

Code Complexity and Coverage in the Godot Engine

Assignment 3 in DD2480

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1 Project

Name: The Godot Game Engine

URL: <https://github.com/godotengine/godot>

OUR REPO URL: <https://github.com/Teonord/godot-DD2480>

Godot is a open-source, free to use Game Engine for 2D and 3D projects. It is the engine of choice for many popular Indie games, such as Buckshot Roulette, Brotato and Luck be a Landlord.

2 Onboarding Experience

Godot, as a very open-source friendly project, has a detailed documentation stating pretty much everything one could need to start helping with developement of the engine¹. After fiddling a bit with WSL and not having any luck, it was realized that building straight in Windows was much easier. All one needed to do was to install the Python Software Construction Tool called SCons through PIP, and then run it with the command prompt inside of the Godot folder. This folder has all the files necessary for SCons to understand what and how to compile, and it installs all dependencies automatically. It also detected our operating system and compiled immediately as an executable for Windows, which meant it was easy to test that the compiled version worked. First compilation takes quite a while, but the compilation finishes with no major errors.

For running the tests, we just had to compile the project with the command `scons tests=yes`, and then run the generated executable with a special flag by calling `bin\godot.windows.tools.x86_64.exe`

¹<https://docs.godotengine.org/en/latest/contributing/development/compiling/index.html>

--test. More information about the testing can be found in the Godot Docs². Running the tests show some errors, but these seem to be purposeful as all 1171 tests run with success, though one test is skipped.

3 Complexity

Linus: I have chosen to look at `get_euler()` function in `core/math/basis.cpp`, start line 457. It is a method that computes and returns Euler angles from a given 3x3 matrix. When running with Lizard we get a CCN of 29. We also get 29, or 30 if including the function start itself. The function has a total of 141 lines of code, which means that it on average contains a path on every 5 lines. Most of these are single line `if()` containers or `case()`. According to our best guess, the tool (Lizard) does not take the function start in consideration. The documentation of the function is not clear about the different possible outcomes.

Teo: The part that I focused on is `intersects_transformed` from `/core/math/rect2.cpp`. It is a method that checks whether a transformed rectangle in 2D space would intersect with the current rectangle. When running with Lizard, this function gets a CCN of 26, which is unlike manually counted 25. This may be because Lizard counts the `#ifdef` as an extra `if` statement. To get our value, we still need to assume that compiler pre-directive `MATH_CHECKS` is defined. With a total of 133 lines of code, the function is quite cyclomatically complex, with a new path on average every ≈ 5 lines. However, almost all of these are just leading to the same points and furthering the program to the next jump, so they are single line `if` containers. There are no exceptions in this function, but if there are faulty arguments or problems in the called methods that we counted the CCN would rise dramatically. The documentation³ does not mention this function at all.

Rifat: I chose to look at `et_closest_points_between_segments` from `/core/math/geometry_3d.cpp`. It tries to find the closes point between two vectors. The closest points are then stored in the location given by two pointers that are passed in as arguments. Running lizard on `geometry_3d.cpp` gives CCN of 28 on the function. My manual count yields 29 CCN. To calculate the CCN i made a control flow graph and counted edges and nodes, although I didn't include the ternary operators in it and just counted them. The documentation of what the function does is fairly clear⁴. Or well technically there is no documentation for the function as it is a helper function to the documented function (its not private though) so technically it should be documented but its not.

²https://docs.godotengine.org/en/stable/contributing/development/core_and_modules/unit_testing.html

³https://docs.godotengine.org/en/stable/classes/class_rect2.html

⁴https://docs.godotengine.org/en/stable/classes/class_geometry3d.html#class-geometry3d-method-get-closest-points-between-segments

4 Refactoring

Linus: The `get_euler()` function contains much code replication. Each euler order follows a similar structure with minor variations. Thus, we could refactor by introducing a helper function with the repeated logic for getting the euler angles while handling singularities (gimbal lock cases). This helper function would take the relevant matrix value, row indices and sign adjustments to calculate the angles. By doing this, we would replace six very similar code segments with a single function call per euler order. With this, `get_euler()` would go from a CCN of 29 (or 30), to a CCN of 29 (or 30) - 22, since there are a total of 22 `if` statements and extra `&&` within the logic that will be moved to the helper function. Although the actual helper function would of course add cyclomatic complexity. This refactoring would result in much more readable and less cyclomatic complex code in `get_euler()`. However, there might be a slight performance impact by introducing extra function calls, although it should be minimal. I decided not to implement my refactor.

Teo: The `intersects_transformed` has several goto-points, which not only is generally considered bad practice but can also be easily replaced by functions. So, to start the refactor, we will put each jump destination into a separate helper function. We can also move the first goto check, as the code is very similar to that used in the jump segments. Now, instead of one function with a CCN of 25, we have 6 functions with the main function having a CCN of 9 and all others having a CCN of 5. This gives a TOTAL CCN 9 higher than the original, which makes sense considering we are adding 5 functions and adding a return point in an `if` statement for each of these, while not removing any paths. Each function now tests for one individual aspect necessary for intersection and returns true if intersection is possible, with the final function being the one who decides if intersection actually is happening or not. The impact of this refactoring is slightly more readable code, and much improved cyclomatic complexity - however, calling several functions does have an ever so slight performance impact from having to keep track of arguments and returns. These functions in specific all only require a pointer as an argument, however, which hopefully alleviates this. The git diff for the refactoring can be found here: <https://github.com/Teonord/godot-DD2480/commit/c4ad089dd60a0a7cc39fb175d788bde492e2c902>.

