L-System using a context-free grammar; the grammar in the first example was *also* deterministic.

For this example, consider a new grammar G with the alphabet V, where a and b are the only symbols. We start with the following axiom ω, which is just a. We now have a set of rules P which is, this time, of size *2*:

$$\mathrm{a} \rightarrow \mathrm{ab}$$

$$\mathrm{b} \rightarrow \mathrm{a}$$

The first few steps of the resulting derivation can be modelled like so:

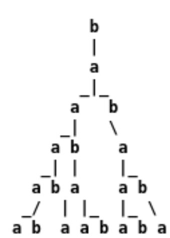


Figure 3.7: The first few steps of a derivation of our example grammar.[7]

3.1.2 Voronoi Cells

Named after the Ukranian mathematician Georgy Voronoy, Voronoi cells work by taking a map of points, and randomly selecting a group of points. Within that selected group, cells are formed by calculating, in each point of the grid, the closest of the selected points to it. That is, each cell represents the group of points that are the closest to that random point (including that point in the group as well). The final arrangement of cells represents a Voronoi Diagram or Voronoi Tesselation.

Distances between points can be calculated with either the Euclidean distance:

$$d_E(p,q) = \sqrt{(q_x - p_x)^2 + (q_y - p_y)^2}$$

or the Manhattan distance:

$$d_M(p,q) = |q_x - p_x| + |q_y - p_y|$$

With the Euclidean distance producing a more “triangulated” tesselation than the Manhattan distance, the geometry of which is more ”blocky” and resembles taxicabs (hence its alternate name ”Taxicab Geometry”).

3.1.3 Poisson Disk Sampling

Poisson disk distributions are an easy way to randomly scatter objects across a field. It’s commonly used for tree placement and placement of other random objects.

3.1.4 Simplex Noise

Kenneth Perlin designed a type of noise named after himself (Perlin Noise), in which each pixel of noise is affected by its surroundings.

3.2 Implementations

Here I will describe, at surface level, the methods I went about implementing the above algorithms and what references I used.

Chapter 4

Design & Specification

4.1 Section Heading

Here, I will provide an abstract level of how I compared the performance of each content generation algorithm and how I made sure each implementation could produce as similar/like-for-like results as possible (and where they *couldn't* do so).

Chapter 5

Implementation

Here I will go a bit deeper as to how I made each algorithm work.

5.1 Section Heading

Chapter 6

Legal, Social, Ethical and Professional Issues

Your report should include a chapter with a reasoned discussion about legal, social ethical and professional issues within the context of your project problem. You should also demonstrate that you are aware of the regulations governing your project area and the Code of Conduct & Code of Good Practice issued by the British Computer Society, and that you have applied their principles, where appropriate, as you carried out your project.

6.1 Section Heading

Chapter 7

Results/Evaluation

Here I will mention how I tested the small games and made sure they ran as they should.

7.1 Software Testing

7.2 Section Heading

Chapter 8

Conclusion and Future Work

The project's conclusions should list the key things that have been learnt as a consequence of engaging in your project work. For example, "The use of overloading in C++ provides a very elegant mechanism for transparent parallelisation of sequential programs", or "The overheads of linear-time n-body algorithms makes them computationally less efficient than $O(n \log n)$ algorithms for systems with less than 100000 particles". Avoid tedious personal reflections like "I learned a lot about C++ programming...", or "Simulating colliding galaxies can be real fun...". It is common to finish the report by listing ways in which the project can be taken further. This might, for example, be a plan for turning a piece of software or hardware into a marketable product, or a set of ideas for possibly turning your project into an MPhil or PhD.

References

[1] Paul Bourke. L-system user notes. July 1991.

[2] Codat. Code that: L-system, 2020.

[3] Codat and contributors. An implementation of the rewriting system: Lindenmayer system., April 2020. [Online; accessed 10-April-2023].

[4] Codat, Zishan Rahman, and contributors. An implementation of the rewriting system: Lindenmayer system., March 2023. [Online; accessed 10-April-2023].

[5] Jonas Freiknecht and Wolfgang Effelsberg. A survey on the procedural generation of virtual worlds. *Multimodal Technologies and Interaction*, 1:27, 10 2017.

[6] Aristid Lindenmayer. Mathematical models for cellular interactions in development ii. simple and branching filaments with two-sided inputs. *Journal of Theoretical Biology*, 18(3):300–315, 1968.

[7] Gabriela Ochoa. An introduction to lindenmayer systems: D0l-system, February 1998. [Online; accessed 11-April-2023].

[8] Wikipedia contributors. L-system — Wikipedia, the free encyclopedia, 2022. [Online; accessed 23-February-2023].

Appendix A

Extra Information

A.1 Tables, proofs, graphs, test cases, ...

The appendices contain information that is peripheral to the main body of the report. Information typically included in the Appendix are things like tables, proofs, graphs, test cases or any other material that would break up the theme of the text if it appeared in the body of the report. It is necessary to include your source code listings in an appendix that is separate from the body of your written report (see the information on Program Listings below).

Appendix B

User Guide

B.1 Instructions

To run the projects in the .zip file, extract the projects in one folder. Then open Godot 4 (at the moment all projects are Godot 4 projects), and, when opening the Godot editor, click ”Scan”, then go to that folder and select it. The projects can then be opened in the project manager and edited as needed in Godot. When you click on some of the scenes in the projects, there may be some ”exported” variables from scripts that are visible to you in the editor (examples include the ”Distance” and ”Random Starting Points” variables in the Voronoi Cells project).

Appendix C

Source Code

C.1 Instructions

Complete source code listings must be submitted as an appendix to the report. The project source codes are usually spread out over several files/units. You should try to help the reader to navigate through your source code by providing a "table of contents" (titles of these files/units and one line descriptions). The first page of the program listings folder must contain the following statement certifying the work as your own: "I verify that I am the sole author of the programs contained in this folder, except where explicitly stated to the contrary". Your (typed) signature and the date should follow this statement.

All work on programs must stop once the code is submitted to KEATS. You are required to keep safely several copies of this version of the program and you must use one of these copies in the project examination. Your examiners may ask to see the last-modified dates of your program files, and may ask you to demonstrate that the program files you use in the project examination are identical to the program files you have uploaded to KEATS. Any attempt to demonstrate code that is not included in your submitted source listings is an attempt to cheat; any such attempt will be reported to the KCL Misconduct Committee.

You may find it easier to firstly generate a PDF of your source code using a text editor and then merge it to the end of your report. There are many free tools available that allow you to merge PDF files.

