Genetic Algorithm Robots

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Problem.

You are going to reproduce an experiment first conducted at Harvard University in 1968. This assignment is a bit different from the other homework assignments in this class because there are no specification bundles for this. You either make it work or you don't. You are going to study the effects of evolution on a population of robots. The robots need to maneuver around a grid collecting energy. The robots must collect more energy than they expend to survive. Your robots will maneuver around a 10 x 10 grid looking for batteries. A battery gives the robot five more power. Moving a square costs 1 power. The sensors are always on and cost no power. Robots have five power when they first emerge on the map.

The key is the robot behavior. Each robot has a collection of direction sensors and a motor. Robot success depends upon the map between these two elements. We do not hard code the map between the sensor data and the motor actions, however. The robots start with a random mapping, but over time, the mappings evolve into successful strategies. We'll get to how they do this in a minute.

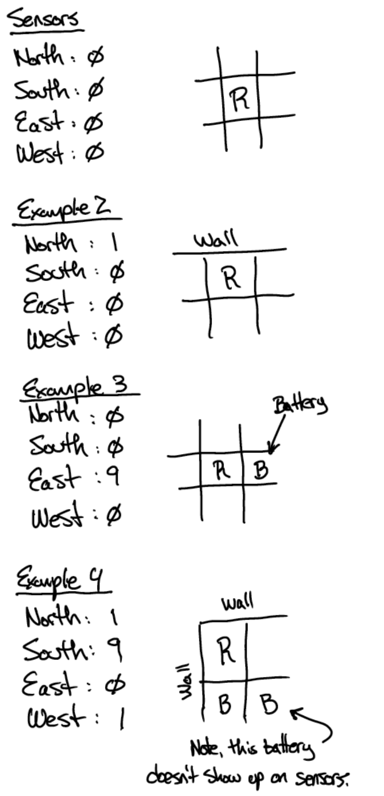


Figure 1: Example of sensor readings with various obstacles on the map.

Robot Sensors.

The robot has four sensors - each facing in a different direction. This way, the robot can detect what is in the squares adjacent to the North, South, East, and West. Each map feature will generate a different code for that sensor. See figure 1 for four examples. The codes you see here are examples, you can use whatever codes you wish.

Robot sensor states:

- No object in square.
- Wall object.
- Battery object.
- Don't care if anything is there.

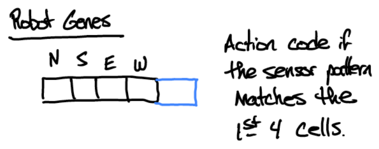


Figure 2: Example of an individual robot gene.

Robot Genes.

Each robot will have 16 genes. Each gene is an array containing five codes. See figure 2 of a single gene. The first four codes correspond to possible sensor states. The last code instructs the robot what to do in the event the current sensor state matches the four states on the gene.

Robot actions:

- Move 1 north.
- Move 1 south.
- Move 1 east.
- Move 1 west.
- Move 1 random direction.

This means that every turn the robot is comparing the current sensor state with it's genetic code in an attempt to find a match. A gene must match exactly for it's behavior to be executed. If it does not find an exact match, the robot will execute the last gene (number 16). Robots will continue to do this until they run out of energy. KEEP TRACK OF THE NUMBER OF TURNS A ROBOT SURVIVES. This will become very important later. A robot gains energy running into a square containing a battery. The battery is consumed in the process. Figure 3 is an example of 1 robot turn.

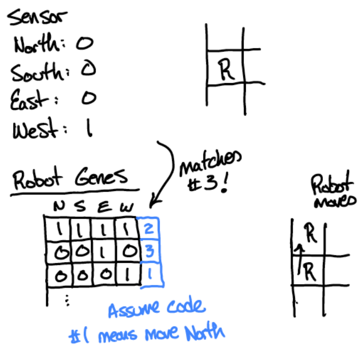


Figure 3: Example of a robot moving along the map for 1 turn.

The Map.

