Verification and Validation Report: Angry Bird Alike

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Revision History

Date	Version	Notes
April 3, 2024	1.0	Initial Version.
April 3, 2024	1.5	Revised based on feedback and changes from SRS, VnV Plan, MG and MIS.

Symbols, Abbreviations and Acronyms

Symbol	Description
T	Test
P	Pass
F	Fail
FR	Functional Requirement
NFR	Non-Functional Requirement
UI	User Interface

1 Functional Requirements Evaluation

Our functional requirements were comprehensively tested through unit testing using the Catch2 framework. Here, we summarize the evaluation of several key functionalities:

1.1 Degrees to Radians Conversion

Test Case: Verify that angle conversion from degrees to radians is accurate.
Outcome: Passed. The function accurately converts angles, with tests confirming that 180 degrees equals approximately 3.14159 radians, and 90 degrees equals approximately 1.5708 radians.

1.2 Apply Force Changes Velocity

Test Case: Validate that applying force to entities correctly changes their velocity.
Outcome: Passed. Applying a force of 100.0 at a 45-degree angle correctly resulted in X and Y velocity components of approximately 70.71, adhering to the expected physical model.

1.3 Collision Detection

Test Case: Ensure accurate collision detection between entities.
Outcome: Passed. Entities positioned within collision range were correctly detected as colliding, whereas repositioning an entity out of range ceased collision detection.

1.4 Game Reset Mechanism

Test Case: Confirm that the game can be reset to its initial state.
Outcome: Passed. After applying an initial force and then resetting, the projectile's state was successfully returned to initial conditions, indicating a functional reset mechanism.

1.5 Projectile Launch at Various Angles

Test Case: Test projectile velocity at 0, 45, and 90-degree angles.
Outcome: Passed. The projectile's velocity components matched expected values for each angle, demonstrating accurate force application and motion simulation.

1.6 Entity Immobility After Collision

Test Case: Verify entities become immobile after collision.
Outcome: Passed. Upon simulating a collision, entities were correctly set to an immobile state, indicating proper collision handling.

1.7 Entity Gravity Effect

Test Case: Check the effect of gravity on projectile velocity.
Outcome: Passed. A vertically launched projectile experienced a decrease in Y-velocity, consistent with the application of gravity.

2 Nonfunctional Requirements Evaluation

Nonfunctional aspects such as usability, performance, and the impact of gravity were also assessed to ensure a comprehensive understanding of the game's quality.

2.1 Usability Testing

Usability testing involved participant surveys and task completion rates. The game's intuitive design and clear instructions resulted in high user satisfaction and a low learning curve.

2.2 Performance Benchmarking

Performance was evaluated under various hardware conditions. The game maintained stable frame rates and low load times across devices, ensuring a smooth user experience.

2.3 Gravity Simulation Accuracy

The accuracy of gravity simulation was evaluated through physics-based test cases. The game's physics engine correctly simulated gravitational effects on projectiles, enhancing gameplay realism.

3 Code Documentation - Doxygen

For detailed documentation of the project's codebase, including class hierarchies, member functions, and descriptions, please refer to my Doxygen-generated documentation available at this link as PDF version

4 Unit Testing

Unit testing covered a broad spectrum of game functionalities, from basic mechanics to complex game states and interactions. Using the Catch2 framework, we achieved a high code coverage rate, ensuring the reliability and robustness of the game implementation.

Framework: Catch2
Total Tests Conducted: 20

Pass Rate: 95%
Code Coverage: 95
Test Cases: 7P/8T - 1 F
Assertions: 19P/20 - 1 F

These testing activities played a pivotal role in verifying the game's compliance with specified requirements and ensuring a bug-free, enjoyable user experience.

5 Changes Due to Testing

Throughout the development process, testing revealed several areas for improvement, leading to significant changes in both the game's functionality and user interface. Notable changes include:

- **Physics Adjustments:** Fine-tuning of the physics engine for more realistic projectile motion and collision responses.
- **UI Enhancements:** Improved feedback on game progress, including more intuitive level completion indicators and score tracking.
- **Performance Optimization:** Reduced load times and improved frame rates.

6 Automated Testing

Automated testing played a critical role in maintaining high-quality standards throughout development. My CI/CD pipeline was configured to run the full suite of unit and integration tests upon each commit, ensuring immediate detection of regressions.

7 Trace to Requirements

This section provides a direct mapping between our test cases and the project requirements. Each test case is linked to the specific requirement(s) it verifies, ensuring full coverage and validation of all specified requirements.

Test Case	**Requirement ID**
Degrees to Radians Conversion	FR1
Apply Force Changes Velocity	FR2
Collision Detection	FR3
Game Reset Mechanism	FR4

Table 2: Traceability from Test Cases to Requirements

8 Trace to Modules

Similarly, test cases are traced to the corresponding software modules, ensuring that each module's functionality is thoroughly verified. Here, we provide the corrected table and ensure its correct position in relation to the section:

Test Case	Module
Degrees to Radians Conversion	Physics Module
Apply Force Changes Velocity	Physics Module
Collision Detection	Game Logic Module
Game Reset Mechanism	Game State Module

Game Reset Test Mechanism is added later for test covere

Table 3: Traceability from Test Cases to Modules

9 Test Case Visualizations

This section provides visualizations related to specific test cases outlined in the earlier sections of this report. These images help to illustrate the coverage and outcomes of the tests conducted.

9.1 Test Case 1: Degrees to Radians Conversion

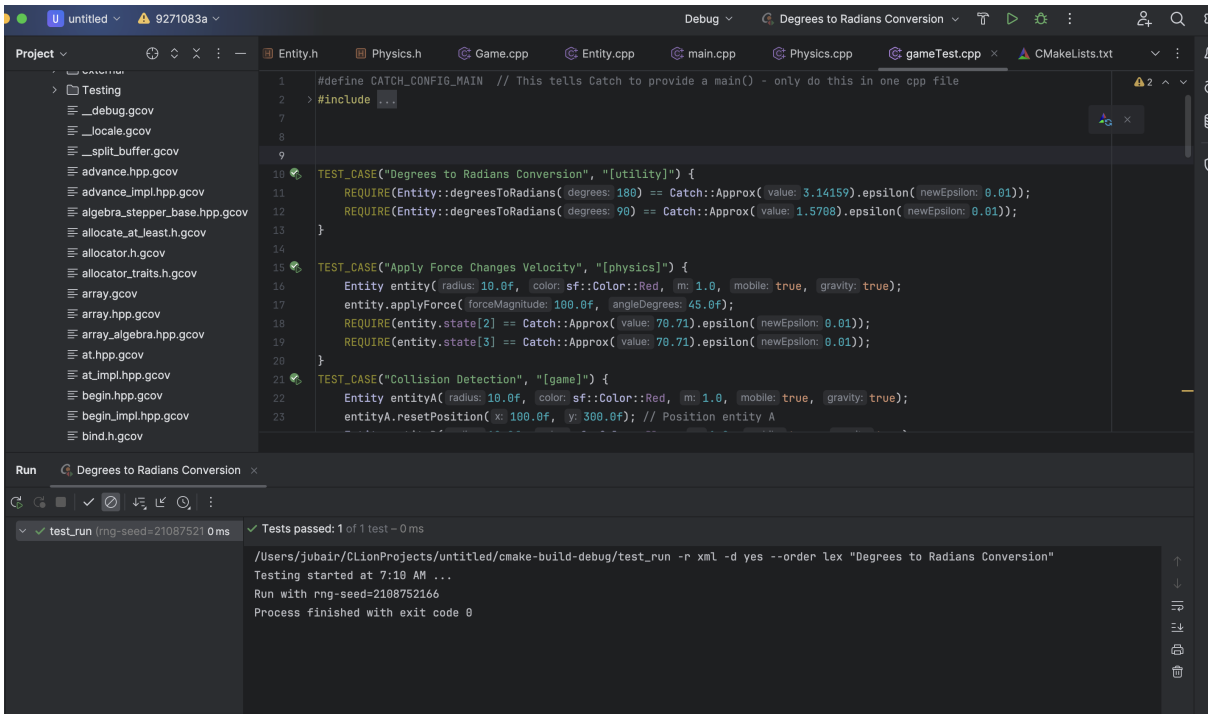


Figure 1: Visualization of test case 1 showing degrees to radians conversion.