C.2 LSystemGrammarDemo

C.2.1 .gitattributes

```
# Normalize EOL for all files that Git considers text files.
* text=auto eol=lf
```

C.2.2 .gitignore

```
# Godot 4+ specific ignores
.godot/
```

C.2.3 project.godot

```
; Engine configuration file.
; It's best edited using the editor UI and not directly,
; since the parameters that go here are not all obvious.
;
; Format:
;   [section] ; section goes between []
;   param=value ; assign values to parameters

config_version=5

[application]

config/name="LSystemGrammarDemo"
run/main_scene="res://DemoNode.tscn"
config/features=PackedStringArray("4.0")

[display]
```

```

window/stretch/mode="canvas_items"
window/stretch/aspect="expand"

[gui]

common/drop_mouse_on_gui_input_disabled=true

[physics]

common/enable_pause_aware_picking=true
```

C.2.4 DemoNode.tscn

```
[gd_scene load_steps=2 format=3 uid="uid://bu380we4od0ln"]

[ext_resource type="Script" path="res://DemoNode.gd" id="1"]

[node name="DemoNode" type="Node"]
script = ExtResource("1")
choices = "deterministic"

[node name="Timer" type="Timer" parent="."]

[node name="Line2D" type="Line2D" parent="."]
points = PackedVector2Array(69, 297)

[node name="TextLabel" type="Label" parent="."]
offset_right = 1152.0
offset_bottom = 23.0
autowrap_mode = 3

```

```
[connection signal="timeout" from="Timer" to="." method="_on_Timer_timeout"]
```

C.2.5 DemoNode.gd

```
extends Node

# Basic: https://youtu.be/feNVBEPXAcE?t=77 (L = +)
# Choices: http://paulbourke.net/fractals/lsys/
# Deterministic: https://www1.biologie.uni-hamburg.de/b-online/e28_3/lsys.html#D0L-system

@export_enum("basic", "choices", "deterministic") var choices: String = "choices"
@export var axiom: String
@onready var string: String
@onready var timer = \${Timer}
@onready var line = \${Line2D}
@onready var label = \${TextLabel}
@onready var rules: Array[Dictionary]

func set_values():
   if choices == "basic":
      rules = [
         {
            "from": "F",
            "to": "F+F"
         }
      ]
      axiom = "F+"
   elif choices == "choices":
      rules = [
```

```
            {
                "from": "F",
                "to": "F+--FFFF+F+-FF"
            }
        ]
        axiom = "F+F+F+F"
    elif choices == "deterministic":
        rules = [
            {
                "from": "a",
                "to": "ab"
            },
            {
                "from": "b",
                "to": "a"
            }
        ]
        axiom = "b"

func _ready():
    set_values()
    string = axiom
    label.size.x = get_viewport().size.x
    label.text = string
    timer.start()

func get_new_replacement(character: String) -> String:
    for rule in rules:
        if rule["from"] == character:
            return rule["to"]
    return ""

func _on_Timer_timeout():
```

```
    var new_string = ""
    for character in string:
        new_string += get_new_replacement(character)
    string = new_string
    label.text = string
    print(len(string))
```

C.2.6 icon.svg.import

```
[remap]

importer="texture"
type="CompressedTexture2D"
uid="uid://cwnnuqmejj04q"
path="res://.godot/imported/icon.svg-218
    a8f2b3041327d8a5756f3a245f83b.ctex"
metadata={
"vram_texture": false
}

[deps]

source_file="res://icon.svg"
dest_files=["res://.godot/imported/icon.svg-218
    a8f2b3041327d8a5756f3a245f83b.ctex"]

[params]

compress/mode=0
compress/high_quality=false
compress/lossy_quality=0.7
compress/hdr_compression=1
```

```
compress/normal_map=0
compress/channel_pack=0
mipmaps/generate=false
mipmaps/limit=-1
roughness/mode=0
roughness/src_normal=""
process/fix_alpha_border=true
process/premult_alpha=false
process/normal_map_invert_y=false
process/hdr_as_srgb=false
process/hdr_clamp_exposure=false
process/size_limit=0
detect_3d/compress_to=1
svg/scale=1.0
editor/scale_with_editor_scale=false
editor/convert_colors_with_editor_theme=false
```

C.3 ProcGenRPG (L-System)

C.3.1 .gitattributes

```
# Normalize EOL for all files that Git considers text files.
* text=auto eol=lf
```

C.3.2 .gitignore

```
# Godot 4+ specific ignores
.godot/
```

C.3.3 project.godot

```
; Engine configuration file.
; It's best edited using the editor UI and not directly,
; since the parameters that go here are not all obvious.
;
; Format:
;   [section] ; section goes between []
;   param=value ; assign values to parameters

config_version=5

[application]

config/name="Proc Gen RPG"
run/main_scene="res://tile_map.tscn"
config/features=PackedStringArray("4.0", "Forward Plus")
config/icon="res://icon.svg"

[display]

window/size/viewport_height=640
window/stretch/mode="canvas_items"
```

C.3.4 l_system.tscn

```
[gd_scene load_steps=2 format=3 uid="uid://d0v18e7ms571f"]

[ext_resource type="Script" path="res://l_system.gd" id="1_elydp"]

[node name="LSystem" type="Node"]
script = ExtResource("1_elydp")
```

C.3.5 l_system.gd

```
extends Node

class_name LSystem

@onready var tile_map: TileMap = get_parent()
@export var axiom: String = "OWB"
@onready var string: String = axiom
@export var rules: Array[Dictionary] = [
   {
      "from": "O",
      "to": "OWO"
   },
   {
      "from": "W",
      "to": "WB"
   },
   {
      "from": "B",
      "to": "BWO"
   }
]

const FLOWERS_1: Vector2i = Vector2i(3, 7) # "O" = ORANGE
const FLOWERS_2: Vector2i = Vector2i(3, 10) # "W" = WHITE
const FLOWERS_3: Vector2i = Vector2i(3, 13) # "B" = BLUE

func get_new_replacement(character: String) -> String:
   for rule in rules:
      if rule["from"] == character:
         return rule["to"]
   return ""
```

```

func size() -> int:
    return tile_map.x_tile_range * tile_map.y_tile_range

func parse() -> String:
    var size: int = size()
    while len(string) <= size:
        var new_string = ""
        for character in string:
            new_string += get_new_replacement(character)
        string = new_string
    string = string.substr(0, size)
    return string

func paint() -> void:
    string = parse()
    var size: int = size()
    var i: int = -1
    for x in range(tile_map.x_tile_range):
        for y in range(tile_map.y_tile_range):
            i += 1
            if string[i] == "O":
                tile_map.set_cell(1, Vector2i(x, y), 0, FLOWERS_1)
            elif string[i] == "W":
                tile_map.set_cell(1, Vector2i(x, y), 0, FLOWERS_2)
            elif string[i] == "B":
                tile_map.set_cell(1, Vector2i(x, y), 0, FLOWERS_3)
```

C.3.6 tile_map.tscn

```
[gd_scene load_steps=4 format=3 uid="uid://bwhvtqld3yo8m"]

