



CS 475/575 -- Spring Quarter 2019

Project #3

Functional Decomposition

100 Points

Due: May 6

This page was last updated: April 3, 2019

Introduction

This project will use parallelism, not for speeding data computation, but for programming convenience. You will create a month-by-month simulation in which each agent of the simulation will execute in its own thread where it just has to look at the state of the world around it and react to it.

You will also get to exercise your creativity by adding an additional "agent" to the simulation, one that impacts the state of the other agents and is impacted by them.

Requirements

1. You are creating a month-by-month simulation of a grain-growing operation. The amount the grain grows is affected by the temperature, amount of precipitation, and the number of "graindeer" around to eat it. The number of graindeer depends on the amount of grain available to eat.
2. The "state" of the system consists of the following global variables:

```
int    NowYear;           // 2019 - 2024
int    NowMonth;          // 0 - 11

float  NowPrecip;         // inches of rain per month
float  NowTemp;           // temperature this month
float  NowHeight;         // grain height in inches
int    NowNumDeer;        // number of deer in the current population
```

3. Your basic time step will be one month. Interesting parameters that you need are:

```
const float GRAIN_GROWS_PER_MONTH =      8.0;
const float ONE_DEER_EATS_PER_MONTH =     0.5;

const float AVG_PRECIP_PER_MONTH =        6.0;    // average
const float AMP_PRECIP_PER_MONTH =        6.0;    // plus or minus
const float RANDOM_PRECIP =              2.0;    // plus or minus noise

const float AVG_TEMP =                   50.0;    // average
const float AMP_TEMP =                   20.0;    // plus or minus
```

```

const float RANDOM_TEMP = 10.0;    // plus or minus noise

const float MIDTEMP = 40.0;
const float MIDPRECIP = 10.0;

```

Units of grain growth are inches.

Units of temperature are degrees Fahrenheit (°F).

Units of precipitation are inches.

4. Because you know ahead of time how many threads you will need (3 or 4), start the threads with a parallel sections directive:

```

omp_set_num_threads( 4 );    // same as # of sections
#pragma omp parallel sections
{
    #pragma omp section
    {
        GrainDeer( );
    }

    #pragma omp section
    {
        Grain( );
    }

    #pragma omp section
    {
        Watcher( );
    }

    #pragma omp section
    {
        MyAgent( );    // your own
    }
}    // implied barrier -- all functions must return in order
    // to allow any of them to get past here

```

5. The temperature and precipitation are a function of the particular month:

```

float ang = ( 30.*(float)NowMonth + 15. ) * ( M_PI / 180. );

float temp = AVG_TEMP - AMP_TEMP * cos( ang );
unsigned int seed = 0;
NowTemp = temp + Ranf( &seed, -RANDOM_TEMP, RANDOM_TEMP );

float precip = AVG_PRECIP_PER_MONTH + AMP_PRECIP_PER_MONTH * sin( ang );
NowPrecip = precip + Ranf( &seed, -RANDOM_PRECIP, RANDOM_PRECIP );
if( NowPrecip < 0. )
    NowPrecip = 0.;

```

To keep this simple, a year consists of 12 months of 30 days each. The first day of winter is considered to be January 1. As you can see, the temperature and precipitation follow cosine and sine wave patterns with some randomness added.

6. Starting values are:

```

// starting date and time:
NowMonth = 0;
NowYear = 2019;

// starting state (feel free to change this if you want):
NowNumDeer = 1;
NowHeight = 1.;

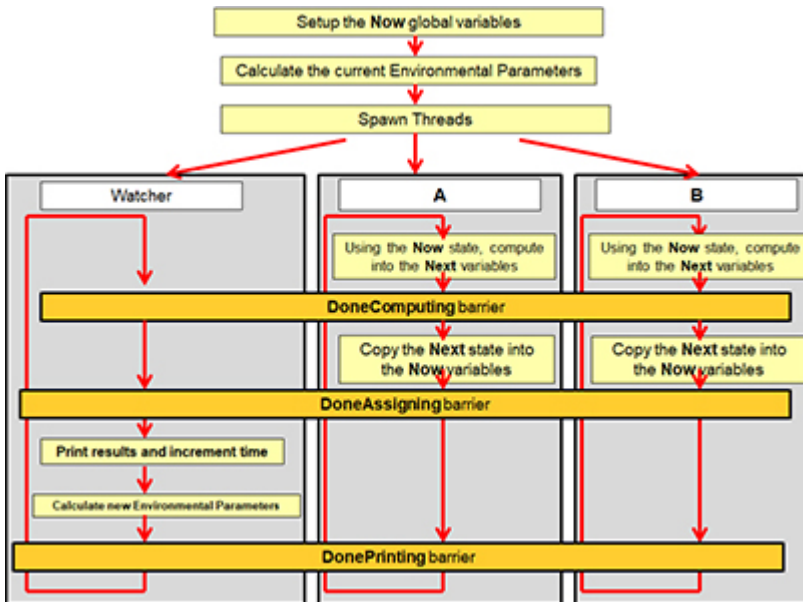
```

