The Functional (or Task) Decomposition Design Pattern

A good example of this is the computer game *SimPark*.
The Functional (or Task) Decomposition Design Pattern

- 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 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 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.

Credit: Maxis (Sim Park)
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
}

The Functional Decomposition Design Pattern
```c
void Watcher()
{
    while( << You decide how to know when 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.
    }
}
```

```c
void Animals()
{
    while( << You decide how to know when 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.
    }
}
```
You Might Have to Make Your Own Barrier Function

Why can’t we just use `#pragma omp barrier`?

The Functional Decomposition is a good example of when you sometimes can’t.

There are two ways to think about how to allow a program to use a barrier:
1. Let the barrier happen at a specific location in the code
2. Let the barrier work after a specific number of threads have gotten there

- g++ allows both #1 and #2
- Visual Studio requires #1
- The Functional Decomposition shown here wants to have #2, because the barriers need to be in different functions
Sometimes You Have to Make Your Own Barrier Function

```c
omp_lock_t Lock;
int NumInThreadTeam;
int NumAtBarrier;
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:
            if( 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++;
}
```

The WaitAtBarrier( ) Logic

<table>
<thead>
<tr>
<th>Thread #1</th>
<th>Thread #2</th>
<th>NumInThreadTeam</th>
<th>NumAtBarrier</th>
<th>NumGone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calls WaitAtBarrier()</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sets the lock</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Increments NumAtBarrier</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>NumAtBarrier = NumInThreadTeam</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Stuck at while-loop #1</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Calls WaitAtBarrier()</td>
<td>3</td>
<td>1</td>
<td>0</td>
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</tr>
<tr>
<td>Sets the lock</td>
<td>3</td>
<td>2</td>
<td>0</td>
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</tr>
<tr>
<td>Increments NumAtBarrier</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>NumAtBarrier = NumInThreadTeam</td>
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<td>3</td>
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</tr>
<tr>
<td>Stuck at while-loop #2</td>
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<tr>
<td>Calls WaitAtBarrier()</td>
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<td>2</td>
<td>0</td>
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</tr>
<tr>
<td>Sets the lock</td>
<td>3</td>
<td>2</td>
<td>0</td>
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</tr>
<tr>
<td>Increments NumAtBarrier</td>
<td>3</td>
<td>3</td>
<td>0</td>
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</tr>
<tr>
<td>NumAtBarrier = NumInThreadTeam</td>
<td>3</td>
<td>3</td>
<td>0</td>
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</tr>
<tr>
<td>Stuck at while-loop #3</td>
<td>3</td>
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</tr>
<tr>
<td>Falls through while-loop #2</td>
<td>3</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Increments NumGone</td>
<td>3</td>
<td>0</td>
<td>1</td>
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</tr>
<tr>
<td>Returns</td>
<td>3</td>
<td>0</td>
<td>1</td>
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</tr>
<tr>
<td>Falls through while-loop #3</td>
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<tr>
<td>Increments NumGone</td>
<td>3</td>
<td>0</td>
<td>1</td>
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</tr>
<tr>
<td>Returns</td>
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<td>1</td>
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</tr>
<tr>
<td>Falls through while-loop #4</td>
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</tr>
<tr>
<td>Increments NumGone</td>
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<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Returns</td>
<td>3</td>
<td>0</td>
<td>2</td>
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</table>