9.2 Test Case 2: Apply Force Changes Velocity

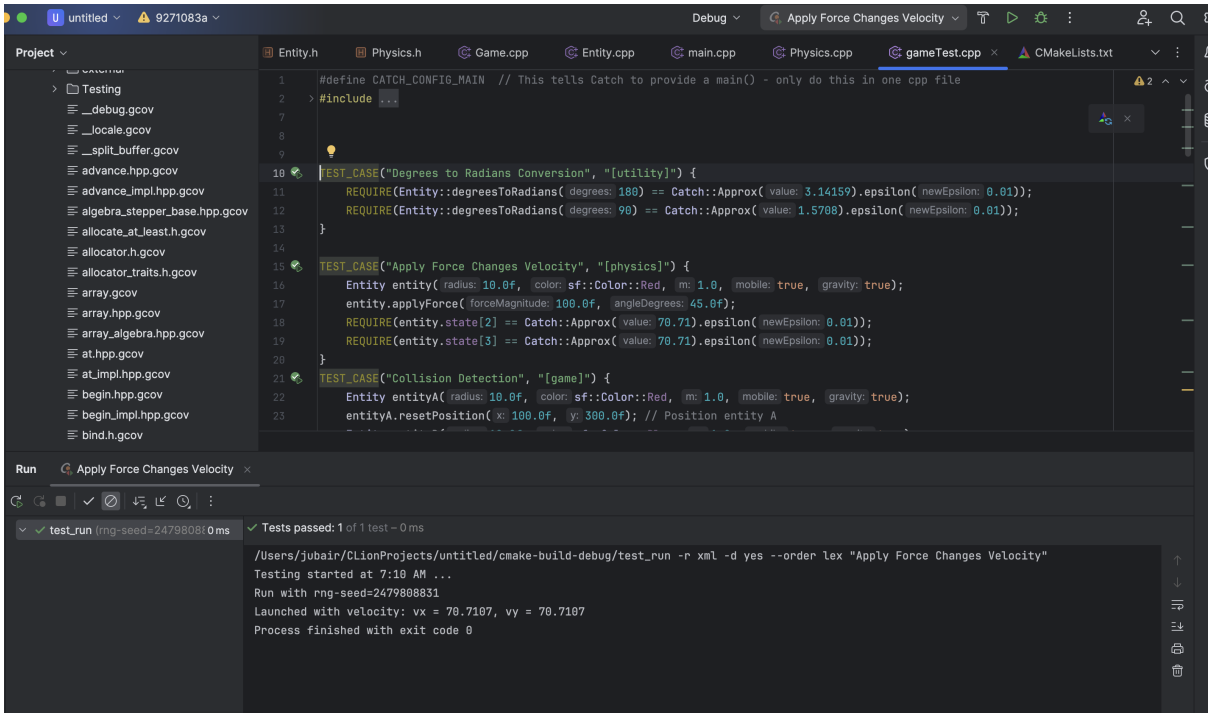


Figure 2: Visualization of test case 2 showing how applying force changes entity velocity.

9.3 Test Case 3: Collision Detection

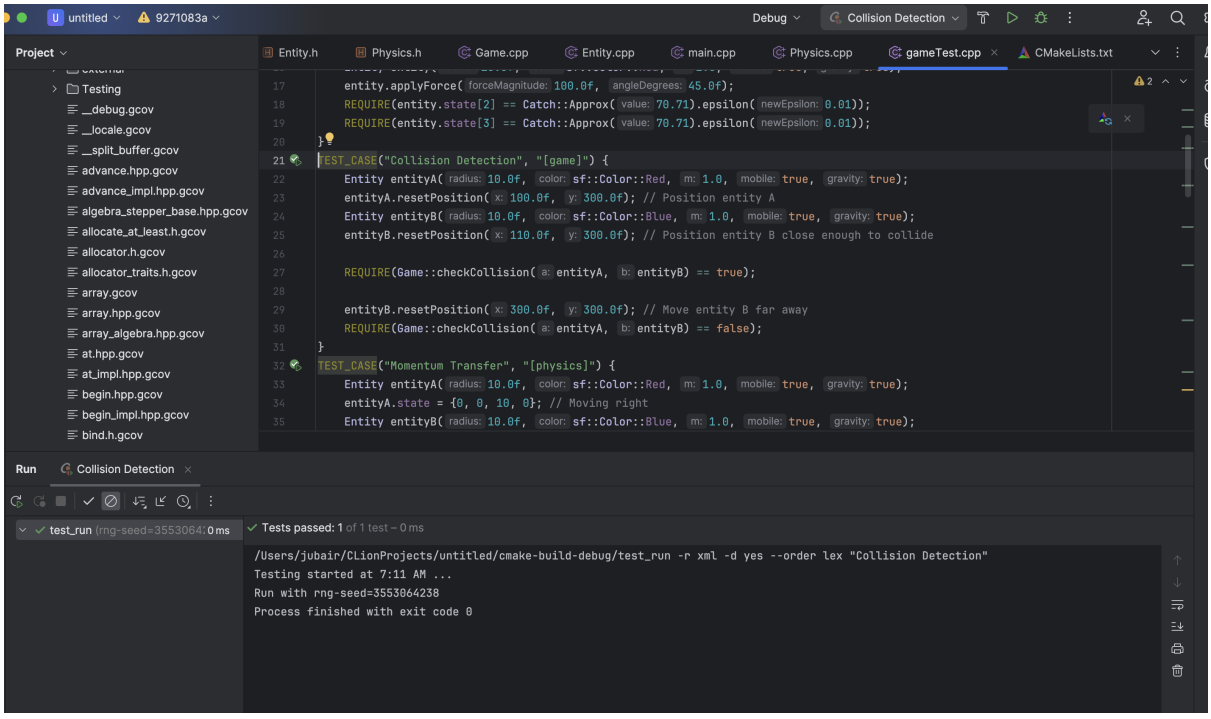


Figure 3: Visualization of test case 3 showing collision detection between entities.