```

```
[ext_resource type="TileSet" uid="uid://c168x78r0tful" path="res://Tiles.tres" id="1_l3nwg"]
[ext_resource type="Script" path="res://tile_map.gd" id="2_wrxl8"]
[ext_resource type="PackedScene" uid="uid://d0v18e7ms571f" path="res://l_system.tscn" id="3_ktw1n"]

[node name="TileMap" type="TileMap"]
tile_set = ExtResource("1_l3nwg")
format = 2
layer_0/name = "Grass"
layer_1/name = "Things"
layer_1/enabled = true
layer_1/modulate = Color(1, 1, 1, 1)
layer_1/y_sort_enabled = false
layer_1/y_sort_origin = 0
layer_1/z_index = 0
layer_1/tile_data = PackedInt32Array()
script = ExtResource("2_wrxl8")

[node name="LSystem" parent="." instance=ExtResource("3_ktw1n")]
```

C.3.7 tile_map.gd

```
extends TileMap

@onready var l_system: LSystem = \${LSystem}

var x_tile_range: int = ProjectSettings.get_setting("display/window/size/viewport_width") / tile_set.tile_size.x
var y_tile_range: int = ProjectSettings.get_setting("display/window/size/viewport_height") / tile_set.tile_size.y

```

```
const GRASS_1: Vector2i = Vector2i(5, 0)
const GRASS_2: Vector2i = Vector2i(5, 1)

func pick_grass_tile() -> Vector2i:
    return [GRASS_1, GRASS_2].pick_random()

func cover_map_with_grass() -> void:
    for x in range(-50, x_tile_range + 50):
        for y in range(-50, y_tile_range + 50):
            set_cell(0, Vector2i(x, y), 0, pick_grass_tile())

\# Called when the node enters the scene tree for the first time.
func _ready() -> void:
    randomize()
    cover_map_with_grass()
    l_system.paint()
```

C.3.8 icon.svg.import

```
[remap]

importer="texture"
type="CompressedTexture2D"
uid="uid://b45qexb3wmhym"
path="res://.godot/imported/icon.svg-218a8f2b3041327d8a5756f3a245f83b.ctex"
metadata={
"vram_texture": false
}

[deps]

```

```
source_file="res://icon.svg"
dest_files=["res://.godot/imported/icon.svg-218
    a8f2b3041327d8a5756f3a245f83b.ctex"]

[params]

compress/mode=0
compress/high_quality=false
compress/lossy_quality=0.7
compress/hdr_compression=1
compress/normal_map=0
compress/channel_pack=0
mipmaps/generate=false
mipmaps/limit=-1
roughness/mode=0
roughness/src_normal=""
process/fix_alpha_border=true
process/premult_alpha=false
process/normal_map_invert_y=false
process/hdr_as_srgb=false
process/hdr_clamp_exposure=false
process/size_limit=0
detect_3d/compress_to=1
svg/scale=1.0
editor/scale_with_editor_scale=false
editor/convert_colors_with_editor_theme=false
```

C.3.9 roguelikeSheet_transparent.png.import

```
[remap]

importer="texture"
```

```
type="CompressedTexture2D"
uid="uid://13ktp0qup5xb"
path="res://.godot/imported/roguelikeSheet_transparent.png-22
    f6b70da04549e371d1f15fe9d96005.ctex"
metadata={
"vram_texture": false
}

[deps]

source_file="res://roguelikeSheet_transparent.png"
dest_files=["res://.godot/imported/roguelikeSheet_transparent.png
    -22f6b70da04549e371d1f15fe9d96005.ctex"]

[params]

compress/mode=0
compress/high_quality=false
compress/lossy_quality=0.7
compress/hdr_compression=1
compress/normal_map=0
compress/channel_pack=0
mipmaps/generate=false
mipmaps/limit=-1
roughness/mode=0
roughness/src_normal=""
process/fix_alpha_border=true
process/premult_alpha=false
process/normal_map_invert_y=false
process/hdr_as_srgb=false
process/hdr_clamp_exposure=false
process/size_limit=0
detect_3d/compress_to=1
```

C.4 VoronoiCellsGD4

C.4.1 .gitattributes

```
# Normalize EOL for all files that Git considers text files.
* text=auto eol=lf
```

C.4.2 .gitignore

```
# Godot 4+ specific ignores
.godot/
```

C.4.3 project.godot

```
; Engine configuration file.
; It's best edited using the editor UI and not directly,
; since the parameters that go here are not all obvious.
;
; Format:
;   [section] ; section goes between []
;   param=value ; assign values to parameters

config_version=5

[application]

config/name="Voronoi Cells"
run/main_scene="res://tile_map.tscn"
config/features=PackedStringArray("4.0", "Forward Plus")
config/icon="res://icon.svg"