Rifat: **Planning:** The reason the CCN is so high on `geometry_3d::get_closest_points_between_segments` is because it has so many `if` and `else` statements, and then on top of that it has a lot of ternary operations which in themselves are `if else` statements. Easiest way to reduce the CCN for the function is to just split it up to different functions, one way to do that would be maybe to have the computation for parallel vectors in one function and non-parallel in another function. Although maybe it doesn't yield the most satisfactory result. The ternary operators in the functions do the same thing though, so I could possibly swap out that for a function instead. Drawback of first solution would be that it would be same code and it would also just be another function and more code. The drawback of both solutions is that we add another function albeit private, but could be potentially less code, and less complexity in the primary function.

Implementation: I decided to only implement the second solution: a helper function to swap

out the ternary operators that were essentially all doing the same thing (limiting the value between a floor and ceiling), that took the CCN of the original function from 29 to 12, the helper function has a CCN of 3. Together they have a CCN of 15. Individually the function has 16 less CCN from original which is a reduction of $\approx 57\%$. And if you calculate the helper function to it is a reduction of $\approx 46\%$. The git diff of the refactoring can be found here: <https://github.com/Teonord/godot-DD2480/pull/26/files>

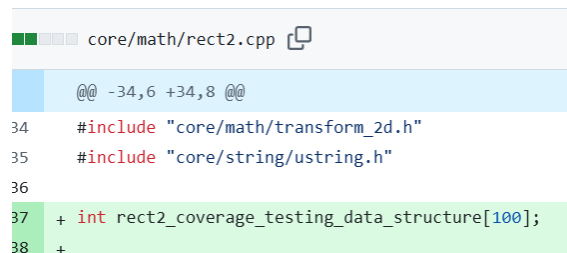
Drawback of the solution is potentially that it is slower, but you could probably do inline instead of a function to make it faster, although I'm not completely sure about how the compiler would compile this.

5 Coverage

5.1 Our Own Coverage Tool

To gather data around coverage, we used a simple 100 object list of ints that would be global when running tests. This will keep track of which branches has been taken by simply adding one to an index when the code passes through the point defined by that index. This is then printed after the tests have been run, giving us full coverage knowledge about our functions (assuming they are instrumented correctly).

For the `intersects_transformed` method, this is how the instrumentation looked.



```
core/math/rect2.cpp
@@ -34,6 +34,8 @@
34  #include "core/math/transform_2d.h"
35  #include "core/string/ustring.h"
36
37  + int rect2_coverage_testing_data_structure[100];
38  +
```

Figure 1: Adding of data structure for `Rect2::intersects_transformed` coverage testing.

```

28 core/math/rect2.cpp
108 108 }
109 109
110 110 bool Rect2::intersects_transformed(const Transform2D &p_xform, const Rect2 &p_rect) const {
111 + rect2_coverage_testing_data_structure[1]++;
112 +
113 113 #ifdef MATH_CHECKS
114 114 if (unlikely(size.x < 0 || size.y < 0 || p_rect.size.x < 0 || p_rect.size.y < 0)) {
115 + if (unlikely(size.x < 0)) rect2_coverage_testing_data_structure[2]++;
116 + if (unlikely(size.y < 0)) rect2_coverage_testing_data_structure[3]++;
117 + if (unlikely(p_rect.size.x < 0)) rect2_coverage_testing_data_structure[4]++;
118 + if (unlikely(p_rect.size.y < 0)) rect2_coverage_testing_data_structure[5]++;
119 ERR_PRINT("Rect2 size is negative, this is not supported. Use Rect2.abs() to get a Rect2 with a positive size.");
120 }
121 #endif
122 122
123 123 @@ -127,15 +133,19 @@ bool Rect2::intersects_transformed(const Transform2D &p_xform, const Rect2 &p_re
124 //base rect2 first (faster)
125 125
126 126 if (xf_points[0].y > position.y) {
127 + rect2_coverage_testing_data_structure[6]++;
128 goto next1;
129 }
130 130
131 131 if (xf_points[1].y > position.y) {
132 + rect2_coverage_testing_data_structure[7]++;
133 goto next1;
134 }
135 135
136 136 if (xf_points[2].y > position.y) {
137 + rect2_coverage_testing_data_structure[8]++;
138 goto next1;
139 }
140 140
141 141 }
142 142
143 143 }
144 144
145 145
146 146

```

Figure 2: This is a sample of the coverage calculation done within the intersects_transformed function.

