CCA
Common Component Architecture

Introduction to Components

CCA Forum Tutorial Working Group
http://www.cca-forum.org/tutorials/
tutorial-wg@cca-forum.org



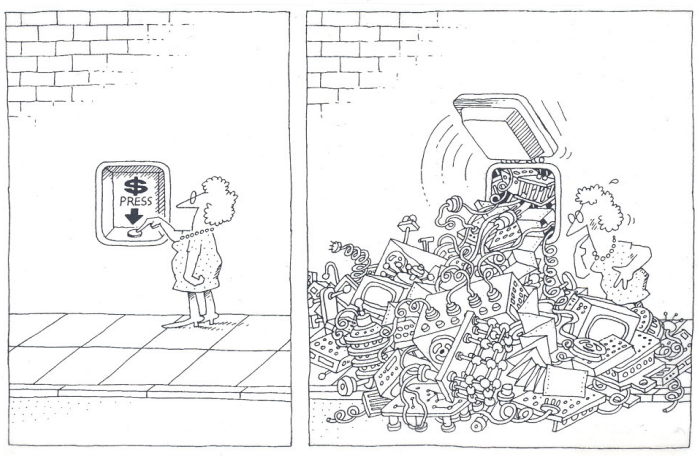
Overview

- **Why** do we need components?
- **What** are components?
- **How** do we make components?

Why Components

- In “Components, The Movie”
  - Interoperability across multiple languages
  - Interoperability across multiple platforms
  - Incremental evolution of large legacy systems (esp. w/ multiple 3rd party software)
- Complexity

Why Components



The task of the software development team is to engineer the illusion of simplicity *[Booch]*.

Software Complexity

- Software crisis
  - "Our failure to master the complexity of software results in projects that are late, over budget, and deficient in their stated requirements." *[Booch]*
- Can't escape it
  - "The complexity of software is an essential property, not an accidental one." *[Brooks]*
- Help is on the way…
  - "A complex system that works is invariably found to have evolved from a simple system that worked… A complex system designed from scratch never works and cannot be patched up to make it work." *[Gall]*
  - "Intracomponent linkages are generally stronger than intercomponent linkages." *[Simon]*
  - "Frequently, complexity takes the form of a hierarchy." *[Courtois]*

The Good the Bad and the Ugly

- An example of what can lead to a crisis in software:
- At least 41 different Fast Fourier Transform (FFT) libraries:
  - see, http://www.fftw.org/benchfft/doc/ffts.html
- Many (if not all) have different interfaces
  - different procedure names and different input and output parameters
- SUBROUTINE FOUR1(DATA, NN, ISIGN)
  - Replaces DATA by its discrete Fourier transform (if ISIGN is input as 1) or replaces DATA by NN times its inverse discrete Fourier transform (if ISIGN is input as -1). DATA is a complex array of length NN or, equivalently, a real array of length 2*NN. NN MUST be an integer power of 2 (this is not checked for!).

Components Promote Reuse

Hero programmer producing single-purpose, monolithic, tightly-coupled parallel codes

- Components promote software reuse
  - "The best software is code you don't have to write" *[Steve Jobs]*
- Reuse, through cost amortization increases software quality
  - thoroughly tested code
  - highly optimized code
  - improved support for multiple platforms
  - developer team specialization

What Are Components

- **Why** do we need components?
- **What** are components?
- **How** do we make components?

What Are Components *[Szyperski]*

- A component is a binary unit of independent deployment
  - well separated from other components
    - fences make good neighbors
  - can be deployed independently
- A component is a unit of third-party composition
  - is composable (even by physicists)
  - comes with clear specifications of what it requires and provides
  - interacts with its environment through well-defined interfaces
- A component has no persistent state
  - temporary state set only through well-defined interfaces
  - throw away that dependence on global data (common blocks)
- Similar to Java packages and Fortran 90 modules (with a little help)

What Does This Mean

- So what does this mean
  - Components are “plug and play”
  - Components are reusable
  - Component applications are evolvable