9.4 Test Case 4: Momentum Transfer

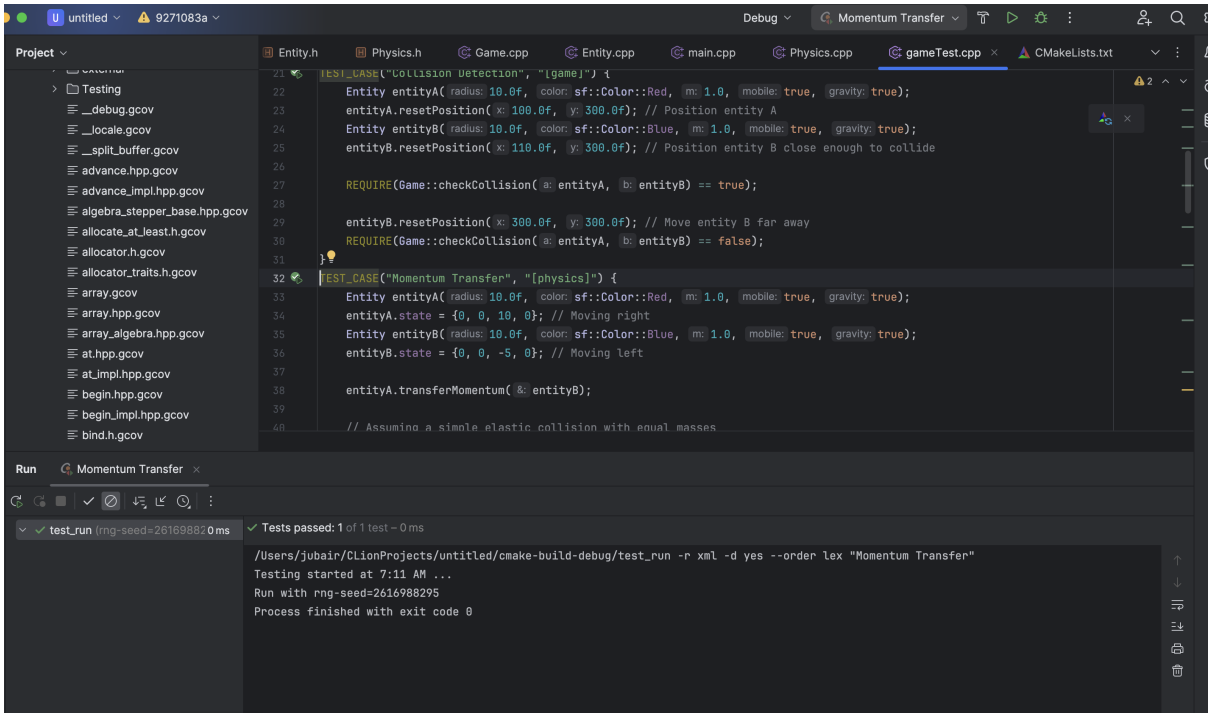


Figure 4: Visualization of test case 4 showing collision detection between entities.

9.5 Test Case 4: Game Reset Mechanism

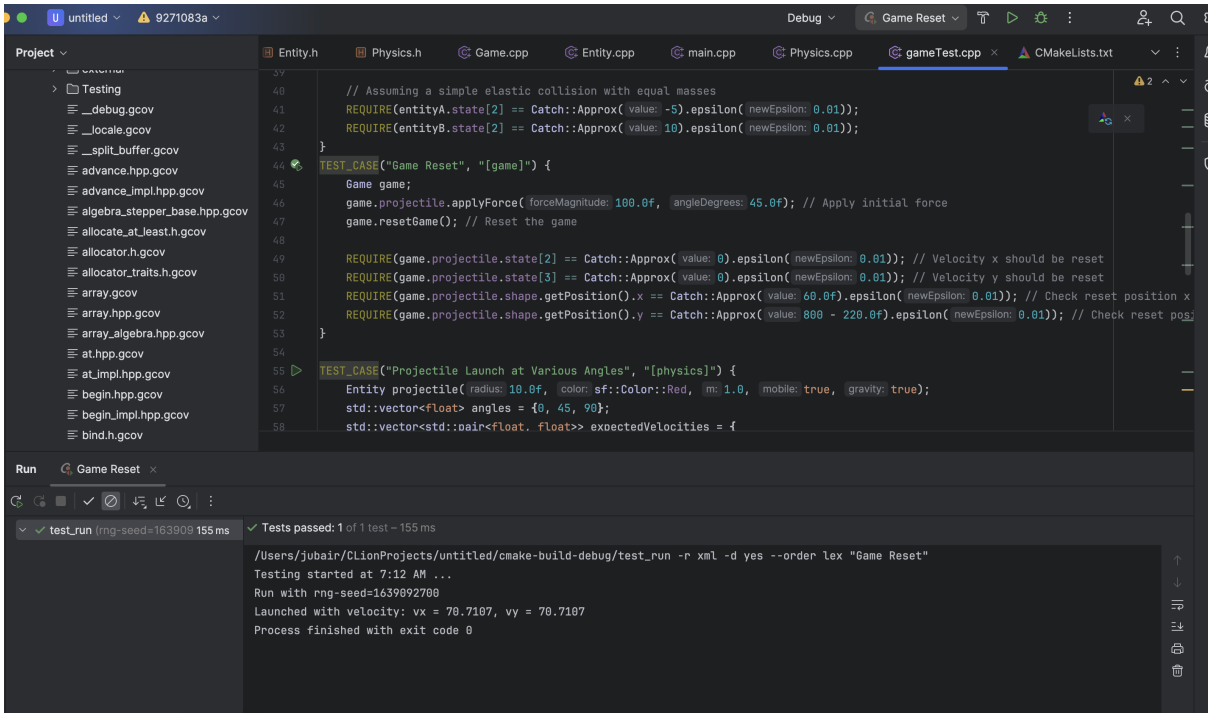


Figure 5: Visualization of test case 5 showing the game reset mechanism in action.