```

```
[display]

window/size/viewport_height=640
```

C.4.4 tile_map.tscn

```
[gd_scene load_steps=5 format=3 uid="uid://d6lxnr5bdh1w"]

[ext_resource type="Texture2D" uid="uid://cpign73sfbsrt" path="res
    ://monochrome_packed.png" id="1_o183d"]
[ext_resource type="Script" path="res://tile_map.gd" id="2_lf4lw"]

[sub_resource type="TileSetAtlasSource" id="
    TileSetAtlasSource_6h0bd"]
texture = ExtResource("1_o183d")
0:0/0 = 0
1:0/0 = 0
2:0/0 = 0
3:0/0 = 0
4:0/0 = 0
5:0/0 = 0
6:0/0 = 0
7:0/0 = 0
8:0/0 = 0
9:0/0 = 0
10:0/0 = 0
11:0/0 = 0
12:0/0 = 0
13:0/0 = 0
14:0/0 = 0
15:0/0 = 0
16:0/0 = 0
```

```
17:0/0 = 0
18:0/0 = 0
19:0/0 = 0
20:0/0 = 0
21:0/0 = 0
22:0/0 = 0
23:0/0 = 0
24:0/0 = 0
25:0/0 = 0
26:0/0 = 0
27:0/0 = 0
28:0/0 = 0
29:0/0 = 0
30:0/0 = 0
31:0/0 = 0
32:0/0 = 0
33:0/0 = 0
34:0/0 = 0
35:0/0 = 0
36:0/0 = 0
37:0/0 = 0
38:0/0 = 0
39:0/0 = 0
40:0/0 = 0
41:0/0 = 0
42:0/0 = 0
43:0/0 = 0
44:0/0 = 0
45:0/0 = 0
46:0/0 = 0
47:0/0 = 0
48:0/0 = 0
0:1/0 = 0
```

```
1:1/0 = 0
2:1/0 = 0
3:1/0 = 0
4:1/0 = 0
5:1/0 = 0
6:1/0 = 0
7:1/0 = 0
8:1/0 = 0
9:1/0 = 0
10:1/0 = 0
11:1/0 = 0
12:1/0 = 0
13:1/0 = 0
14:1/0 = 0
15:1/0 = 0
16:1/0 = 0
17:1/0 = 0
18:1/0 = 0
19:1/0 = 0
20:1/0 = 0
21:1/0 = 0
22:1/0 = 0
23:1/0 = 0
24:1/0 = 0
25:1/0 = 0
26:1/0 = 0
27:1/0 = 0
28:1/0 = 0
29:1/0 = 0
30:1/0 = 0
31:1/0 = 0
32:1/0 = 0
33:1/0 = 0
```

```
34:1/0 = 0
35:1/0 = 0
36:1/0 = 0
37:1/0 = 0
38:1/0 = 0
39:1/0 = 0
40:1/0 = 0
41:1/0 = 0
42:1/0 = 0
43:1/0 = 0
44:1/0 = 0
45:1/0 = 0
46:1/0 = 0
47:1/0 = 0
48:1/0 = 0
0:2/0 = 0
1:2/0 = 0
2:2/0 = 0
3:2/0 = 0
4:2/0 = 0
5:2/0 = 0
6:2/0 = 0
7:2/0 = 0
8:2/0 = 0
9:2/0 = 0
10:2/0 = 0
11:2/0 = 0
12:2/0 = 0
13:2/0 = 0
14:2/0 = 0
15:2/0 = 0
16:2/0 = 0
17:2/0 = 0
```

```
18:2/0 = 0
19:2/0 = 0
20:2/0 = 0
21:2/0 = 0
22:2/0 = 0
23:2/0 = 0
24:2/0 = 0
25:2/0 = 0
26:2/0 = 0
27:2/0 = 0
28:2/0 = 0
29:2/0 = 0
30:2/0 = 0
31:2/0 = 0
32:2/0 = 0
33:2/0 = 0
34:2/0 = 0
35:2/0 = 0
36:2/0 = 0
37:2/0 = 0
38:2/0 = 0
39:2/0 = 0
40:2/0 = 0
41:2/0 = 0
42:2/0 = 0
43:2/0 = 0
44:2/0 = 0
45:2/0 = 0
46:2/0 = 0
47:2/0 = 0
48:2/0 = 0
0:3/0 = 0
1:3/0 = 0
```

```
2:3/0 = 0
3:3/0 = 0
4:3/0 = 0
5:3/0 = 0
6:3/0 = 0
7:3/0 = 0
8:3/0 = 0
9:3/0 = 0
10:3/0 = 0
11:3/0 = 0
12:3/0 = 0
13:3/0 = 0
14:3/0 = 0
15:3/0 = 0
16:3/0 = 0
17:3/0 = 0
18:3/0 = 0
19:3/0 = 0
20:3/0 = 0
21:3/0 = 0
22:3/0 = 0
23:3/0 = 0
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25:3/0 = 0
26:3/0 = 0
27:3/0 = 0
28:3/0 = 0
29:3/0 = 0
30:3/0 = 0
31:3/0 = 0
32:3/0 = 0
33:3/0 = 0
34:3/0 = 0
```

```
35:3/0 = 0
36:3/0 = 0
37:3/0 = 0
38:3/0 = 0
39:3/0 = 0
40:3/0 = 0
41:3/0 = 0
42:3/0 = 0
43:3/0 = 0
44:3/0 = 0
45:3/0 = 0
46:3/0 = 0
47:3/0 = 0
48:3/0 = 0
0:4/0 = 0
1:4/0 = 0
2:4/0 = 0
3:4/0 = 0
4:4/0 = 0
5:4/0 = 0
6:4/0 = 0
7:4/0 = 0
8:4/0 = 0
9:4/0 = 0
10:4/0 = 0
11:4/0 = 0
12:4/0 = 0
13:4/0 = 0
14:4/0 = 0
15:4/0 = 0
16:4/0 = 0
17:4/0 = 0
18:4/0 = 0
```

```
19:4/0 = 0
20:4/0 = 0
21:4/0 = 0
22:4/0 = 0
23:4/0 = 0
24:4/0 = 0
25:4/0 = 0
26:4/0 = 0
27:4/0 = 0
28:4/0 = 0
29:4/0 = 0
30:4/0 = 0
31:4/0 = 0
32:4/0 = 0
33:4/0 = 0
34:4/0 = 0
35:4/0 = 0
36:4/0 = 0
37:4/0 = 0
38:4/0 = 0
39:4/0 = 0
40:4/0 = 0
41:4/0 = 0
42:4/0 = 0
43:4/0 = 0
44:4/0 = 0
45:4/0 = 0
46:4/0 = 0
47:4/0 = 0
48:4/0 = 0
0:5/0 = 0
1:5/0 = 0
2:5/0 = 0
```

```
3:5/0 = 0
4:5/0 = 0
5:5/0 = 0
6:5/0 = 0
7:5/0 = 0
8:5/0 = 0
9:5/0 = 0
10:5/0 = 0
11:5/0 = 0
12:5/0 = 0
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14:5/0 = 0
15:5/0 = 0
16:5/0 = 0
17:5/0 = 0
18:5/0 = 0
19:5/0 = 0
20:5/0 = 0
21:5/0 = 0
22:5/0 = 0
23:5/0 = 0
24:5/0 = 0
25:5/0 = 0
26:5/0 = 0
27:5/0 = 0
28:5/0 = 0
29:5/0 = 0
30:5/0 = 0
31:5/0 = 0
32:5/0 = 0
33:5/0 = 0
34:5/0 = 0
35:5/0 = 0
```

```
36:5/0 = 0
37:5/0 = 0
38:5/0 = 0
39:5/0 = 0
40:5/0 = 0
41:5/0 = 0
42:5/0 = 0
43:5/0 = 0
44:5/0 = 0
45:5/0 = 0
46:5/0 = 0
47:5/0 = 0
48:5/0 = 0
0:6/0 = 0
1:6/0 = 0
2:6/0 = 0
3:6/0 = 0
4:6/0 = 0
5:6/0 = 0
6:6/0 = 0
7:6/0 = 0
8:6/0 = 0
9:6/0 = 0
10:6/0 = 0
11:6/0 = 0
12:6/0 = 0
13:6/0 = 0
14:6/0 = 0
15:6/0 = 0
16:6/0 = 0
17:6/0 = 0
18:6/0 = 0
19:6/0 = 0
```

```
20:6/0 = 0
21:6/0 = 0
22:6/0 = 0
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24:6/0 = 0
25:6/0 = 0
26:6/0 = 0
27:6/0 = 0
28:6/0 = 0
29:6/0 = 0
30:6/0 = 0
31:6/0 = 0
32:6/0 = 0
33:6/0 = 0
34:6/0 = 0
35:6/0 = 0
36:6/0 = 0
37:6/0 = 0
38:6/0 = 0
39:6/0 = 0
40:6/0 = 0
41:6/0 = 0
42:6/0 = 0
43:6/0 = 0
44:6/0 = 0
45:6/0 = 0
46:6/0 = 0
47:6/0 = 0
48:6/0 = 0
0:7/0 = 0
1:7/0 = 0
2:7/0 = 0
3:7/0 = 0
```

```
4:7/0 = 0
5:7/0 = 0
6:7/0 = 0
7:7/0 = 0
8:7/0 = 0
9:7/0 = 0
10:7/0 = 0
11:7/0 = 0
12:7/0 = 0
13:7/0 = 0
14:7/0 = 0
15:7/0 = 0
16:7/0 = 0
17:7/0 = 0
18:7/0 = 0
19:7/0 = 0
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27:7/0 = 0
28:7/0 = 0
29:7/0 = 0
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31:7/0 = 0
32:7/0 = 0
33:7/0 = 0
34:7/0 = 0
35:7/0 = 0
36:7/0 = 0
```

```
37:7/0 = 0
38:7/0 = 0
39:7/0 = 0
40:7/0 = 0
41:7/0 = 0
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43:7/0 = 0
44:7/0 = 0
45:7/0 = 0
46:7/0 = 0
47:7/0 = 0
48:7/0 = 0
0:8/0 = 0
1:8/0 = 0
2:8/0 = 0
3:8/0 = 0
4:8/0 = 0
5:8/0 = 0
6:8/0 = 0
7:8/0 = 0
8:8/0 = 0
9:8/0 = 0
10:8/0 = 0
11:8/0 = 0
12:8/0 = 0
13:8/0 = 0
14:8/0 = 0
15:8/0 = 0
16:8/0 = 0
17:8/0 = 0
18:8/0 = 0
19:8/0 = 0
20:8/0 = 0
```