7. In addition to this, you must add in some other phenomenon that directly or indirectly controls the growth of the grain and/or the graindeer population. Your choice of this is up to you.

8. You are free to tweak the constants to make everything turn out "more interesting".

Use of Threads

As shown here, you will spawn three threads (four, when you add your own agent):



The **GrainGrowth** and **GrainDeer** threads will each compute the next grain height and the next number of deer based on the current set of global state variables. They will compute these into local, temporary, variables. They both then will hit the **DoneComputing** barrier.

At that point, both of those threads are done computing using the current set of global state variables. Each thread should then copy the local variable into the global version. All 3 threads will then hit the **DoneAssigning** barrier.

At this point, the **Watcher** thread will print the current set of global state variables, increment the month count, and then use the new month to compute the new Temperature and Precipitation. Note that the **GrainGrowth** and **GrainDeer** threads can't proceed because there is a chance they would re-compute the global state variables before they are done being printed. All 3 threads will then hit the **DonePrinting** barrier.

After spawning the threads, the main program should wait for the **parallel sections** to finish.

Each thread should return when the year hits 2025 (giving us 6 years, or 72 months, of simulation).

Remember that this description is for the core part of the project, before you add your own agent to the simulation. That will involve another thread and some additional interaction among the global state variables.

Quantity Interactions

The Carrying Capacity of the graindeer is the number of inches of height of the grain. If the number of graindeer exceeds this value at the end of a month, decrease the number of graindeer by one. If the number of graindeer is less than this value at the end of a month, increase the number of graindeer by one.

Each month you will need to figure out how much the grain grows. If conditions are good, it will grow by `GRAIN_GROWS_PER_MONTH`. If conditions are not good, it won't.

You know how good conditions are by seeing how close you are to an ideal temperature (°F) and precipitation (inches). Do this by computing a Temperature Factor and a

Precipitation Factor like this:

$$TF = e^{-\left(\frac{T - MidTemp}{10}\right)^2}$$

$$PF = e^{-\left(\frac{P - MidPrecip}{10}\right)^2}$$

Note that there is a standard math function, `exp(x)`, to compute e-to-the-x:

```
float tempFactor = exp( -SQR( ( NowTemp - MIDTEMP ) / 10. ) );
float precipFactor = exp( -SQR( ( NowPrecip - MIDPRECIP ) / 10. ) );
```

I like squaring things with another function:

```
float
SQR( float x )
{
    return x*x;
}
```

You then use `tempFactor` and `precipFactor` like this:

```
NowHeight += tempFactor * precipFactor * GRAIN_GROWS_PER_MONTH;
NowHeight -= (float)NowNumDeer * ONE_DEER_EATS_PER_MONTH;
```

Be sure to clamp `NowHeight` against zero.

Structure of the Simulation Functions

Each simulation function will have a structure that looks like this:

```
while( NowYear < 2025 )
{
    // compute a temporary next-value for this quantity
    // based on the current state of the simulation:
    . . .

    // DoneComputing barrier:
    #pragma omp barrier
    . . .

    // DoneAssigning barrier:
    #pragma omp barrier
    . . .

    // DonePrinting barrier:
    #pragma omp barrier
    . . .
}
```

Doing the Barriers on Visual Studio

You will probably get this error when doing this type of project in Visual Studio:

'#pragma omp barrier' improperly nested in a work-sharing construct

The OpenMP specifications says: "All threads in a team must execute the barrier region." Presumably this means that placing corresponding barriers in the different functions does not qualify, but somehow gcc/g++ are OK with it.

Here is a work-around. Instead of using the **#pragma omp barrier** line, use this:
WaitBarrier();

You must call **InitBarrier(n)** as part of your setup process, where **n** is the number of threads you will be waiting for at this barrier. Presumably this is **3** before you add your own quantity and is **4** after you add your own quantity.