Randomly place each robot on a spot on the map. Populate 40% of the squares with batteries. Generate a new map for each robot. We run one robot through at a time. Moving each square consumes 1 energy unit - even if it's not a valid move (a wall). Invalid moves consume energy, but keep the robot on the original square. This is usually the death knell for that robot unless the move action was move in a random direction.

You don't need to display the map on the console. It's interesting to watch if you want to do so, however. Perhaps display the map of the best performing robot or the worst performing one.

Robot Population.

Evolution works on populations, not individuals. You need a population of robots to run through your maps. Create a population of 200 randomly generated robots to start. That is, you randomly generate the mappings between allowable behaviors and sensor codes for the first generate of robots only. Each robot is run through a random map and the number of turns they survive is recorded.

Robot Reproduction.

Once all the robots in a population have had a turn (and acquired energy scores), record the total energy harvested by the entire generation and breed your robots. Sort your population by energy harvested and kill off the lowest 50%. Then pair up the top 2 robots and produce 2 children by combining genes from both parents. The children enter the gene pool with the parents in the next round. Then, breed the 3rd and 4th highest scoring robots. Repeat until all the parent robots have reproduced. Keep the number of robots at a fixed number for the entire simulation. Genes are randomly created for the first population only - the robots breed after that.

Each parent supplies 50% of the 16 genes for a child. The simplest way is for one parent to supply the first 8 and the other to supply the last 8. You will not want the siblings to have the same genes (unless you are investigating the effects of identical twins). However, you can use a different swap scheme if you would like.

Swapping genes is a tricky business and mistakes happen. In 5% of the individual genes swapping there is an error - a mutation. Randomly change one character on the gene the child has inherited from it's parent. Just generate another value and insert that value over the old one. You can also shift all genes down 1 and the 16th gene moves to the top.

Genetic Algorithms.

The degree to which the robot successfully harvests energy from the environment is called 'fitness'. We measure that by the total amount of power harvested when each individual robot's time ends. When we finish with the entire population of 200, we calculate an average fitness score for the population. Save the average fitness for each generation. You will most likely see slow and steady improvement over time - evolution at work. When the simulation completes, print out the average fitness scores on the console. This is even more effective if you are able to draw a console graph (not a requirement).

The fascinating thing about this experiment is your robots will get better and better at navigating the map over time. They will evolve strategies dealing with walls and corners. The most exciting part is it doesn't require any further participation from you - just set it in motion and watch it go.

Bonus Features.

No bonus features are needed with this assignment. However, past students have:

- Added obstacles for the robots to avoid.
- Added predator robots.
- Added vision so the robots can 'see' 2 spaces away.
- Added memory of moves.
- Plotted fitness over time on the console (a common modification).
- Created Don Juan robots that have children with several partners.
- Stored many of the constraints as constants so they could explore the effects of modifying them (ex: change the mutation rate to 8% from 5%) - another common modification.
- Keep track of how many generations a specific robot survived.

Due Date.

This assignment is due by the close of Canvas for the semester.

Late Work.

There is no late penalty for this assignment because it is due when Canvas closes. You simply cannot turn it in after that.

How to Turn in your Homework.

Follow these guidelines for turning in your work:

1. Each assignment has a submit button to turn in your work.
2. Upload your .cpp file, but make sure you change the file extension to .txt. The plagiarism checker doesn't read .cpp files and I've disabled uploading them. I'll rename your homework to .cpp when I download them.
3. Only submit your homework through Canvas. Do not email them to me or attach them in the comments.
4. Submit a source file I can compile. Do not submit a link to an online editor like repl.it. Do not zip a file. Submit self contained programs - they only have one file to run (no data files, config files, object files, etc.).
5. It is OK to turn in multiple versions of the same file (that you've updated. Canvas will automatically download the latest version.
6. It is your responsibility to make sure your file is readable. If your file is 'corrupted' I will not accept it and you will have failed to turn in that assignment. I expect to be able to see your code in Canvas as well as compile and run it on my computer using Ubuntu.
7. Let me know if you are having any trouble uploading your homework immediately.

