**Spike:** 12
**Title:** Performance Measurement and Optimisations

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**Goals / deliverables:**

- Code, see \24 - Spike - Profiling, Performance and Optimsation\Task 24\
- Spike Report

**Technologies, Tools, and Resources used:**

List of information needed by someone trying to reproduce this work

- Visual Studio 2019
- C plus plus reference (https://www.cplusplus.com/reference/)
- SDL2
- Cpp file from canvas

**Tasks undertaken:**

- Download and install Visual Studio
- Create a new C++ project
- Download SDL2 Development libraries
- Link libraries to project
- Download the cpp file from canvas and put it in the project
- Run the tests and record data.
- Analyse data using a graph
- Make optimisations based on results

**What we found out:**

On canvas there is a file that runs  SDL performance tests with rects and collision detection.

There are 4 different functions that test for collision between two rects.

```
bool crash_test_A(int i, int j) // via index
{   //yeap - lazyfoo style!

    //The sides of the rectangles
    int leftA, leftB;
    int rightA, rightB;
    int topA, topB;
    int bottomA, bottomB;

    CrashBox A, B;
    A = boxes[i];
    B = boxes[j];

    //Calculate the sides of rect A
    leftA = A.x;
    rightA = A.x + A.w;
    topA = A.y;
    bottomA = A.y + A.h;

    //Calculate the sides of rect B
    leftB = B.x;
    rightB = B.x + B.w;
    topB = B.y;
    bottomB = B.y + B.h;

    //If any of the sides from A are outside of B
    if (bottomA <= topB) return false;
    if (topA >= bottomB) return false;
    if (rightA <= leftB) return false;
    if (leftA >= rightB) return false;

    //If none of the sides from A are outside B
    return true;
}
```

The first function, test A, gets the two boxes it wants to get collisions for by having the indexes for the global array of boxes passed to it. It uses the indexes to get each box and then use each bot to assign values to each integer variable for use in the collision test.

```
bool crash_test_B(CrashBox A, CrashBox B) // struct (copy)
{
    //The sides of the rectangles
    int leftA, leftB;
    int rightA, rightB;
    int topA, topB;
    int bottomA, bottomB;

    //Calculate the sides of rect A
    leftA = A.x;
    rightA = A.x + A.w;
    topA = A.y;
    bottomA = A.y + A.h;

    //Calculate the sides of rect B
    leftB = B.x;
    rightB = B.x + B.w;
    topB = B.y;
    bottomB = B.y + B.h;

    //If any of the sides from A are outside of B
    if (bottomA <= topB) return false;
    if (topA >= bottomB) return false;
    if (rightA <= leftB) return false;
    if (leftA >= rightB) return false;
    //If none of the sides from A are outside B
    return true;
}
```

Crash test b passes in two boxes to be compared as variable to use in the test. They are passed as regular variables, so the boxes passed in are copied and reconstructed for use in the function scope.

```
bool crash_test_C(CrashBox& A, CrashBox& B) // via struct (ref!)
{
    //The sides of the rectangles
    int leftA, leftB;
    int rightA, rightB;
    int topA, topB;
    int bottomA, bottomB;

    //Calculate the sides of rect A
    leftA = A.x;
    rightA = A.x + A.w;
    topA = A.y;
    bottomA = A.y + A.h;

    //Calculate the sides of rect B
    leftB = B.x;
    rightB = B.x + B.w;
    topB = B.y;
    bottomB = B.y + B.h;

    //If any of the sides from A are outside of B
    if (bottomA <= topB) return false;
    if (topA >= bottomB) return false;
    if (rightA <= leftB) return false;
    if (leftA >= rightB) return false;

    //If none of the sides from A are outside B
    return true;
}
```

Crash test C uses references to each box, meaning they do not have to be reconstructed.

```
bool crash_test_D(CrashBox& A, CrashBox& B)
{
    if ((A.y + A.h) <= B.y) return false;
    if (A.y >= (B.y + B.h)) return false;
    if ((A.x + A.w) <= B.x) return false;
    if (A.x >= (B.x + B.w)) return false;
    return true;
}
```