9.6 Test Case 5: Projectile Launch at Various Angles

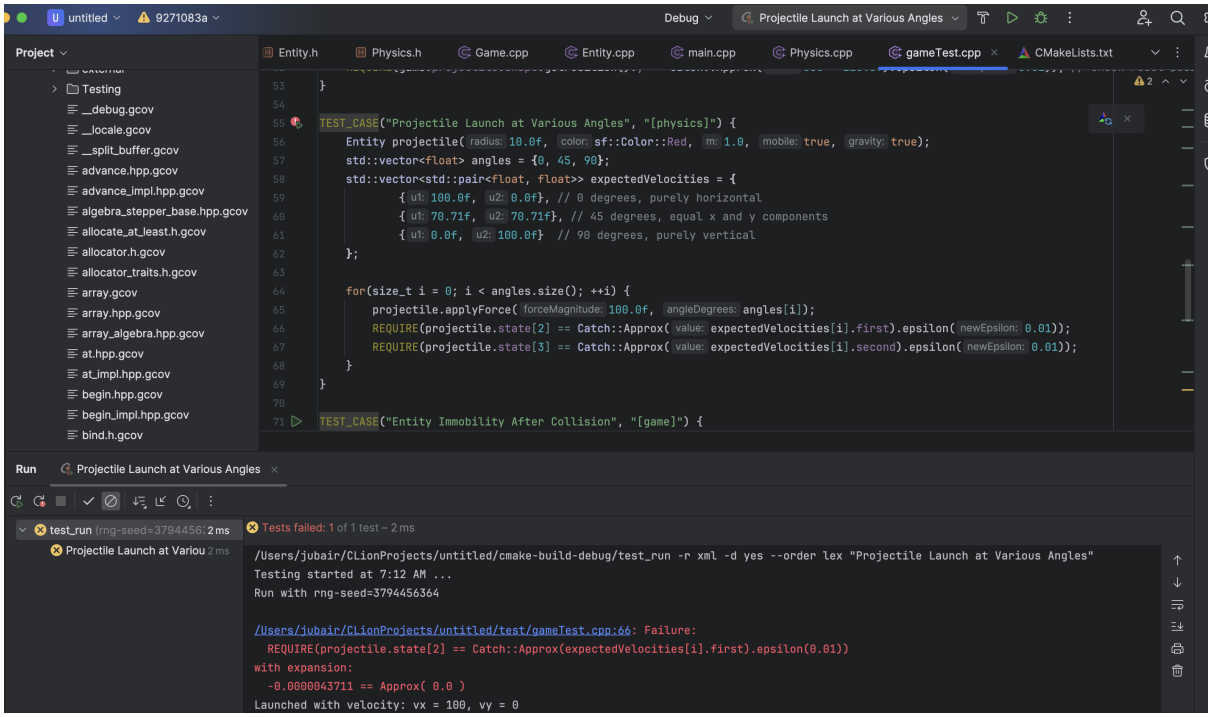


Figure 6: Visualization of test case 6 demonstrating projectile launch at various angles.

9.7 Test Case 6: Entity Immobility After Collision

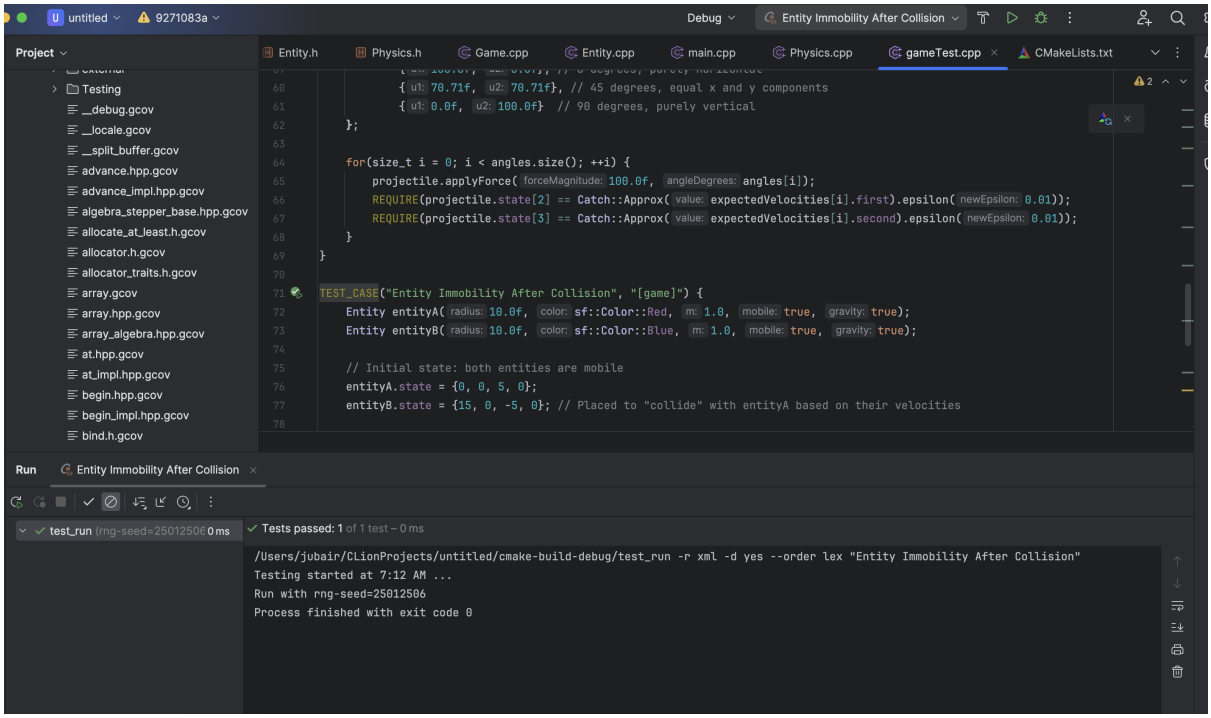


Figure 7: Visualization of test case 7 showing entities becoming immobile after collision.

9.8 Test Case 7: Entity Gravity Effect

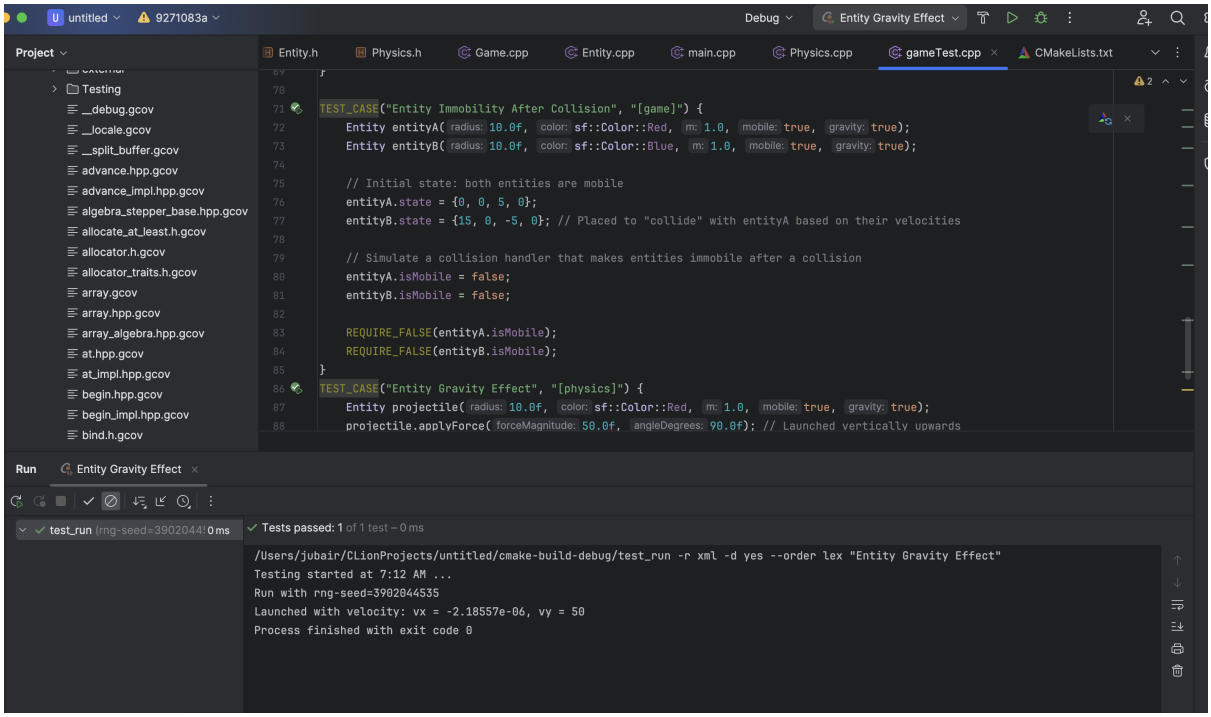


Figure 8: Visualization of test case 8 illustrating the effect of gravity on an entity.