8. I download your files, compile and execute them as well as look over your source code.

Style Guide.

All programs you write MUST conform to the following style specifications.

Comments.

Use white space and comments to make your code more readable. I run a program called cloc (count lines of code) which actually looks for this stuff.

End of line comments are only permitted with variable declarations. Full line comments are used everywhere else.

Comment Rate.

I use a program called cloc to calculate the total number of blank lines, total number of comments and the total number of lines in your program. When you divide the number of comments by the number of lines you get the comment rate. This number gives me a rough approximation of how well commented your code is. When I see a rate of 10% (for example) I have a good idea of what I will find when I look at the program - pretty much no comments at all. Ditto, when I see a rate of 45% (for example). This code will have comments for many tricky or complex sections as well as functions.

Specification Comments.

Specifications are bundled into groups: "A", "B", "C", "D". You must meet the specifications of the lowest group before I will count the specifications for the highest group. For example, you must meet the "D" specifications before I will count the "C" specifications. If you miss one element of a specification bundle, that is the grade you will get for the assignment - regardless of how much extra work you do.

Use whole line comments for Specifications. Put the comment on the line above the start of the code implementing the Specification. If the same Specification code appears in more than 1 place, only comment the first place that Specification code appears. Number your Specifications according to the specification bundle and the specific specification you are using, also provide a very short description. DO NOT BUNCH ALL YOUR SPECIFICATIONS AT THE TOP OF THE SOURCE FILE. Example specification comment:

```
// Specification A2 - Display variables
```

```
Your code to do this starts here;
```

It's very important to get the specifications down correctly. If your specification code isn't commented, it doesn't count. I use the grep trick to find your specification code. Proper documentation is part of the solution, just like actually coding the solution is.

Compiler Warnings.

Compiler warnings are a potential problem. They are not tolerated in the production environment. In CISP 360 you can have them. I will deduct a small number of points. CISP 400 - I will deduct lots of points if compiler warnings appear. Make sure you compile with -Wall option. This is how you spot them.

C++ Libraries.

We are coding in C++, not C. Therefore, you must use the C++ libraries. The only time you can use the C libraries is if they haven't been ported to C++ (very, very rare).

Functions.

Functions are used to segment your code into easier to work with chunks. You want your functions to do only one thing - one activity. Functions are coded BELOW main(), not above it. Use arguments and parameters to pass information to your functions - global variables are discouraged with prejudice . Whenever possible, try to have a brief comment below the function signature describing what the function does.

```
void foo()
// a meaningless function to show a function comment in
the style guide.
```

Function Prototypes.

Use function prototypes and comment them. This is a constraint in this class even if not expressly stated in the homework. I use the grep trick for Function Prototype to look for this. You only need to comment it once, at the top of your source file - above main(). Example:

```
// Function Prototype
void ProgramGreeting();
```

Non-Standard Language Extensions.

Some compilers support unapproved extensions to the C++ syntax. These extensions are **unacceptable.** Unsupported extensions are compiler specific and non-portable. Do not use them in your programs.

Program Greeting.

Display a program greeting as soon as the program runs. This is a description of what the program does. Example:

```
// Function Greeting
cout « "Simple program description text here." « endl;
```

You can make this much more elaborate - usually used as cover so clients don't realize we are loading huge data files. If your assignment calls for a menu, DO NOT put the menu in here - that goes in it's own section.

Source File Header.

Start your source file with a program header. This includes the program name, your name, date and this class. I use the grep trick for .cpp (see below) to look for this. I focus on that homework name and display the next 3 lines. Example:

```
// homeworkname.cpp
// Pat Jones, CISP 413
// 12/34/56
```

Space Rate.

I use a program called cloc to calculate the total number of blank lines, total number of comments and the total number of lines in your program. When you divide the number of blank lines by the total number of lines you get the space rate. This number gives me a rough approximation of how well laid out your code is. When I see a rate of 10% (for example) I have a good idea of what I will find when I look at the program - wall of words. Ditto, when I see a rate of 45% (for example). This code will have good spacing between major blocks of code and functions. Note: when this number get's too high (like 70% of so) the blank space becomes a distraction.