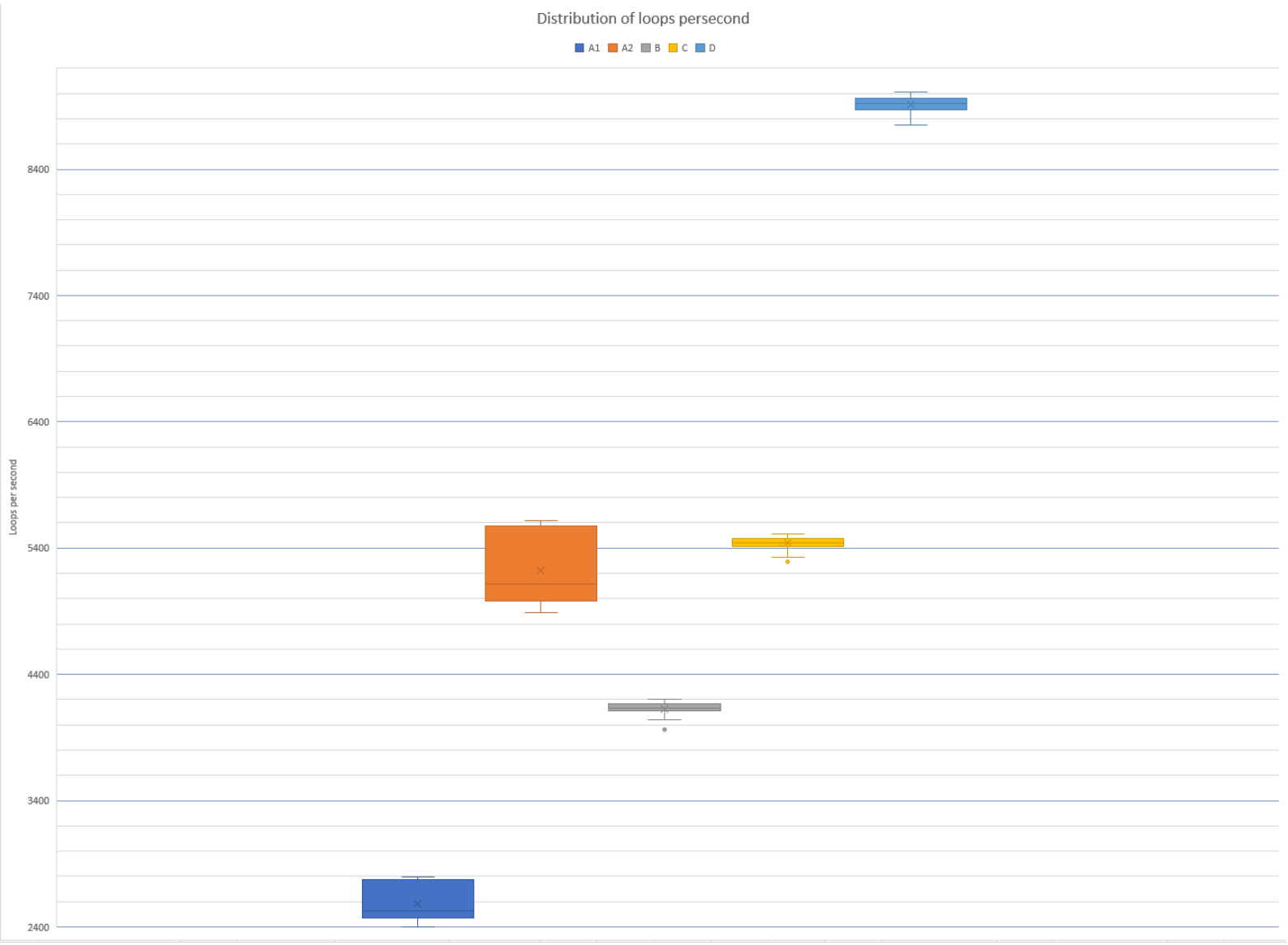
Crash test D also uses constant references but instead of creating local variables and assigning them to the data needed for the calculations the math to work out the bottom and right of the rect is done in the if statement.

I ran the program 30 times and recorded the average number of times the game loop can be called in a second.

I ran the tests for 3 seconds, 5 seconds and 10 seconds, 10 times per duration.