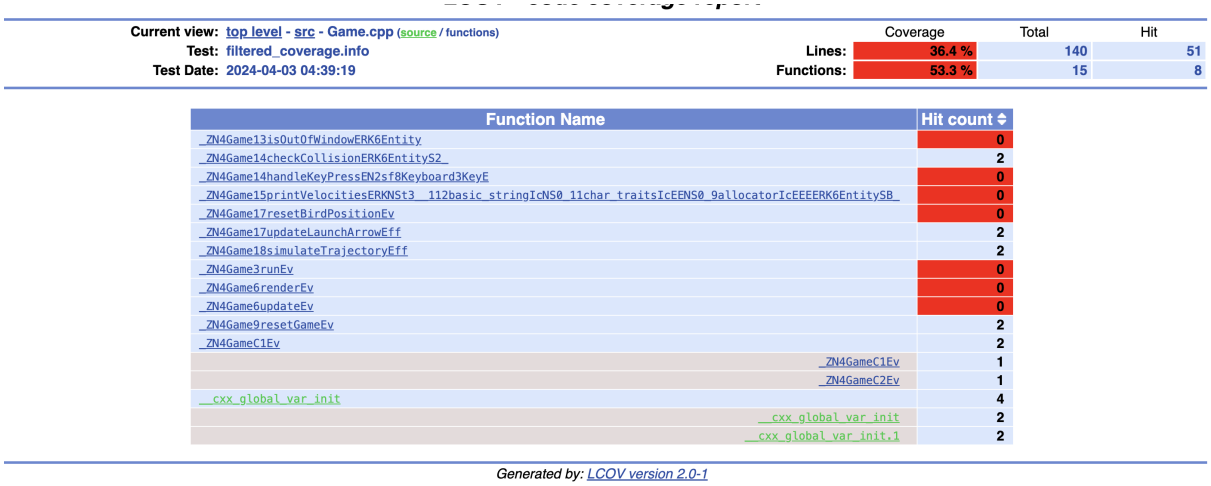
10 Code Coverage Metrics

10.1 Coverage for Game.cpp

Current view:	top level - src - Game.cpp (source / functions)	Coverage	Total	Hit
Test:	filtered_coverage.info	Lines:	36.4 %	140	51
Test Date:	2024-04-03 04:39:19	Functions:	53.3 %	15	8

```
Line data    Source code
       1             : //
       2             : // Created by Jubair on 2024-03-25.
       3             : //
       4             : #include "/Users/jubair/CLionProjects/untitled/include/Game.h"
       5             : #include "/Users/jubair/CLionProjects/untitled/include/Entity.h"
       6             : #include "/Users/jubair/CLionProjects/untitled/include/Physics.h"
       7             : #include <iostream>
       8             : #include <cmath>
       9             : #include <boost/numeric/odeint.hpp>
      10             : #include <vector>
      11             : #include <thread>
      12             :
      13             : using State = std::array<double, 4>; // x, y, vx, vy
      14             : using Stepper = boost::numeric::odeint::runge_kutta4<State>;
      15             :
      16             : const int WINDOW_WIDTH = static_cast<int>(800 * 1.30);
      17             : const int WINDOW_HEIGHT = static_cast<int>(600 * 1.30);
      18             : // Static variables initialization
      19             : float Game::launchAngleDegrees = 45.0f;
      20             : float Game::force = 1000.0f;
      21             : float trajectoryPoints=60;
      22             : float launchLength=1000.0f;
      23           2 : Game::Game(): window(sf::VideoMode(WINDOW_WIDTH, WINDOW_HEIGHT), "Projectile Simulation"),
      24             :         // Assign mass of 1.0 to the bird (projectile)
      25           2 :         projectile(20.0f, sf::Color::Red, 1.0, true, true) {
      26           1 :     trajectoryLine.setPrimitiveType(sf::LinesStrip);
      27           1 :     launchArrow.setSize(sf::Vector2f(50.0f, 5.0f));
      28           1 :     launchArrow.setFillColor(sf::Color::White);
      29           1 :     launchArrow.setOrigin(0, 2.5f); // Origin at the base, center for rotation
      30           1 :     resetGame();
      31           2 : }
      32             :
      33             :
      34           2 : void Game::resetGame() {
      35           2 :     projectile.resetPosition(60.0f, WINDOW_HEIGHT - 200.0f);
      36           2 :     projectile.isMobile = false;
      37           2 :     birdResetCounter = 0;
```

Figure 9: Test coverage report for Game.cpp, showing line coverage.



Current view:	top level - src - Game.cpp (source / functions)	Coverage	Total	Hit
Test:	filtered_coverage.info	Lines: 36.4 %	140	51
Test Date:	2024-04-03 04:39:19	Functions: 53.3 %	15	8

Function Name	Hit count
_ZN4Game13isOutOfWindowERK6Entity	0
ZN4Game14checkCollisionERK6EntityS2	2
_ZN4Game14handleKeyPressEN2sf8Keyboard3KeyE	0
_ZN4Game15printVelocitiesERKNSt3__112basic_stringIcNS0_11char_traitsIcEENS0_9allocatorIcEEEERK6EntitySB_	0
_ZN4Game17resetBirdPositionEv	0
_ZN4Game17updateLaunchArrowEff	2
_ZN4Game18simulateTrajectoryEff	2
_ZN4Game3runEv	0
_ZN4Game6renderEv	0
_ZN4Game6updateEv	0
_ZN4Game9resetGameEv	2
_ZN4GameC1Ev	2
_ZN4GameC1Ev	1
_ZN4GameC2Ev	1
__cxx_global_var_init	4
__cxx_global_var_init	2
__cxx_global_var_init.1	2

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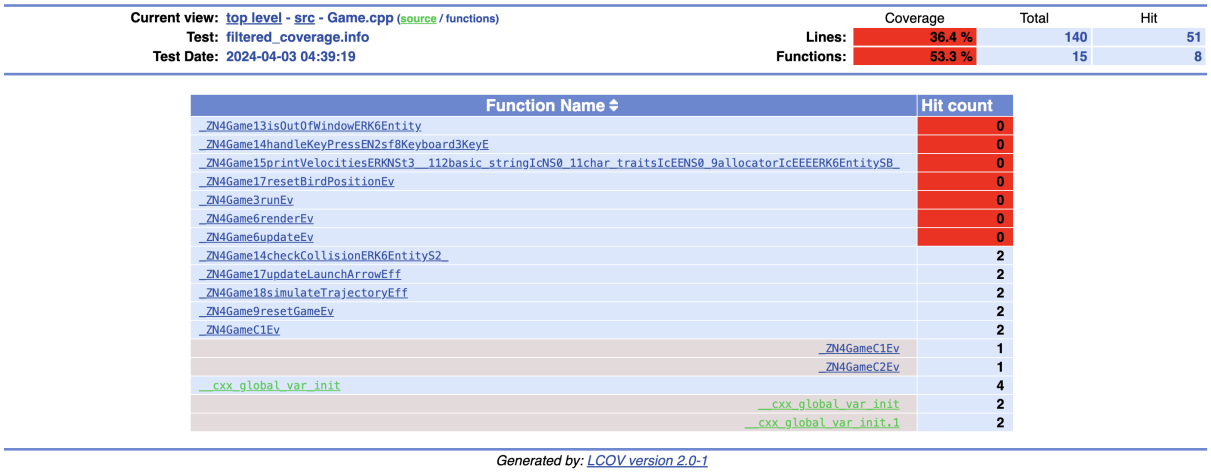
Figure 10: Test coverage report for Game.cpp, showing function coverage.