Variables.

Document constants with ALLCAPS variables and the const keyword. Magic numbers are generally frowned upon.

Grep Trick.

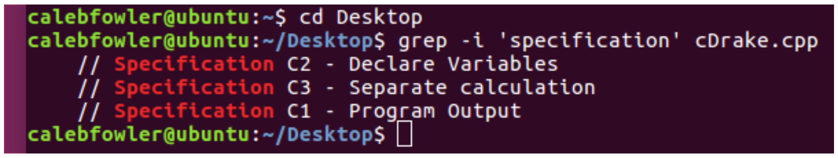
Always run your code immediately before your turn it in. I can't tell you how many times students make 'one small change' and turn in broken code. It kills me whenever I see this. Don't kill me.

You can check to see if I will find your specification and feature comments by executing the following command from the command line. If you see your comments on the terminal, then I will see them.

If not, I will NOT see them and you will NOT get credit for them. The following will check to see if you have commented your specifications:

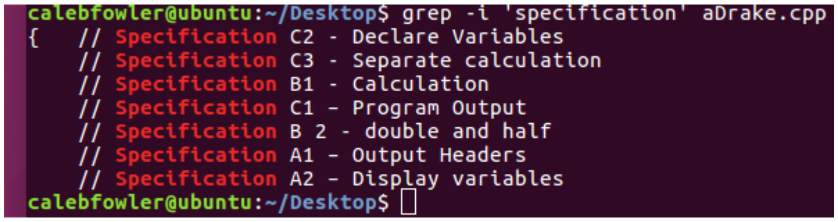
```
grep -i 'specification' homework.cpp
```

This will generate the following output. Notice the specifications are numbered to match the specification number in the assignment. This is what I would expect to see for a 'C' Drake assignment. Note the cd Desktop changes the file location to the desktop - which is where the source file is located.



```
calebfowler@ubuntu:~$ cd Desktop
calebfowler@ubuntu:~/Desktop$ grep -i 'specification' cDrake.cpp
    // Specification C2 - Declare Variables
    // Specification C3 - Separate calculation
    // Specification C1 - Program Output
calebfowler@ubuntu:~/Desktop$ 
```

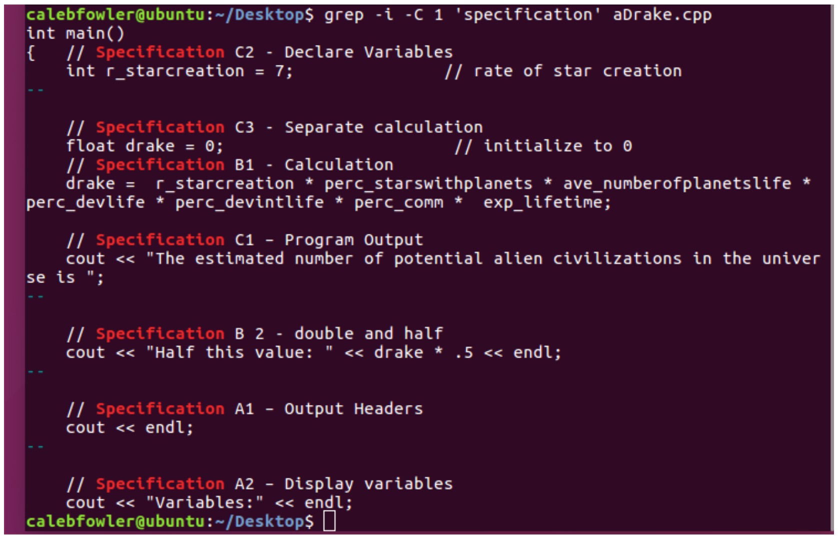
This is what I would expect to see for an 'A' level Drake assignment.



```
calebfowler@ubuntu:~/Desktop$ grep -i 'specification' aDrake.cpp
{   // Specification C2 - Declare Variables
    // Specification C3 - Separate calculation
    // Specification B1 - Calculation
    // Specification C1 - Program Output
    // Specification B 2 - double and half
    // Specification A1 - Output Headers
    // Specification A2 - Display variables
calebfowler@ubuntu:~/Desktop$ 
```

