Ecolab: Agent Based Modeling for C++ programmers

Russell K. Standish and Richard Leow
High Performance Computing Support Unit
University of New South Wales, Sydney 2052, Australia
{R.Standish,R.Leow}@unsw.edu.au
http://parallel.hpc.unsw.edu.au/ecolab

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Abstract

Ecolab is an agent based modeling system for C++ programmers, strongly influenced by the design of Swarm. This paper is just a brief outline of *Ecolab*'s features, more details can be found in other published articles, documentation and source code from the *Ecolab* website.

1 Ecolab

Ecolab is an ABM system for C++ programmers. This is not the time or place to debate the merits of C++ over any other object oriented language. If you have chosen C++ as an implementation language for your models because of performance, expressibility, familiarity or compatibility with other software libraries, then ABM environments such as Swarm or Repast offer little support to you. In this case, you should consider *Ecolab*.

2 Scripting

Ecolab uses the Classdesc[2] object descriptor technology. This provides a form of object reflection, or the ability to query an object's internal structure at runtime. This may seem obvious to a Java or Objective C programmer, as object reflection is built into the language.

How is Classdesc used in *Ecolab*? The user codes their entire model as a class. Usually, there will only be one instantiated object of that class (the model). Most model instance variables, and model methods adhering to particular calling conventions are exposed to a TCL interpreter. This allows great flexibility to

configure different sorts of experiments at runtime. For example, if your model class is:

```
class model_t {
public:
int tstep; double foo;
void step();
double average_something();
} model;
```

then by inserting the macro call `make_model(model)` into your code, the following TCL script is possible:

```
model.tstep 0
model.foo 0
while {[model.tstep]<100000} {
   model.step
   if {[model.tstep]%1000==0} {puts stdout [model.average_something]}
}
```

This initialises the instance variables, and runs the model for 100000 steps, writing out the average of something every 1000th timestep.

3 GUI mode for exploration

The TCL interpreter also has a complete GUI toolkit (Tk), and a visualisation and analysis toolkit (BLT). It is possible to turn the above script into a continuously updated plot by changing one line:

```
   if {[model.tstep]%1000==0} {
      set av_something [model.average_something]
      plot av av_something
}
```

With this ability to script experiments at runtime, one can use one script for exploratory visualisation or debugging, and another for batch production work. Items in common, such as the model's parameters can be stored in a third file and included using TCL's `source` command.

The main point is that it is not necessary to be proficient at TCL programming to be productive with *EcoLab*. Many example scripts exist in the source code that can be adapted for you use. However, a proficient TCL programmer can exploit a large amount of functionality to create some great visualisations — using Tk's ability to handle pixmaps for instance. The jellyfish simulation example provided as part of the package is a case in point.

4 Object Browser

Using Classdesc to expose your C++ objects to the TCL environment has some other interesting features. EcoLab comes with an *object browser*, which allows the user to drill down into the model to see why a particular object is doing what it is doing. The object browser is EcoLab's answer to Swarms probes. To use the object browser, just click on the "Object Browser" button on the GUI toolbar. This will pop a list of TCL procedures, and top level objects (procedures with "." in their name). Clicking on objects pops up another box containing the procedures within that (corresponding to instance variables and methods) and objects (compound instance variables). Clicking on a procedure will execute that procedure (using any arguments you have provided) and displays the result. You can also arrange to have the procedure executed automatically every second to give a continuous update of (say) and instance variable.

5 Checkpoint/Restart

By invoking Classdesc on your model in this way, TCL commands are created for checkpointing and restarting your model, with no further coding required of your model (provided the complete state of your model is stored in the model object of course). So, if you are using a high performance computing bureau, which forces you to continuously checkpoint and restart your jobs to allow other peoples jobs to run, you can write something like the following TCL script:

```
if [file exists checkpoint] {
   model.restart checkpoint
} else {
   source model-parms
}

while {[model.tstep]<100000} {
   model.step
   if {[cputime] > 10000} {
      model.checkpoint checkpoint
      exit
   }
}

if {[model.tstep]<100000} {
  exec qsub myjob.tcl
}
```

which is self-submitting batch script in which each job only runs for less that 3 hours, but the chain of jobs continues until the calculation is complete.

6 Parallel Processing

Ecolab provides support for parallel processing using the MPI[3] distributed memory programming model. By turning on the MPI flag at compile time, *Ecolab* will start an interpreter on each processor. Normally, your script will run on processor 0, but any TCL command can be run on all processors simultaneously with the `parallel` command. Plus, a method can be declared parallel, so when invoked, it will be invoked on all processors simultaneously. The *ClassdescMP*[4] can be used to easily code communication between processors, or the full power of MPI used. At this point in time, it is the model implementor's responsibility to arrange for objects to be distributed across the processors, however an experimental project called *Graphcode*[1] will allow arbitrary agents on an arbitrary grid topology (graph) to be automatically distributed across parallel processors, even having dynamic updating of the object distribution to optimise load balancing.

7 Supported Machines

Ecolab is an open source project which depends on ANSI standard C++, TCL, Tk and BLT. The primary development environment is Linux, but by its adherence to standards, *Ecolab* has been successfully ported to Irix, Solaris, AIX, Tru64, Mac OSX and Windows (under Cygwin), often using the native C++ compiler rather than gcc. It should be noted that the Mac OSX port of *Ecolab* was completed about 6 months ago, and took about 2 days to do, which is one area in which it out competed Swarm. At present the interface depends on X-windows, work on a native Aqua interface is being planned in the next 6 months.

Ecolab has now been deployed for 5 distinctly different modelling projects. Each project has its own requirements, which are fed back into the core system where it is useful.

There are no plans for a Java interface. The aim of this project is to provide an environment for C++ programmers, not Java programmers who are already catered for with other packages.

We welcome contributers to the *Ecolab* project. The source code is managed by Peter Miller's AEGIS system, so you will need to email Russell Standish to obtain a user login to access AEGIS. Anonymous readonly access to the repository is however already available via the *Ecolab* website, where you can pick a version of *Ecolab* at any revision level as a gzipped tarball. Unlike CVS, AEGIS ensures that the code compiles, and that some consistency checks are performed at code check in time. Plus whenever a branch is closed (*Ecolab*.4.Dx as opposed to *Ecolab*.4.x.Dy), further tests are performed to ensure that the code compiles and runs a test suite on all supported platforms.

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