5.2 Evaluation

- How detailed is your coverage measurement?
 - Our coverage measurement is as detailed as we want to make it. It can cover every path, if we make it do so. If there is a ternary condition or an OR within an if, all that is required is to create another check for each one. This can give us details about exactly which branches are tested and which are not.
- What are the limitations of your own tool?
 - An issue with our tool is that it potentially introduces extra if statements that will be necessary to add values when the path is within a ternary condition or an or statement in an if. This would technically make the function more cyclomatically complex. However, this is only done for testing, and these checks would be removed in the case of developing production code. It is certainly something worth considering, however. There's also no testing done for the entire paths, only which branches that the tests cross on their way to the end. This means we only know that one execution has gotten into a specific branch, not which branches led us to there.
- Are the results of your tool consistent with existing coverage tools?
 - Because of the size of Godot, it was hard to manage to get an existing coverage tool to

```

latest status: SUCCESS!
Path 0 was covered 0 times.
Path 1 was covered 11 times.
Path 2 was covered 0 times.
Path 3 was covered 0 times.
Path 4 was covered 0 times.
Path 5 was covered 0 times.
Path 6 was covered 6 times.
Path 7 was covered 1 times.
Path 8 was covered 2 times.
Path 9 was covered 0 times.
Path 10 was covered 6 times.
Path 11 was covered 0 times.
Path 12 was covered 0 times.
Path 13 was covered 0 times.
Path 14 was covered 2 times.
Path 15 was covered 4 times.
Path 16 was covered 0 times.
Path 17 was covered 0 times.
Path 18 was covered 6 times.
Path 19 was covered 0 times.
Path 20 was covered 0 times.
Path 21 was covered 0 times.
Path 22 was covered 0 times.
Path 23 was covered 0 times.
Path 24 was covered 0 times.

```

Figure 3: intersects_transformed code coverage after the addition of four new tests.

work within the program. However, we have found nothing that would point towards our program getting any different responses than they would get.

6 Coverage Improvement

Linus: For the `get_euler()` function almost all branches were already tested. The only branch that was not tested was `default`. Although, there were also lacking tests for scenarios that should be invalid (not visiting any branch). Two tests, aimed to reach the `default` branch, were implemented. One with an invalid input and one with a correct input that is corrupted before use. Two tests for invalid scenarios were also added. One test with a `nullptr` as input and one with an uninitialized order.

Teo: For the method `intersects_transformed`, there was actually no coverage at all when we begun. This meant that increasing coverage was easy - testing in the first place would improve coverage wildly. For this function a total of five test cases were added. One of these did not give correct answers on obviously correct input data, which makes us believe that the function does not work properly when `Rect2s` are scaled. This one had to be commented out. There are, however, still four fully functional test cases with a total of eleven assertions. Once the code is run again with our code coverage shown, the output looks like this:

The test cases can be found in the GitHub repository commit 109bb3⁵ in file `tests/core/math/test_rect2.h`.

Rifat: For the method `geometry_3d::get_closest_points_between_segments` very few branches are tested. Only 6 out of 17 branches are tested and that does not include ternary expressions as our

⁵<https://github.com/Teonord/godot-DD2480/pull/4/commits/109bb3992010c5a35cea79a345d4520b525d39ba>

tool cannot test those. Changes to the ternary expressions were made at some point but were changed back to the original. After adding four test cases for the function the coverage went to 11 out of 17 branches. So some improvement was gained. What exactly each branch is doing was kind of hard to understand though, so to improve the coverage I was kind of going with my gut thinking of different ways you can setup two vectors instead of looking at what the math in the function was doing, which isn't really the best approach, but it did yield an improvement. Test case can be found on <https://github.com/Teonord/godot-DD2480/pull/25/files#diff-916614ddbefa1d6062fa9e05d4870421f32c9aeaccd9a17c823d029723936d76>.

7 Self-Assessment: Way of Working

We kept on working with GitHub issues as we have before. Every group member was expected to count and work on coverage for one function each. All other tasks were collaborated on, as in previous assignments. The rest of the Essence standard self-assessment can be found in a separate PDF.

8 Overall Experience

Linus: I feel that there are not many tasks during studies that teach or require you to provide further work on an existing large project. Which I presume will be a very likely thing that we all have to do when we actually work. I find this task to be an interesting experience that I believe will be very useful later on.

Teo: Working in a large project like this was equal parts fun and pain. There's a lot of code to look through which is very interesting, and the documentation was generally really well written which was a good help. The painful part was mostly compiling, and occasionally understanding what a function was expecting from us. The compiling took a long time on my computer, and it wasn't bettered by the fact that nearly the entire codebase had to be re-compiled occasionally if the compilation failed because of an error. However, I have learned to not be quite as scared of working at these already developed programs, as there always seems to be room for improvement.

Rifat: Personally this was an interesting experience, I've always wanted to contribute to an open source project (or more specifically path of building community fork). But I've never really looked into how to do it, and now I have some general knowledge of how to go about doing it. When it comes to this project specifically, it is probably the first time I've had to modify and look into code written by someone else on something I initially had no clue on what it was doing or how.

This is also the first time I'm working on a big program that takes a long time to compile, normally I will every once in a while just do random things at see if things work. But this forced me to think through my changes before trying to compile as not doing so would just waste time.