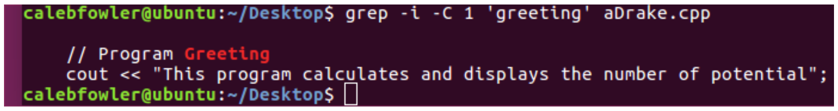
We can also look at the line(s) after the grep statement. I do this to pay attention to code segments.

```
grep -i -C 1 'specification' aDrake.cpp
```



```
calebfowler@ubuntu:~/Desktop$ grep -i -C 1 'specification' aDrake.cpp
int main()
{   // Specification C2 - Declare Variables
    int r_starcreation = 7;               // rate of star creation
--

    // Specification C3 - Separate calculation
    float drake = 0;                       // initialize to 0
    // Specification B1 - Calculation
    drake =  r_starcreation * perc_starswithplanets * ave_numberofplanetslife *
perc_devlife * perc_devintlife * perc_comm *  exp_lifetime;

    // Specification C1 - Program Output
    cout << "The estimated number of potential alien civilizations in the univer
se is ";
--

    // Specification B 2 - double and half
    cout << "Half this value: " << drake * .5 << endl;
--

    // Specification A1 - Output Headers
    cout << endl;
--

    // Specification A2 - Display variables
    cout << "Variables:" << endl;
calebfowler@ubuntu:~/Desktop$ 
```

We can also use this to look for other sections of your code. The grep command searches for anything withing the single quotes ”, and the -i option makes it case insensitive. This is how I will look for your program greeting:



```
calebfowler@ubuntu:~/Desktop$ grep -i -C 1 'greeting' aDrake.cpp

    // Program Greeting
    cout << "This program calculates and displays the number of potential";
calebfowler@ubuntu:~/Desktop$ 
```

The grep trick is extremely powerful. Use it often, especially right before you turn in your code. This is the best way I can think of for you to be sure you met all the requirements of the assignment.

Client System.

Your code must compile and run on the client’s system. That will be Ubuntu Desktop Linux, version 18.04. Remember, sourcefile.cpp is YOUR program’s name. I will type the following command to compile your code:

```
g++ -std=c++14 -g -Wall sourcefile.cpp
```

If you do not follow this standard it is likely I will detect errors you miss - and grade accordingly. If you choose to develop on another system there is a high likelihood your program will fail to compile. You have been warned.

Using the Work of Others.

This is an individual assignment, you may use the Internet and your text to research it, but I expect you to work alone. You **may** discuss code and the assignment. Copying code from someone else and turning it in as your own is plagiarism. I also consider isomorphic homework to be plagiarism. You are ultimately responsible for your homework, regardless of who may have helped you on it.

ProTip: Get a bare bones copy of your code running and turn it in. Then go ahead and modify it with bonuses and whatnot. Upload it with the same name so it replaces your previous homework. This way, if something comes up or you can’t finish your homework for some reason, you still have something turned in. A "C" is better than a zero. Risk management class, risk management.

Canvas has a built in plagiarism detector. You should strive to generate a green color box. If you submit it and the score is too high, delete it, change your code and resubmit. You are still subject to the due date, however. This does not apply if I have already graded your homework.

Often, you will not be able to change the code to lower the score. In this case, include as a comment with your homework, what you did and why you thought it was ineffective in lowering your score. This shows me something very important - you are paying attention to what you are doing and you are mindful of your plagiarism score.

Comments.

Genetic Algorithms are the real deal in Artificial Intelligence. It is still an active area of research. You will see how powerful this technique can be with this homework. Students frequently tell me they get a real sense of accomplishment when they turn this in. They often feel like they can handle any programming assignment after this - which is exactly what we are trying to do in this class!