| | A1 | A2 | B | C | D |
|---|---|---|---|---|---|
| 3000 | 2396.333218 | 4995.666504 | 4174.666882 | 5449.6665 | 8919.66629 |
| | 2433.333397 | 4907.666683 | 4105.333328 | 5425.666809 | 8869.667053 |
| | 2470.999956 | 4980.666637 | 4164.333344 | 5432.333469 | 8882.333755 |
| | 2447.333336 | 4954.666615 | 4128.666878 | 5415.333271 | 8876.000404 |
| | 2470.999956 | 4935.99987 | 4156.000137 | 5428.666592 | 8871.00029 |
| | 2461.999893 | 4986.666679 | 4169.333458 | 5435.99987 | 8932.999611 |
| | 2463.666677 | 4978.666782 | 4174.333096 | 5433.000088 | 8966.333389 |
| | 2470.000029 | 4890.999794 | 4038.000107 | 5389.333248 | 8892.000198 |
| | 2460.666656 | 4933.000088 | 3964.333296 | 5326.666832 | 8750.666618 |
| | 2459.33342 | 4976.333141 | 4135.000229 | 5386.000156 | 8855.999947 |
| 5000 | 2544.60001 | 5185.200214 | 4199.399948 | 5489.999771 | 9014.5998 |
| | 2547.199965 | 5080.999851 | 4159.599781 | 5486.599922 | 8951.000214 |
| | 2545.200109 | 5135.60009 | 4177.599907 | 5379.000187 | 8811.599731 |
| | 2498.399973 | 5085.000038 | 4108.200073 | 5289.999962 | 8888.199806 |
| | 2530.600071 | 5105.59988 | 4164.199829 | 5375.199795 | 8799.599648 |
| | 2515.1999 | 5101.60017 | 4140.600204 | 5435.599804 | 8927.200317 |
| | 2536.600113 | 5128.799915 | 4144.40012 | 5408.400059 | 8808.199883 |
| | 2515.1999 | 5118.800163 | 4166.800022 | 5474.400043 | 9013.400078 |
| | 2526.99995 | 5154.799938 | 4147.799969 | 5460.400105 | 8924.599648 |
| | 2517.800093 | 5095.399857 | 4120.200157 | 5418.000221 | 8867.799759 |
| 10000 | 2717.099905 | 5538.199902 | 4103.199959 | 5450.799942 | 8835.300446 |
| | 2753.900051 | 5568.200111 | 4062.399864 | 5457.099915 | 8943.099976 |
| | 2776.900053 | 5595.699787 | 4127.500057 | 5476.200104 | 9008.500099 |
| | 2785.79998 | 5596.600056 | 4110.70013 | 5468.299866 | 8977.499962 |
| | 2774.300098 | 5611.700058 | 4118.000031 | 5480.29995 | 8961.400032 |
| | 2784.300089 | 5592.700005 | 4122.900009 | 5492.499828 | 8963.80043 |
| | 2774.499893 | 5564.799786 | 4110.499859 | 5449.60022 | 8911.800385 |
| | 2781.899929 | 5620.299816 | 4124.499798 | 5497.600079 | 8948.300362 |
| | 2784.499884 | 5600.599766 | 4087.39996 | 5513.000011 | 8959.799767 |
| | 2795.599937 | 5605.700016 | 4139.100075 | 5485.799789 | 8988.200188 |

The program the results of each test to the console. So I added a loop to the main function to run the tests 10 times. I then copied the data into a spreadsheet table. Test A is ran twice as the second time it is called it runs faster.




I made a box and whisker plot of each dataset to compare the average performance for each test. Interestingly the A2 tests are almost on par with the C tests, though the c tests are much more consistent. However, the D tests are the most efficient by far, consistently running the loop just below 9000 times per second as nothing has to be initialised. A1 is super slow for some reason, there must be some sort of setup that the program has to do first. B is also pretty slow as the construction must take up a fair bit of time.

From the data we can tell that using pointers where possible and avoiding unnecessary construction is a good way to improve upon performance.

From the results function D is clearly the best so that is the function I am going to use. Now to add some improvements.

```
void render_box(CrashBox &box, SDL_Renderer* renderer, SDL_Color& color) /
{
    SDL_Rect r = { box.x, box.y, box.w, box.h };
    SDL_SetRenderDrawColor(renderer, color.r, color.g, color.b, color.a);
    SDL_RenderFillRect(renderer, &r);
}
```

First, I changed the render function to use a reference rather than copying the box. Though this wont show in the results as the renderer is turned off.

```
bool crash_test_D(CrashBox& A, CrashBox& B)
{
    return ((A.y + A.h) > B.y) && (A.y < (B.y + B.h)) && ((A.x + A.w) > B.x) && (A.x < (B.x + B.w));
}
```

I changed the return using an && comparison. This is very small but it means that if there is a collision it wont have to go through to another return or through multiple if statements.