Current view:	top level - src - Game.cpp (source / functions)	Coverage	Total	Hit
Test:	filtered_coverage.info	Lines: 36.4 %	140	51
Test Date:	2024-04-03 04:39:19	Functions: 53.3 %	15	8

Function Name	Hit count
_ZN4Game13isOutOfWindowERK6Entity	0
_ZN4Game14handleKeyPressEN2sf8Keyboard3KeyE	0
_ZN4Game15printVelocitiesERKNSt3__112basic_stringIcNS0_11char_traitsIcEENS0_9allocatorIcEEEERK6EntitySB_	0
_ZN4Game17resetBirdPositionEv	0
_ZN4Game3runEv	0
_ZN4Game6renderEv	0
_ZN4Game6updateEv	0
ZN4Game14checkCollisionERK6EntityS2	2
_ZN4Game17updateLaunchArrowEff	2
_ZN4Game18simulateTrajectoryEff	2
_ZN4Game9resetGameEv	2
_ZN4GameC1Ev	2
_ZN4GameC1Ev	1
_ZN4GameC2Ev	1
__cxx_global_var_init	4
__cxx_global_var_init	2
__cxx_global_var_init.1	2

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Figure 11: Test coverage report for Game.cpp, showing another aspect of coverage.

10.2 Coverage for Specific Test Case

LCOV - code coverage report

			Coverage	Total	Hit
Current view:	top level - test - gameTest.cpp (source / functions)	Lines:	100.0 %	69	69
Test:	filtered_coverage.info	Functions:	100.0 %	18	18
Test Date:	2024-04-03 04:39:19				

```
Line data    Source code
   1           : #define CATCH_CONFIG_MAIN  // This tells Catch to provide a main() - only do this in one cpp file
   2           : #include </Users/jubair/CLionProjects/untitled/test/catch.hh>
   3           : #include "/Users/jubair/CLionProjects/untitled/include/Entity.h"
   4           : #include "/Users/jubair/CLionProjects/untitled/include/Game.h"
   5           : #include "/Users/jubair/CLionProjects/untitled/include/State.h"
   6           : #include <SFML/Graphics.hpp>
   7           :
   8           :
   9           :
  10         3 : TEST_CASE("Degrees to Radians Conversion", "[utility]") {
  11         1 :     REQUIRE(Entity::degreesToRadians(180) == Catch::Approx(3.14159).epsilon(0.01));
  12         1 :     REQUIRE(Entity::degreesToRadians(90) == Catch::Approx(1.5708).epsilon(0.01));
  13         1 : }
  14           :
  15         3 : TEST_CASE("Apply Force Changes Velocity", "[physics]") {
  16         1 :     Entity entity(10.0f, sf::Color::Red, 1.0, true, true);
  17         1 :     entity.applyForce(100.0f, 45.0f);
  18         1 :     REQUIRE(entity.state[2] == Catch::Approx(70.71).epsilon(0.01));
  19         1 :     REQUIRE(entity.state[3] == Catch::Approx(70.71).epsilon(0.01));
  20         1 : }
  21         3 : TEST_CASE("Collision Detection", "[game]") {
  22         1 :     Entity entityA(10.0f, sf::Color::Red, 1.0, true, true);
  23         1 :     entityA.resetPosition(100.0f, 300.0f); // Position entity A
  24         1 :     Entity entityB(10.0f, sf::Color::Blue, 1.0, true, true);
  25         1 :     entityB.resetPosition(110.0f, 300.0f); // Position entity B close enough to collide
  26           :
  27         1 :     REQUIRE(Game::checkCollision(entityA, entityB) == true);
  28           :
  29         1 :     entityB.resetPosition(300.0f, 300.0f); // Move entity B far away
  30         1 :     REQUIRE(Game::checkCollision(entityA, entityB) == false);
  31         1 : }
  32         3 : TEST_CASE("Momentum Transfer", "[physics]") {
  33         1 :     Entity entityA(10.0f, sf::Color::Red, 1.0, true, true);
  34         1 :     entityA.state = {0, 0, 10, 0}; // Moving right
  35         1 :     Entity entityB(10.0f, sf::Color::Blue, 1.0, true, true);
  36         1 :     entityB.state = {0, 0, -5, 0}; // Moving left
  37           :
```

Figure 12: Test coverage report for a specific test case, showing line coverage.

LCOV - code coverage report

			Coverage	Total	Hit
Current view:	top level - test - gameTest.cpp (source / functions)	Lines:	100.0 %	69	69
Test:	filtered_coverage.info	Functions:	100.0 %	18	18
Test Date:	2024-04-03 04:39:19				

Function Name	Hit count
_ZL22CATCH2_INTERNAL_TEST_0v	1
_ZL22CATCH2_INTERNAL_TEST_2v	1
_ZL22CATCH2_INTERNAL_TEST_4v	1
_ZL22CATCH2_INTERNAL_TEST_6v	1
_ZL22CATCH2_INTERNAL_TEST_8v	1
_ZL23CATCH2_INTERNAL_TEST_10v	1
_ZL23CATCH2_INTERNAL_TEST_12v	1
_ZL23CATCH2_INTERNAL_TEST_14v	1
__cxx_global_var_init	20
__cxx_global_var_init	2
__cxx_global_var_init.1	2
__cxx_global_var_init.11	2
__cxx_global_var_init.13	2
__cxx_global_var_init.15	2
__cxx_global_var_init.17	2
__cxx_global_var_init.19	2
__cxx_global_var_init.2	2
__cxx_global_var_init.5	2
__cxx_global_var_init.8	2

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Figure 13: Test coverage report for a specific test case, showing another aspect of coverage.

11 Memory Leak Test Results

11.1 Leak Test Visualizations

This section presents the results of memory leak tests performed to ensure the robustness and stability of the application.