Component Forms *[Cheesman & Daniels]*

- Component Standard
  - must conform to some sort of environment standard (Framework)
- Component Specification
  - specification of what a component does
- Component Interface
  - specification of procedure names and procedure parameters
- Component Implementation
  - written in a computer language (Fortran for example)
- Installed Component
  - a shared object library (.so file)
- Component Object
  - services and state joined together

What is a Component Architecture

- A set of standards that allows:
  - Multiple groups to write units of software (components)
  - The groups to be sure that their components will work with other components written in the same architecture
- A framework that holds and runs the components
  - And provides services to the components to allow them to know about and interact with other components

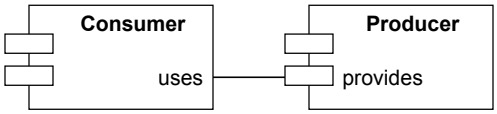
What Are Components II

- Components live in an environment and interact with the environment through a framework and connections with other components.
- Components can discover information about their environment from the framework.
- Components must explicitly publish what capabilities they provide.
- Components must explicitly publish what connections they require.
- Components are a runtime entity.

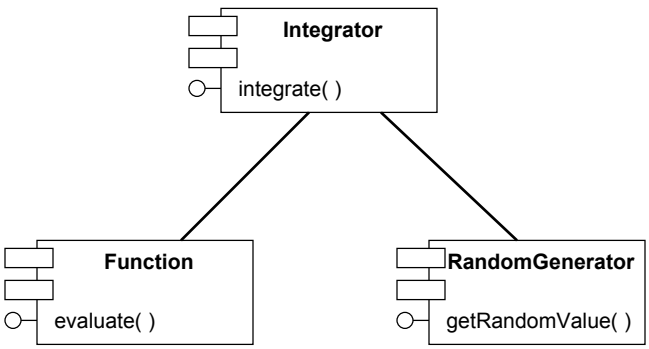
Components Are Different From Objects

- You can build components out of object classes.
  - (or out of Fortran procedures)
- But a component is more that just an object.
- A component only exists in the context of a Component Standard (Framework).

Pictorial Example



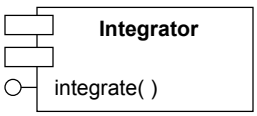
Three Components



How Do We Make Components

- **Why** do we need components?
- **What** are components?
- **How** do we make components?

Interface Declaration



Integrator.h

```
class Integrator
{
  virtual void
  integrate( double lowBound,
             double upBound,
             int count ) = 0;
};
```

Integrator.f90

```
interface
  function integrate( lowBound,
                      upBound,
                      count )
   real(kind(1.0D0)) :: lowBound, upBound
   integer :: count
  end function
end interface
```

Publish the Interface in SIDL

- Publish the interface
  - interfaces are published in SIDL (Scientific Interface Definition Language)
  - can't publish in native language because of language interoperability requirement
- Integrator example:

```
interface Integrator extends cca.Port
 {
   double integrate(in double lowBound,
                    in double upBound,
                    in int count);
 }
```


F90 Integrator Interface

```
MODULE Integrator

  interface

    !
    ! Returns the result of the integration from lowBound to upBound.
    !
    ! lowBound - the beginning of the integration interval
    ! upBound  - the end of the integration interval
    ! count    - the number of integration points
    !
    function integrate(port, lowBound, upBound, count)
      use CCA
      type(CCAPort) :: port
      real(kind(1.0D0)) :: integrate, lowBound, upBound
      integer :: count
    end function integrate

  end interface

END MODULE Integrator
```

F90 Program

```
program Driver
  use CCA
  use MonteCarloIntegrator
  type (CCAPort) :: port

  print *, "Integral = ", integrate(port, 0.0D0, 1.0D0, 1000)

end program
```


C++ Abstract Integrator Class

```
/**
 * This abstract class declares the Integrator interface.
 */

class Integrator : public virtual gov::cca::port
{
  public:
    virtual ~Integrator() { }

   /**
     * Returns the result of the integration from lowBound to upBound.
     *
     * lowBound - the beginning of the integration interval
     * upBound  - the end of the integration interval
     * count    - the number of integration points
     */
    virtual double integrate(double lowBound, double upBound, int count) = 0;
};
```