421 21:8/0 = 0

422 22:8/0 = 0

423 23:8/0 = 0

424 24:8/0 = 0

425 25:8/0 = 0

426 26:8/0 = 0

427 27:8/0 = 0

428 28:8/0 = 0

429 29:8/0 = 0

430 30:8/0 = 0

431 31:8/0 = 0

432 32:8/0 = 0

433 33:8/0 = 0

434 34:8/0 = 0

435 35:8/0 = 0

436 36:8/0 = 0

437 37:8/0 = 0

438 38:8/0 = 0

439 39:8/0 = 0

440 40:8/0 = 0

441 41:8/0 = 0

442 42:8/0 = 0

443 43:8/0 = 0

444 44:8/0 = 0

445 45:8/0 = 0

446 46:8/0 = 0

447 47:8/0 = 0

448 48:8/0 = 0

449 0:9/0 = 0

450 1:9/0 = 0

451 2:9/0 = 0

452 3:9/0 = 0

453 4:9/0 = 0

```
5:9/0 = 0
6:9/0 = 0
7:9/0 = 0
8:9/0 = 0
9:9/0 = 0
10:9/0 = 0
11:9/0 = 0
12:9/0 = 0
13:9/0 = 0
14:9/0 = 0
15:9/0 = 0
16:9/0 = 0
17:9/0 = 0
18:9/0 = 0
19:9/0 = 0
20:9/0 = 0
21:9/0 = 0
22:9/0 = 0
23:9/0 = 0
24:9/0 = 0
25:9/0 = 0
26:9/0 = 0
27:9/0 = 0
28:9/0 = 0
29:9/0 = 0
30:9/0 = 0
31:9/0 = 0
32:9/0 = 0
33:9/0 = 0
34:9/0 = 0
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36:9/0 = 0
37:9/0 = 0
```

```
38:9/0 = 0
39:9/0 = 0
40:9/0 = 0
41:9/0 = 0
42:9/0 = 0
43:9/0 = 0
44:9/0 = 0
45:9/0 = 0
46:9/0 = 0
47:9/0 = 0
48:9/0 = 0
0:10/0 = 0
1:10/0 = 0
2:10/0 = 0
3:10/0 = 0
4:10/0 = 0
5:10/0 = 0
6:10/0 = 0
7:10/0 = 0
8:10/0 = 0
9:10/0 = 0
10:10/0 = 0
11:10/0 = 0
12:10/0 = 0
13:10/0 = 0
14:10/0 = 0
15:10/0 = 0
16:10/0 = 0
17:10/0 = 0
18:10/0 = 0
19:10/0 = 0
20:10/0 = 0
21:10/0 = 0
```

```
22:10/0 = 0
23:10/0 = 0
24:10/0 = 0
25:10/0 = 0
26:10/0 = 0
27:10/0 = 0
28:10/0 = 0
29:10/0 = 0
30:10/0 = 0
31:10/0 = 0
32:10/0 = 0
33:10/0 = 0
34:10/0 = 0
35:10/0 = 0
36:10/0 = 0
37:10/0 = 0
38:10/0 = 0
39:10/0 = 0
40:10/0 = 0
41:10/0 = 0
42:10/0 = 0
43:10/0 = 0
44:10/0 = 0
45:10/0 = 0
46:10/0 = 0
47:10/0 = 0
48:10/0 = 0
0:11/0 = 0
1:11/0 = 0
2:11/0 = 0
3:11/0 = 0
4:11/0 = 0
5:11/0 = 0
```

```
6:11/0 = 0
7:11/0 = 0
8:11/0 = 0
9:11/0 = 0
10:11/0 = 0
11:11/0 = 0
12:11/0 = 0
13:11/0 = 0
14:11/0 = 0
15:11/0 = 0
16:11/0 = 0
17:11/0 = 0
18:11/0 = 0
19:11/0 = 0
20:11/0 = 0
21:11/0 = 0
22:11/0 = 0
23:11/0 = 0
24:11/0 = 0
25:11/0 = 0
26:11/0 = 0
27:11/0 = 0
28:11/0 = 0
29:11/0 = 0
30:11/0 = 0
31:11/0 = 0
32:11/0 = 0
33:11/0 = 0
34:11/0 = 0
35:11/0 = 0
36:11/0 = 0
37:11/0 = 0
38:11/0 = 0
```

```
39:11/0 = 0
40:11/0 = 0
41:11/0 = 0
42:11/0 = 0
43:11/0 = 0
44:11/0 = 0
45:11/0 = 0
46:11/0 = 0
47:11/0 = 0
48:11/0 = 0
0:12/0 = 0
1:12/0 = 0
2:12/0 = 0
3:12/0 = 0
4:12/0 = 0
5:12/0 = 0
6:12/0 = 0
7:12/0 = 0
8:12/0 = 0
9:12/0 = 0
10:12/0 = 0
11:12/0 = 0
12:12/0 = 0
13:12/0 = 0
14:12/0 = 0
15:12/0 = 0
16:12/0 = 0
17:12/0 = 0
18:12/0 = 0
19:12/0 = 0
20:12/0 = 0
21:12/0 = 0
22:12/0 = 0
```

```
23:12/0 = 0
24:12/0 = 0
25:12/0 = 0
26:12/0 = 0
27:12/0 = 0
28:12/0 = 0
29:12/0 = 0
30:12/0 = 0
31:12/0 = 0
32:12/0 = 0
33:12/0 = 0
34:12/0 = 0
35:12/0 = 0
36:12/0 = 0
37:12/0 = 0
38:12/0 = 0
39:12/0 = 0
40:12/0 = 0
41:12/0 = 0
42:12/0 = 0
43:12/0 = 0
44:12/0 = 0
45:12/0 = 0
46:12/0 = 0
47:12/0 = 0
48:12/0 = 0
0:13/0 = 0
1:13/0 = 0
2:13/0 = 0
3:13/0 = 0
4:13/0 = 0
5:13/0 = 0
6:13/0 = 0
```

```
7:13/0 = 0
8:13/0 = 0
9:13/0 = 0
10:13/0 = 0
11:13/0 = 0
12:13/0 = 0
13:13/0 = 0
14:13/0 = 0
15:13/0 = 0
16:13/0 = 0
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18:13/0 = 0
19:13/0 = 0
20:13/0 = 0
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23:13/0 = 0
24:13/0 = 0
25:13/0 = 0
26:13/0 = 0
27:13/0 = 0
28:13/0 = 0
29:13/0 = 0
30:13/0 = 0
31:13/0 = 0
32:13/0 = 0
33:13/0 = 0
34:13/0 = 0
35:13/0 = 0
36:13/0 = 0
37:13/0 = 0
38:13/0 = 0
39:13/0 = 0
```

```
40:13/0 = 0
41:13/0 = 0
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48:14/0 = 0
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916 26:18/0 = 0

917 27:18/0 = 0

918 28:18/0 = 0

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921 31:18/0 = 0

922 32:18/0 = 0

923 33:18/0 = 0

924 34:18/0 = 0

925 35:18/0 = 0

926 36:18/0 = 0

927 37:18/0 = 0

928 38:18/0 = 0

929 39:18/0 = 0

930 40:18/0 = 0

931 41:18/0 = 0

932 42:18/0 = 0

933 43:18/0 = 0

934 44:18/0 = 0

935 45:18/0 = 0

936 46:18/0 = 0

937 47:18/0 = 0

938 48:18/0 = 0

939 0:19/0 = 0

940 1:19/0 = 0

941 2:19/0 = 0

942 3:19/0 = 0

943 4:19/0 = 0

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43:21/0 = 0
```

```
44:21/0 = 0
45:21/0 = 0
46:21/0 = 0
47:21/0 = 0
48:21/0 = 0

[sub_resource type="TileSet" id="TileSet_3drs5"]
sources/0 = SubResource("TileSetAtlasSource_6h0bd")

[node name="TileMap" type="TileMap"]
tile_set = SubResource("TileSet_3drs5")
format = 2
script = ExtResource("2_lf4lw")
```