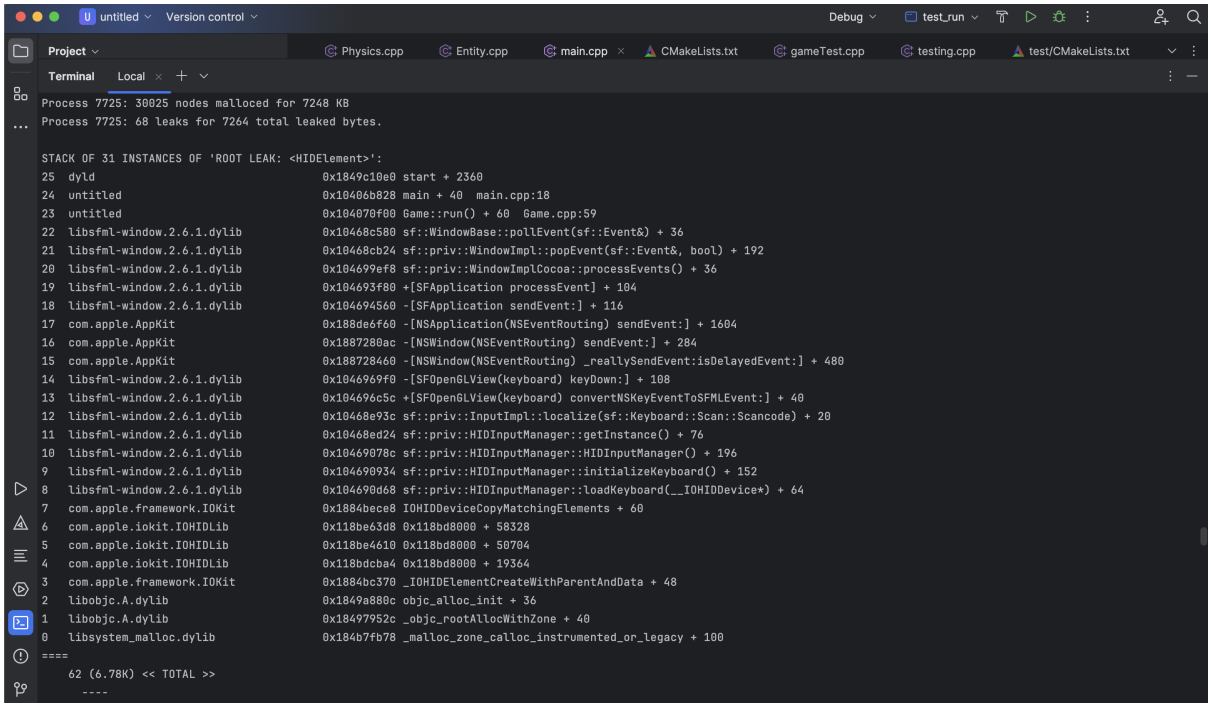

Figure 14: Memory leak test results showcasing the effective management of memory resources within the application.

12 Static Code Analysis with Cppcheck

12.1 Cppcheck Analysis Results

Static code analysis was conducted using Cppcheck to identify potential issues in the codebase such as memory leaks, uninitialized variables, and other common coding mistakes.

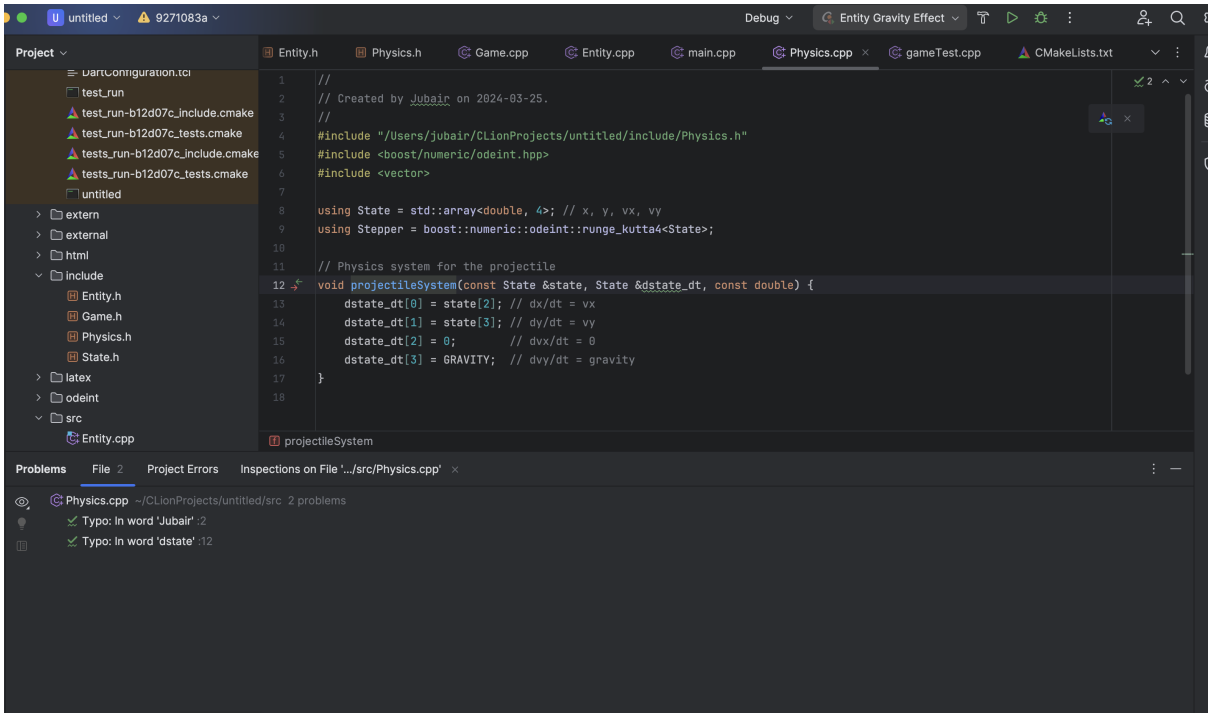

Figure 15: Cppcheck analysis results highlighting the areas of the code requiring attention to improve code quality and reliability.

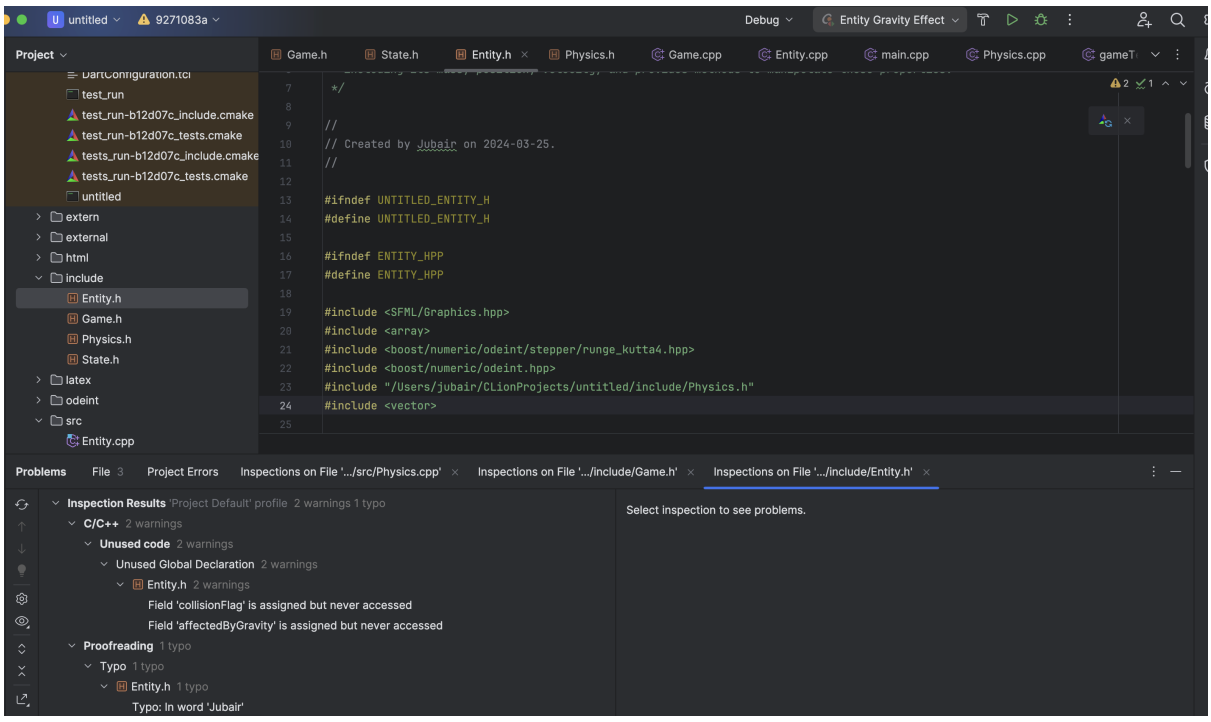

Figure 16: Cppcheck analysis results highlighting the areas of the code requiring attention to improve code quality and reliability.

