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Functional (Task) Decomposition

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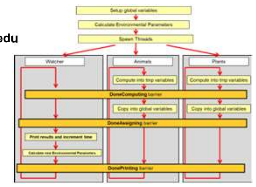

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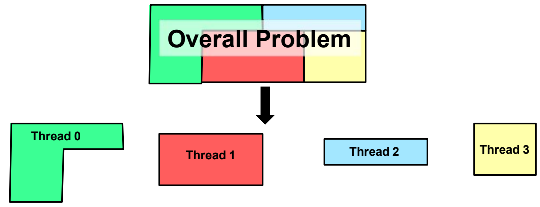
The Functional (or Task) Decomposition Design Pattern



A good example of this is the computer game *SimPark*.

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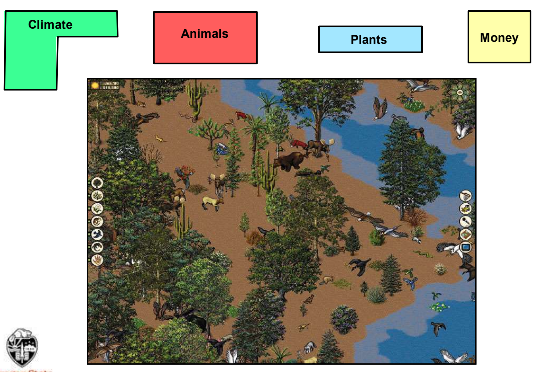
The Functional (or Task) Decomposition Design Pattern



Credit: Maxis (Sim Park)

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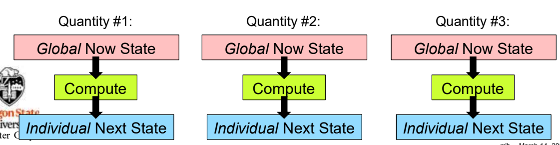
How is this is different from Data Decomposition (such as the OpenMP for-loops)

- This is done less for performance and more for programming convenience.
- This is often done in simulations, where each quantity in the simulation needs to make decisions about what it does *next* based on what it and all the other global quantities are doing *right now*.
- Each quantity takes *all* of the "Now" state data and computes its own "Next" state.
- The biggest trick is to synchronize the different quantities so that each of them is seeing only what the others' data values are *right now*. Nobody is allowed to switch their data states until they are *all* done consuming the current data and thus are ready to switch together.
- The synchronization is accomplished with barriers.



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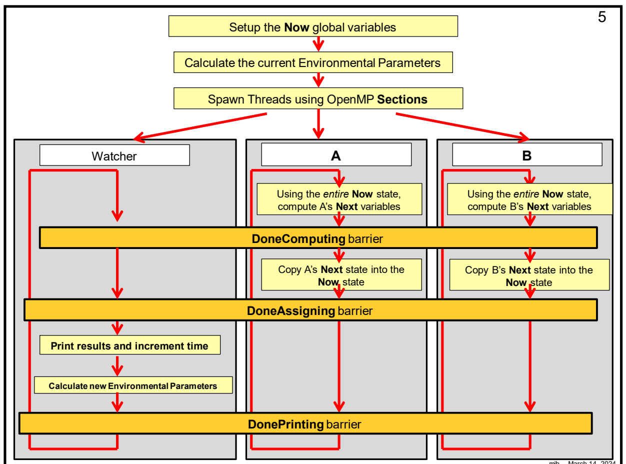

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The Functional Decomposition Design Pattern

```
int
main( int argc, char *argv[ ] )
{
        . . .
        omp_set_num_threads( 3 );
        InitBarrier( 3 );                    // don't worry about this for now, we will get to this later

        #pragma omp parallel sections
        {
                #pragma omp section
                {
                        Watcher( );
                }

                #pragma omp section
                {
                        Animals( );
                }

                #pragma omp section
                {
                        Plants( );
                }
        }   // implied barrier -- all functions must return to get past here
}
```


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The Functional Decomposition Design Pattern
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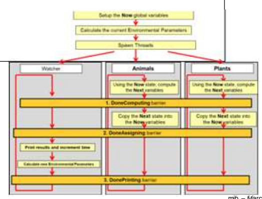
```
void
Watcher( )
{
      while( << You decide how to know when it's all finished? >> )
      {
            // do nothing
            WaitBarrier( );            // 1.

            // do nothing
            WaitBarrier( );            // 2.

            << write out the "Now" state of data >>

            << advance time and re-compute all environmental variables >>

            WaitBarrier( );            // 3.
      }
}
```