C.4.5 tile_map.gd

```
extends TileMap

var points: Array[Dictionary] = []
const EUCLIDEAN: String = "Euclidean distance"
const MANHATTAN: String = "Manhattan distance"
@export_enum(EUCLIDEAN, MANHATTAN) var distance: String = MANHATTAN
@export_range(2, 6, 1) var random_starting_points: int = 4
var x_tile_range: int = ProjectSettings.get_setting("display/window
    /size/viewport_width") / tile_set.tile_size.x
var y_tile_range: int = ProjectSettings.get_setting("display/window
    /size/viewport_height") / tile_set.tile_size.y

# Called when the node enters the scene tree for the first time.
func _ready() -> void:
    randomize()
    for x in range(-50, x_tile_range + 50):
```

```
        for y in range(-50, y_tile_range + 50):
            set_cell(0, Vector2(x, y), 0, Vector2(0, 0))
    var start_time: float = Time.get_ticks_msec()
    define_points(random_starting_points)
    paint_points()
    var new_time: float = Time.get_ticks_msec() - start_time
    print("Time taken: " + str(new_time) + "ms")

func paint_points() -> void:
    for point in points:
        set_cell(0, Vector2(point["x"], point["y"]), 0, point["type"])
        for citizen in point["citizens"]:
            set_cell(0, Vector2(point["x"] + citizen["dx"], point["y"] + citizen["dy"]), 0, point["type"])

func _squared(x: int) -> int:
    return x ** 2

func calculate_points_delta(x: int, y: int, p: int) -> float:
    if distance == EUCLIDEAN:
        return sqrt(_squared(points[p]["x"] - x) + _squared(points[p]["y"] - y))
    return abs(points[p]["x"] - x) + abs(points[p]["y"] - y)

func define_points(num_points: int) -> void:
    var types: Array[Vector2i] = [Vector2i(0,1),Vector2i(1,1),Vector2i(2,1),Vector2i(5,1),Vector2i(6,1),Vector2i(4,2)]
    for i in range(num_points):
        var x: int = randi_range(0, x_tile_range)
        var y: int = randi_range(0, y_tile_range)
        var type: Vector2i = types.pick_random()
        types.erase(type)
```

```
        points.append(
            {
                "type": type,
                "x": x,
                "y": y,
                "citizens": []
            }
        )
    for x in range(x_tile_range):
        for y in range(y_tile_range):
            var lowest_delta: Dictionary = {
                "point_id": 0,
                "delta": x_tile_range * y_tile_range
            }
            for p in range(len(points)):
                var delta: float = calculate_points_delta(x, y, p)
                if delta < lowest_delta["delta"]:
                    lowest_delta = {
                        "point_id": p,
                        "delta": delta
                    }
                var active_point: Dictionary = points[lowest_delta["
                    point_id"]]
                var dx: int = x - active_point["x"]
                var dy: int = y - active_point["y"]
                active_point["citizens"].append(
                    {
                        "dx": dx,
                        "dy": dy
                    }
                )
```

C.4.6 icon.svg.import

```
[remap]

importer="texture"
type="CompressedTexture2D"
uid="uid://du4v6taw8ssax"
path="res://.godot/imported/icon.svg-218
    a8f2b3041327d8a5756f3a245f83b.ctex"
metadata={
"vram_texture": false
}

[deps]

source_file="res://icon.svg"
dest_files=["res://.godot/imported/icon.svg-218
    a8f2b3041327d8a5756f3a245f83b.ctex"]

[params]

compress/mode=0
compress/high_quality=false
compress/lossy_quality=0.7
compress/hdr_compression=1
compress/normal_map=0
compress/channel_pack=0
mipmaps/generate=false
mipmaps/limit=-1
roughness/mode=0
roughness/src_normal=""
process/fix_alpha_border=true
process/premult_alpha=false
```

```
process/normal_map_invert_y=false
process/hdr_as_srgb=false
process/hdr_clamp_exposure=false
process/size_limit=0
detect_3d/compress_to=1
svg/scale=1.0
editor/scale_with_editor_scale=false
editor/convert_colors_with_editor_theme=false
```

C.4.7 monochrome_packed.png.import

```
[remap]

importer="texture"
type="CompressedTexture2D"
uid="uid://cpign73sfbsrt"
path="res://.godot/imported/monochrome_packed.png-6
    b9bd1c64dd50f72acd3afd14d1ac34f.ctex"
metadata={
"vram_texture": false
}

[deps]

source_file="res://monochrome_packed.png"
dest_files=["res://.godot/imported/monochrome_packed.png-6
    b9bd1c64dd50f72acd3afd14d1ac34f.ctex"]

[params]

compress/mode=0
compress/high_quality=false
```

```
compress/lossy_quality=0.7
compress/hdr_compression=1
compress/normal_map=0
compress/channel_pack=0
mipmaps/generate=false
mipmaps/limit=-1
roughness/mode=0
roughness/src_normal=""
process/fix_alpha_border=true
process/premult_alpha=false
process/normal_map_invert_y=false
process/hdr_as_srgb=false
process/hdr_clamp_exposure=false
process/size_limit=0
detect_3d/compress_to=1
```