I'm not particularly proud of this code, but it seems to work. To make this happen, first declare the following global variables:

```
omp_lock_t      Lock;
int             NumInThreadTeam;
int             NumAtBarrier;
int             NumGone;
```

Here are the function prototypes:

```
void    InitBarrier( int );
void    WaitBarrier( );
```

Here is the function code:

```
// specify how many threads will be in the barrier:
//      (also init's the Lock)

void
InitBarrier( int n )
{
    NumInThreadTeam = n;
    NumAtBarrier = 0;
    omp_init_lock( &Lock );
}

// have the calling thread wait here until all the other threads catch up:

void
WaitBarrier( )
{
    omp_set_lock( &Lock );
    {
        NumAtBarrier++;
        if( NumAtBarrier == NumInThreadTeam )
        {
            NumGone = 0;
            NumAtBarrier = 0;
            // let all other threads get back to what they were doing
            // before this one unlocks, knowing that they might immediately
            // call WaitBarrier( ) again:
            while( NumGone != NumInThreadTeam-1 );
            omp_unset_lock( &Lock );
            return;
        }
    }
    omp_unset_lock( &Lock );

    while( NumAtBarrier != 0 );    // this waits for the nth thread to arrive

    #pragma omp atomic
    NumGone++;                    // this flags how many threads have returned
}
```

Random Numbers

How you generate the randomness is up to you. As an example (which you are free to use), Joe Parallel wrote a couple of functions that return a random number between a user-given low value and a high value (note that the name overloading is a C++-ism, not a C-ism):

```
#include <stdlib.h>

unsigned int seed = 0; // a thread-private variable
float x = Ranf( &seed, -1.f, 1.f );

. . .

float
Ranf( unsigned int *seedp, float low, float high )
{
    float r = (float) rand_r( seedp );           // 0 - RAND_MAX

    return( low + r * ( high - low ) / (float)RAND_MAX );
}

int
Ranf( unsigned int *seedp, int ilow, int ihigh )
{
    float low = (float)ilow;
    float high = (float)ihigh + 0.9999f;

    return (int)( Ranf(seedp, low,high) );
}
```

Results

Turn in your code and your PDF writeup. Be sure your PDF is a file all by itself, that is, not part of any zip file. Your writeup will consist of:

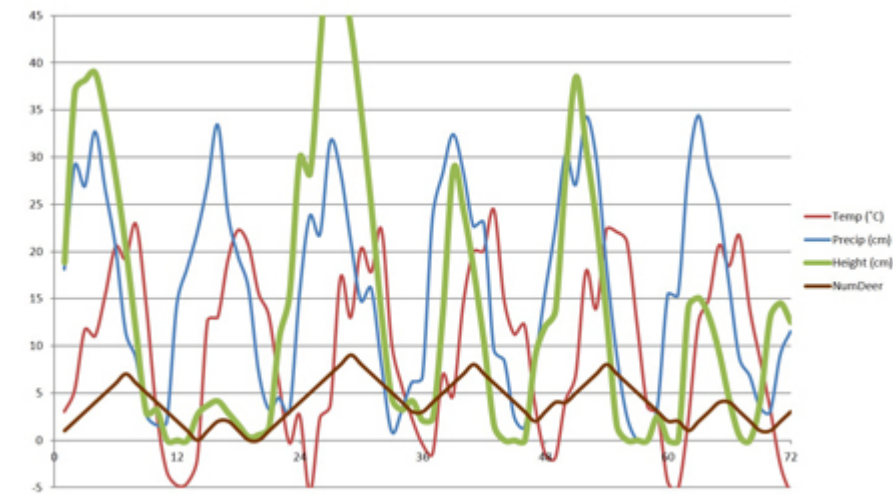
1. What your own-choice quantity was and how it fits into the simulation.
2. A table showing values for temperature, precipitation, number of graindeer, height of the grain, and your own-choice quantity as a function of month number.
3. A graph showing temperature, precipitation, number of graindeer, height of the grain, and your own-choice quantity as a function of month number. Note: if you change the units to °C and centimeters, the quantities might fit better on the same set of axes.

cm = inches * 2.54
 °C = (5./9.)*(°F-32)

This will make your heights have larger numbers and your temperatures have smaller numbers.

4. A commentary about the patterns in the graph and why they turned out that way. What evidence in the curves proves that your own quantity is actually affecting the simulation correctly?

Example Output



Grading:

Feature	Points
Simulate grain growth and graindeer population	20
Simulate your own quantity	20
Table of Results	10
Graph of Results	20
Commentary	30
Potential Total	100