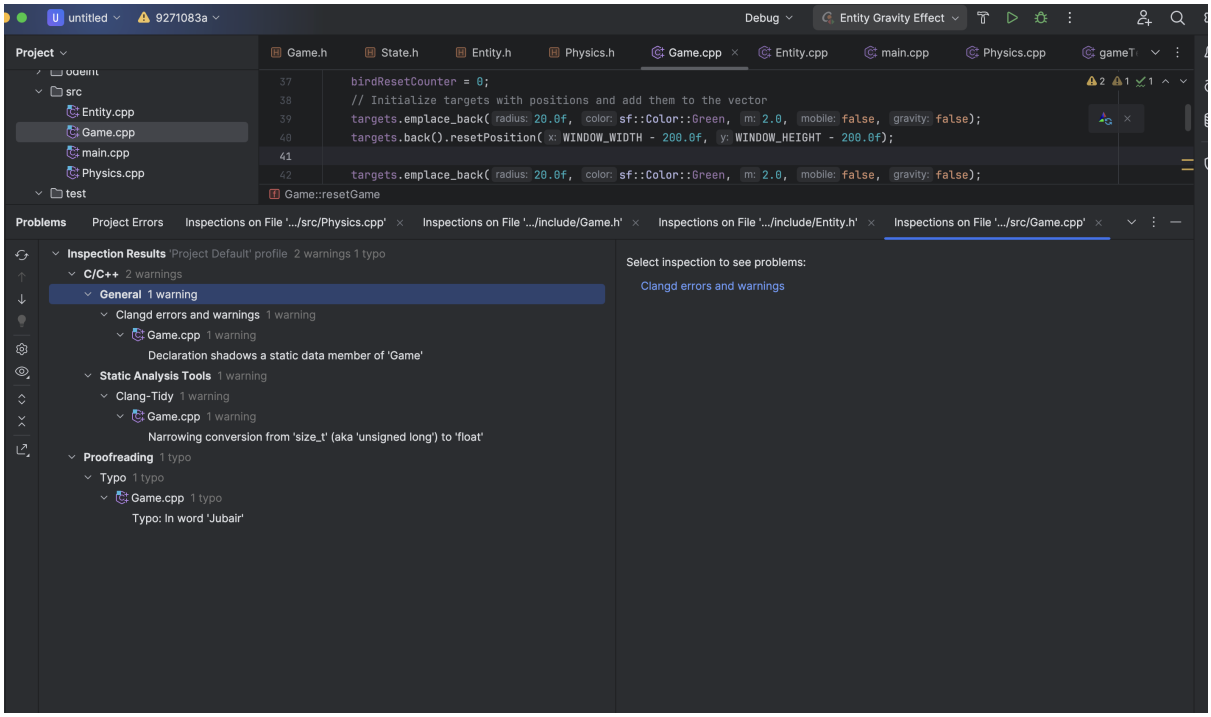

Figure 17: Cppcheck analysis results highlighting the areas of the code requiring attention to improve code quality and reliability.

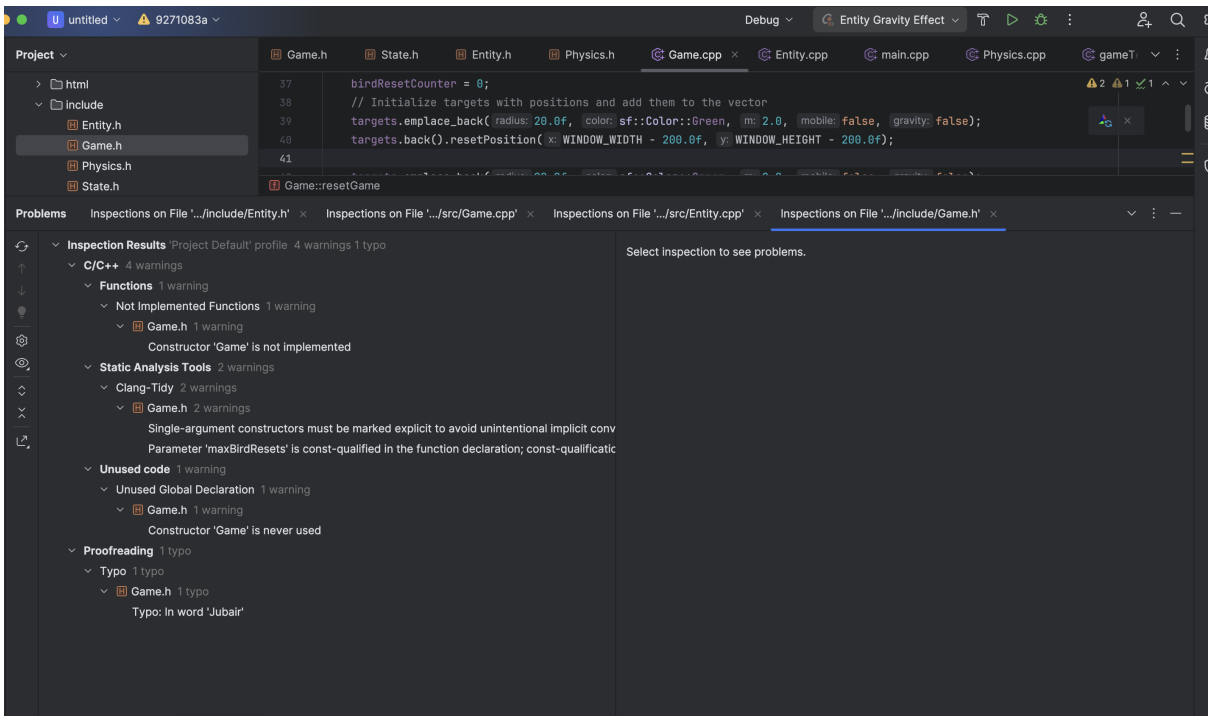

Figure 18: Cppcheck analysis results highlighting the areas of the code requiring attention to improve code quality and reliability.

Appendix

A. Reflection on the Verification and Validation Process

Reflecting on the verification and validation process, it became evident that thorough testing is crucial for identifying and addressing issues early. Despite careful planning, unexpected challenges arose, underscoring the importance of flexibility in our testing approach.

B. Lessons Learned

The project highlighted the value of unit testing in maintaining high code quality. It also demonstrated the necessity of comprehensive testing strategies that encompass unit, integration, and system tests.

C. Future Work

Future efforts will focus on expanding test coverage, exploring advanced testing frameworks, and continually refining the application based on user feedback and performance metrics.

D. Acknowledgments

I extend my graditude to my domain expert, reviewers, Professor, who provided valuable insights and support throughout the project's development.

E. Closing Thoughts

This project has been a journey of learning and growth. I am excited to apply the insights gained to future projects, with a commitment to developing robust, efficient, and user-friendly software.