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The Functional Decomposition Design Pattern
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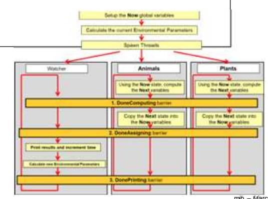
```
void
Animals( )
{
      while( << You decide how to know when it's all finished? >> )
      {
            int nextXXX= << function of what all states are right Now >>
            . . .
            WaitBarrier( );            // 1.

            NowXXX = nextXXX;      // copy the computed next state to the Now state

            WaitBarrier( );            // 2.

             // do nothing
             WaitBarrier( );           // 3.
      }
}
```



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Simulation Output
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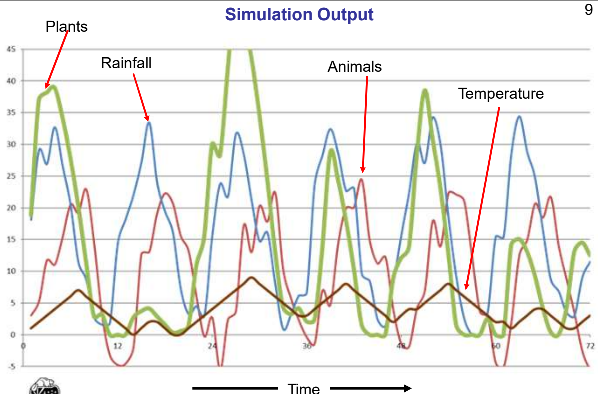

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We Have to Make Our Own Barrier Function
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Why can't we just use **#pragma omp barrier** ?

Functional Decomposition is a good example of when you can't.

There are two ways to think about how to allow a program to implement a barrier:

1. Make a thread wait at a specific address in the code. Keep waiting until *all* threads are waiting there.
2. Make a thread wait when it specifically asks to "Wait". Keep waiting until *all* threads have asked to "Wait".

Both of these sound legitimate, but:

- The OpenMP specification only allows for #1.
- The Functional Decomposition described here wants to use #2, because the waiting needs to happen at different addresses in different functions

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We Have to Make Our Own Barrier Function
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```
omp_lock_t      Lock;
volatile int      NumInThreadTeam;
volatile int      NumAtBarrier;
volatile int      NumGone;

void
InitBarrier( int n )
{
      NumInThreadTeam = n;                    // number of threads you want to block at the barrier
      NumAtBarrier = 0;
      omp_init_lock( &Lock );
}

void
WaitBarrier( )
{
      omp_set_lock( &Lock );
      {
            NumAtBarrier++;
            if( NumAtBarrier == NumInThreadTeam )         // release the waiting threads
            {
                  NumGone = 0;
                  NumAtBarrier = 0;
                  // let all other threads return before this one unlocks:
                  while( NumGone != NumInThreadTeam - 1 );
                  omp_unset_lock( &Lock );
                  return;
            }
      }
      omp_unset_lock( &Lock );

      while( NumAtBarrier != 0 );            // all threads wait here until the last one arrives …

      #pragma omp atomic                       // … and sets NumAtBarrier to 0
            NumGone++;
}
```

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The WaitAtBarrier( ) Logic
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Thread #0	Thread #1	Thread #2	NumInThreadTeam	NumAtBarrier	NumGone
			3	0	
Calls WaitBarrier( )			3	0	
Sets the lock			3	0	
Increments NumAtBarrier			3	1	
NumAtBarrier != NumInThreadTeam			3	1	
Unsets the lock			3	1	
Stuck at while-loop #2			3	1	
	Calls WaitBarrier( )		3	1	
	Sets the lock		3	1	
	Increments NumAtBarrier		3	2	
	NumAtBarrier != NumInThreadTeam		3	2	
	Unsets the lock		3	2	
	Stuck at while-loop #2		3	2	
		Calls WaitBarrier( )	3	2	
		Sets the lock	3	2	
		Increments NumAtBarrier	3	3	
		NumAtBarrier == NumInThreadTeam	3	3	
		Sets NumGone	3	3	0
		Sets NumAtBarrier	3	0	0
		Stuck at while-loop #1	3	0	0
Falls through while-loop #2			3	0	0
Increments NumGone			3	0	1
Returns			3	0	1
	Falls through while-loop #2		3	0	2
	Increments NumGone		3	0	2
	Returns		3	0	2
		Falls through while-loop #1	3	0	2
		Unsets the lock	3	0	2
		Returns	3	0	2

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