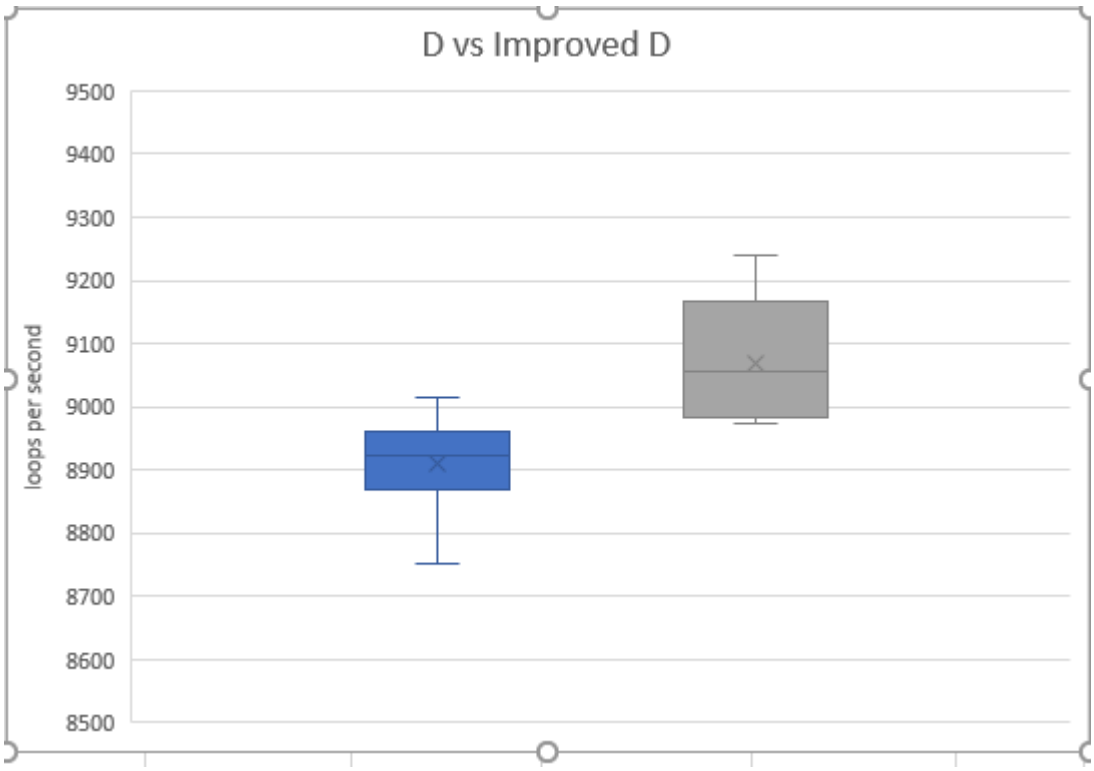
```
void update_boxes()
{
    // First move all boxes
    for (int i = 0; i < BOX_COUNT; i++) {
        // update position using current velocity
        boxes[i].x = boxes[i].x + boxes[i].dx;
        boxes[i].y = boxes[i].y + boxes[i].dy;
        // check for wrap-around condition
        if (boxes[i].x >= SCREEN_WIDTH) boxes[i].x -= SCREEN_WIDTH;
        else if (boxes[i].x < 0) boxes[i].x += SCREEN_WIDTH;
        if (boxes[i].y >= SCREEN_HEIGHT) boxes[i].y -= SCREEN_HEIGHT;
        else if (boxes[i].y < 0) boxes[i].y += SCREEN_HEIGHT;
        //TODO: try else if logic
        boxes[i].state = CONTACT_NO;
    }
    /*
    // 1. mark all boxes as not collided //TODO: put this in the move loop?
    for (int i = 0; i < BOX_COUNT; i++)
        boxes[i].state = CONTACT_NO;
        */
    // 2. call whatever function has been set to test all i against j boxes
    crash_test_all_ptr();
}
```

The CONTACT_NO is now set in the other for loop meaning that the program doesn't have to loop through the array twice.

It also now uses else if logic, so if wrap around is detected it skips over the opposite screen edge.

If we now compare the improved function to the old one we can see the difference. The improvements now let the program make over 9000 loops per second much more consistently .

| D | | D improved |
|---|---|---|
| 8919.66629 | | 9053.00045 |
| 8869.667053 | | 9177.666664 |
| 8882.333755 | | 9168.000221 |
| 8876.000404 | | 9172.66655 |
| 8871.00029 | | 9169.66629 |
| 8932.999611 | | 9173.666954 |
| 8966.333389 | | 9202.666283 |
| 8892.000198 | | 9239.999771 |
| 8750.666618 | | 9133.999825 |
| 8855.999947 | | 9173.333168 |
| 9014.5998 | | 8977.800369 |
| 8951.000214 | | 9090.800285 |
| 8811.599731 | | 8984.199524 |
| 8888.199806 | | 9086.400032 |
| 8799.599648 | | 8982.39994 |
| 8927.200317 | | 9056.799889 |
| 8808.199883 | | 9016.799927 |
| 9013.400078 | | 9031.80027 |
| 8924.599648 | | 8984.000206 |
| 8867.799759 | | 8974.399567 |
| 8835.300446 | | 8977.800369 |
| 8943.099976 | | 9090.800285 |
| 9008.500099 | | 8984.199524 |
| 8977.499962 | | 9086.400032 |
| 8961.400032 | | 8982.39994 |
| 8963.80043 | | 9056.799889 |
| 8911.800385 | | 9016.799927 |
| 8948.300362 | | 9031.80027 |
| 8959.799767 | | 8984.000206 |
| 8988.200188 | | 8974.399567 |


D vs Improved D
loops per second
9500
9400
9300
9200
9100
9000
8900
8800
8700
8600
8500