C.5 PoissonGD4

C.5.1 .gitattributes

```
# Normalize EOL for all files that Git considers text files.
* text=auto eol=lf
```

C.5.2 .gitignore

```
# Godot 4+ specific ignores
.godot/
```

C.5.3 project.godot

```
; Engine configuration file.
; It's best edited using the editor UI and not directly,
; since the parameters that go here are not all obvious.
;
; Format:
;   [section] ; section goes between []
;   param=value ; assign values to parameters

config_version=5

[application]

config/name="Poisson Sampling Project"
run/main_scene="res://tile_map.tscn"
config/features=PackedStringArray("4.0", "Forward Plus")
config/icon="res://icon.svg"

[display]

window/size/viewport_height=640

[rendering]

renderer/rendering_method="gl_compatibility"
```

C.5.4 tile_map.tscn

```
[gd_scene load_steps=5 format=3 uid="uid://f2kv7fettdo7"]

[ext_resource type="Texture2D" uid="uid://c3bpsm4r8t504" path="res
    ://monochrome_packed.png" id="1_uucm3"]
[ext_resource type="Script" path="res://tile_map.gd" id="2_iyhvf"]
```

```

[sub_resource type="TileSetAtlasSource" id="TileSetAtlasSource_j4usm"]
texture = ExtResource("1_uucm3")
0:0/0 = 0
1:0/0 = 0
2:0/0 = 0
3:0/0 = 0
4:0/0 = 0
5:0/0 = 0
6:0/0 = 0
7:0/0 = 0
8:0/0 = 0
9:0/0 = 0
10:0/0 = 0
11:0/0 = 0
12:0/0 = 0
13:0/0 = 0
14:0/0 = 0
15:0/0 = 0
16:0/0 = 0
17:0/0 = 0
18:0/0 = 0
19:0/0 = 0
20:0/0 = 0
21:0/0 = 0
22:0/0 = 0
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26:0/0 = 0
27:0/0 = 0
28:0/0 = 0
```

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29:0/0 = 0
30:0/0 = 0
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37:0/0 = 0
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39:0/0 = 0
40:0/0 = 0
41:0/0 = 0
42:0/0 = 0
43:0/0 = 0
44:0/0 = 0
45:0/0 = 0
46:0/0 = 0
47:0/0 = 0
48:0/0 = 0
0:1/0 = 0
1:1/0 = 0
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46:1/0 = 0
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5:2/0 = 0
6:2/0 = 0
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46:2/0 = 0
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48:2/0 = 0
0:3/0 = 0
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47:3/0 = 0
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6:4/0 = 0
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8:4/0 = 0
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12:4/0 = 0
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19:4/0 = 0
20:4/0 = 0
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22:4/0 = 0
23:4/0 = 0
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29:4/0 = 0
30:4/0 = 0
```

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31:4/0 = 0
32:4/0 = 0
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48:5/0 = 0
0:6/0 = 0
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45:8/0 = 0
46:8/0 = 0
47:8/0 = 0
48:8/0 = 0
0:9/0 = 0
1:9/0 = 0
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16:9/0 = 0
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36:9/0 = 0
37:9/0 = 0
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41:9/0 = 0
42:9/0 = 0
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45:9/0 = 0
46:9/0 = 0
47:9/0 = 0
48:9/0 = 0
0:10/0 = 0
```

```
1:10/0 = 0
2:10/0 = 0
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8:10/0 = 0
9:10/0 = 0
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15:10/0 = 0
16:10/0 = 0
17:10/0 = 0
18:10/0 = 0
19:10/0 = 0
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```

```
34:10/0 = 0
35:10/0 = 0
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42:10/0 = 0
43:10/0 = 0
44:10/0 = 0
45:10/0 = 0
46:10/0 = 0
47:10/0 = 0
48:10/0 = 0
0:11/0 = 0
1:11/0 = 0
2:11/0 = 0
3:11/0 = 0
4:11/0 = 0
5:11/0 = 0
6:11/0 = 0
7:11/0 = 0
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9:11/0 = 0
10:11/0 = 0
11:11/0 = 0
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16:11/0 = 0
17:11/0 = 0
```

```
18:11/0 = 0
19:11/0 = 0
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26:11/0 = 0
27:11/0 = 0
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31:11/0 = 0
32:11/0 = 0
33:11/0 = 0
34:11/0 = 0
35:11/0 = 0
36:11/0 = 0
37:11/0 = 0
38:11/0 = 0
39:11/0 = 0
40:11/0 = 0
41:11/0 = 0
42:11/0 = 0
43:11/0 = 0
44:11/0 = 0
45:11/0 = 0
46:11/0 = 0
47:11/0 = 0
48:11/0 = 0
0:12/0 = 0
1:12/0 = 0
```

```
2:12/0 = 0
3:12/0 = 0
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9:12/0 = 0
10:12/0 = 0
11:12/0 = 0
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```

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35:12/0 = 0
36:12/0 = 0
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43:12/0 = 0
44:12/0 = 0
45:12/0 = 0
46:12/0 = 0
47:12/0 = 0
48:12/0 = 0
0:13/0 = 0
1:13/0 = 0
2:13/0 = 0
3:13/0 = 0
4:13/0 = 0
5:13/0 = 0
6:13/0 = 0
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```

```
19:13/0 = 0
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34:13/0 = 0
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36:13/0 = 0
37:13/0 = 0
38:13/0 = 0
39:13/0 = 0
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41:13/0 = 0
42:13/0 = 0
43:13/0 = 0
44:13/0 = 0
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47:13/0 = 0
48:13/0 = 0
0:14/0 = 0
1:14/0 = 0
2:14/0 = 0
```