C++ Object-Oriented Program

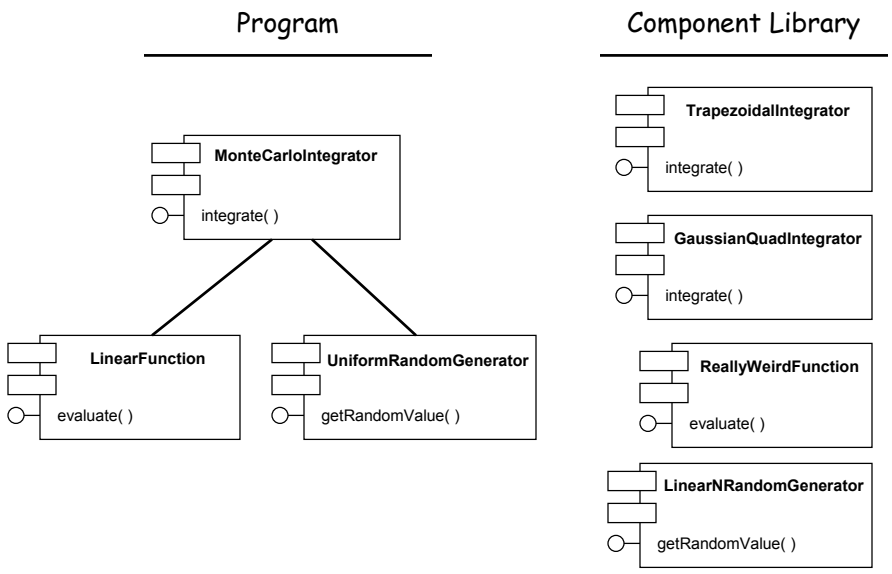
```
#include <iostream>
#include "MonteCarloIntegrator.h"

int main(int argc, char* argv[])
{
   MonteCarloIntegrator* integrator = new MonteCarloIntegrator();

   cout << "Integral = " << integrator->integrate(0.0, 1.0, 1000) << endl;

   return 0;
}
```


Component Program



Questions and Answers

- Is CCA similar to CORBA or COM/DCOM?
  - yes, but is a component architecture oriented towards high-performance computing
- Is CCA for parallel or distributed computing?
  - both, but currently only one or the other
- Can I use CCA today for scientific applications?
  - yes, but it is a research project
- Where can I get more information?
  - http://www.cca-forum.org/
  - join the CCA Forum

Final Thought

- Components are reusable assets. Compared with specific solutions to specific problems, components need to be carefully generalized to enable reuse in a variety of contexts. Solving a general problem rather than a specific one takes more work. In addition, because of the variety of deployment contexts, the creation of proper documentation, test suites, tutorials, online help texts, and so on is more demanding for components than for a specialized solution. *[Szyperski, p. 14]*

Bibliography

Booch, G. 1994. *Object-Oriented Analysis and Design with Applications.* Second Editions. Santa Clara, CA: The Benjamin/Cummings Publishing Company, p. 8.

Brooks, F. April 1987. No Silver Bullet: Essence and Accidents of Software Engineering. *IEEE Computer* vol. 20(4), p. 12.

Cheesman, J. and J. Daniels. *UML Components: A Simple Process for Specifying Component-Based Software.* New York, NY: Addison-Wesley

Courtois, P. June 1985. On Time and Space Decomposition of Complex Structures. *Communications of the ACM* vol 28(6), p. 596.

Gall, J. 1986. *Systemantics: How Systems Really Work and How They Fail.* Second Edition. Ann Arbor, MI: The General Systemantics Press, p. 65.

Simon, H. 1982. *The Sciences of the Artificial.* Cambridge, MA: The MIT Press, p. 217.

Szyperski, C. 1998. *Component Software: Beyond Object-Oriented Programming.* New York, NY: Addison-Wesley, p. 30

Next: CCA Concepts