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3:14/0 = 0
4:14/0 = 0
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```
36:14/0 = 0
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45:14/0 = 0
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48:14/0 = 0
0:15/0 = 0
1:15/0 = 0
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18:15/0 = 0
19:15/0 = 0
```

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20:15/0 = 0
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4:16/0 = 0
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37:16/0 = 0
38:16/0 = 0
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21:17/0 = 0
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40:17/0 = 0
41:17/0 = 0
42:17/0 = 0
43:17/0 = 0
44:17/0 = 0
45:17/0 = 0
46:17/0 = 0
47:17/0 = 0
48:17/0 = 0
0:18/0 = 0
1:18/0 = 0
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5:18/0 = 0
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38:18/0 = 0
39:18/0 = 0
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41:18/0 = 0
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46:18/0 = 0
47:18/0 = 0
48:18/0 = 0
0:19/0 = 0
1:19/0 = 0
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41:19/0 = 0
42:19/0 = 0
43:19/0 = 0
44:19/0 = 0
45:19/0 = 0
46:19/0 = 0
47:19/0 = 0
48:19/0 = 0
0:20/0 = 0
1:20/0 = 0
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5:20/0 = 0
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6:20/0 = 0
7:20/0 = 0
8:20/0 = 0
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25:20/0 = 0
26:20/0 = 0
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31:20/0 = 0
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1027 39:20/0 = 0

1028 40:20/0 = 0

1029 41:20/0 = 0

1030 42:20/0 = 0

1031 43:20/0 = 0

1032 44:20/0 = 0

1033 45:20/0 = 0

1034 46:20/0 = 0

1035 47:20/0 = 0

1036 48:20/0 = 0

1037 0:21/0 = 0

1038 1:21/0 = 0

1039 2:21/0 = 0

1040 3:21/0 = 0

1041 4:21/0 = 0

1042 5:21/0 = 0

1043 6:21/0 = 0

1044 7:21/0 = 0

1045 8:21/0 = 0

1046 9:21/0 = 0

1047 10:21/0 = 0

1048 11:21/0 = 0

1049 12:21/0 = 0

1050 13:21/0 = 0

1051 14:21/0 = 0

1052 15:21/0 = 0

1053 16:21/0 = 0

1054 17:21/0 = 0

1055 18:21/0 = 0

1056 19:21/0 = 0

1057 20:21/0 = 0

1058 21:21/0 = 0

1059 22:21/0 = 0

```
23:21/0 = 0
24:21/0 = 0
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31:21/0 = 0
32:21/0 = 0
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42:21/0 = 0
43:21/0 = 0
44:21/0 = 0
45:21/0 = 0
46:21/0 = 0
47:21/0 = 0
48:21/0 = 0

[sub_resource type="TileSet" id="TileSet_8pb5m"]
sources/0 = SubResource("TileSetAtlasSource_j4usm")

[node name="TileMap" type="TileMap"]
tile_set = SubResource("TileSet_8pb5m")
format = 2
```

```
script = ExtResource("2_iyhvf")
```

C.5.5 tile_map.gd

```
extends TileMap

var cell_points: Array[Vector2]
@export var point_radius: float = 1.0
@export var region_size: Vector2 = Vector2.ONE
@export var rejection_samples: int = 30

var x_tile_range: int = ProjectSettings.get_setting("display/window/size/viewport_width") / tile_set.tile_size.x
var y_tile_range: int = ProjectSettings.get_setting("display/window/size/viewport_height") / tile_set.tile_size.y

# Called when the node enters the scene tree for the first time.
func _ready():
	randomize()
	for x in range(-50, x_tile_range + 50):
		for y in range(-50, y_tile_range + 50):
			set_cell(0, Vector2(x, y), 0, Vector2(0, 0))
	cell_points = generate_points(point_radius, region_size, rejection_samples)

func generate_points(radius: float, sample_region_size: Vector2, number_of_samples_before_rejection: int = 30) -> Array[Vector2]:
	var cell_size: float = radius / sqrt(2)
	var grid: Array[Array] = []
	var points: Array[Vector2] = []
	var spawn_points: Array[Vector2] = []
```

```
	spawn_points.append(sample_region_size/2)

	while spawn_points.size() > 0:
		var spawn_index: int = randi_range(0, spawn_points.size() - 1)
		var spawn_centre: Vector2 = spawn_points[spawn_index]
		var candidate_accepted: bool = false

		for i in range(number_of_samples_before_rejection):
			var angle: float = randf_range(0.0, 1.0) * TAU # TAU = PI * 2
			var direction: Vector2 = Vector2(sin(angle), cos(angle))
			var candidate: Vector2 = spawn_centre + direction * randf_range(radius, 2 * radius)
			if is_valid(candidate, sample_region_size, cell_size, radius, points, grid):
				points.append(candidate)
				spawn_points.append(candidate)
				grid[int(candidate.x/cell_size)][int(candidate.y/cell_size)] = len(points)
				candidate_accepted = true
				break

		if not candidate_accepted:
			spawn_points.remove_at(spawn_index)

	return points

func is_valid(candidate: Vector2, sample_region_size: Vector2, cell_size: float, radius: float, points: Array[Vector2], grid: Array[Array]):
	if candidate.x >= 0 and candidate.x < sample_region_size.x and
```

```
            candidate.y >= 0 and candidate.y < sample_region_size.y:
        var cell_x: int = candidate.x / cell_size
        var cell_y: int = candidate.y / cell_size
        var search_start_x: int = max(0, cell_x - 2)
        var search_end_x: int = min(cell_x + 2, x_tile_range - 1)
        var search_start_y: int = max(0, cell_y - 2)
        var search_end_y: int = min(cell_y + 2, y_tile_range - 1)
        for x in range(search_start_x, search_end_x):
            for y in range(search_start_y, search_end_y):
                var point_index: int = grid[x][y]
                if point_index != -1:
                    var distance: float = (candidate - points[
                        point_index]).length()
                    if distance < radius:
                        return false
        return true
    return false
```

C.5.6 icon.svg.import

```
[remap]

importer="texture"
type="CompressedTexture2D"
uid="uid://uotfe6soknht"
path="res://.godot/imported/icon.svg-218
    a8f2b3041327d8a5756f3a245f83b.ctex"
metadata={
"vram_texture": false
}

[deps]
```

```

source_file="res://icon.svg"
dest_files=["res://.godot/imported/icon.svg-218a8f2b3041327d8a5756f3a245f83b.ctex"]

[params]

compress/mode=0
compress/high_quality=false
compress/lossy_quality=0.7
compress/hdr_compression=1
compress/normal_map=0
compress/channel_pack=0
mipmaps/generate=false
mipmaps/limit=-1
roughness/mode=0
roughness/src_normal=""
process/fix_alpha_border=true
process/premult_alpha=false
process/normal_map_invert_y=false
process/hdr_as_srgb=false
process/hdr_clamp_exposure=false
process/size_limit=0
detect_3d/compress_to=1
svg/scale=1.0
editor/scale_with_editor_scale=false
editor/convert_colors_with_editor_theme=false
```

C.5.7 monochrome_packed.png.import

```
[remap]

```

```
importer="texture"
type="CompressedTexture2D"
uid="uid://c3bpsm4r8t504"
path="res://.godot/imported/monochrome_packed.png-6b9bd1c64dd50f72acd3afd14d1ac34f.ctex"
metadata={
"vram_texture": false
}

[deps]

source_file="res://monochrome_packed.png"
dest_files=["res://.godot/imported/monochrome_packed.png-6b9bd1c64dd50f72acd3afd14d1ac34f.ctex"]

[params]

compress/mode=0
compress/high_quality=false
compress/lossy_quality=0.7
compress/hdr_compression=1
compress/normal_map=0
compress/channel_pack=0
mipmaps/generate=false
mipmaps/limit=-1
roughness/mode=0
roughness/src_normal=""
process/fix_alpha_border=true
process/premult_alpha=false
process/normal_map_invert_y=false
process/hdr_as_srgb=false
process/hdr_clamp_exposure=false
process/size_limit=0
```

```
detect_3d/compress_to=1
```