Data Modeling in VHDL

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Complexity Management

- For system-level design of behavior
  - abstraction of data
  - abstraction of communication & timing
  - abstraction of concurrency
- SUAVE:
  - SAVANT & University of Adelaide
  - VHDL Extensions
  - object-oriented data modeling
  - genericity
  - communication & concurrency
Design Objectives

- Support high-level modeling
  - improve encapsulation and information hiding
  - provide for hierarchies of abstraction
- Support re-use and incremental development
  - polymorphism, dynamic binding
- Support hw/sw codesign
  - improved integration with programming languages
- Preserve correctness of existing models
- Design principles from VHDL-93
  - preserve “conceptual integrity”

Class-Based Approach

- Example: Objective VHDL (Radetzki et al)
- Class is a specific language construct
  - encapsulates data and operations
  - may inherit from a superclass
  - an object is an instance of a class
- cf. Simula, Smalltalk, C++, Java
Programming by Extension

- Example: SUAVE (Ashenden & Wilsey)
- **Class** is a type-derivation hierarchy
  - package encapsulates a tagged type and operations (ADT)
  - a new type may extend a parent type
    - inherits operations
  - T’Class denotes type hierarchy rooted at T
  - an object is of a tagged type or class-wide type
- *cf.* Oberon-2, Ada-95

Integration with VHDL Signals

- Variables denote machine locations
- Signals denote trajectories of values
  - assignment: editing scheduled trajectory
  - update: resolution; type conversions on net
  - event: change of value triggers processes
Classes and Signals

- Problem: data in hidden in the class
  - behavior of operation depends on kind of object
- Objective VHDL solution:

```vhdl
type complex is class
    class attribute re, im : real;
    impure function real_part ( x : complex ) return real;
    impure function imag_part ( x : complex ) return real;
    procedure add ( y : complex );
end class complex;
```

```vhdl
for signal  
    procedure add ( y : complex ) is
    begin
        re <= re + y.real_part;
        im <= im + y.imag_part;
    end procedure add;
end for;
```

```vhdl
for variable  
    procedure add ( y : complex ) is
    begin
        re := re + y.real_part;
        im := re + y.imag_part;
    end procedure add;
end for;
end class complex;
```
ADTs and Signals

• Package defines a type
  – signals declared to be of the type
  – assignment/update” use predefined “:=”, “=”
  – signal/variable operations distinguished by parameter kind if necessary

• SUAVE solution: ...

package complex_numbers is
  type complex is private;
  . .
  function "+" ( x, y : complex ) return complex;
private
  type complex is record
    re, im : real;
  end record complex;
end package complex_numbers;

package body complex_numbers is
  . .
  function "+" ( x, y : complex ) return complex is
  begin
    return ( x.re + y.re, x.im + y.im );
  end function "+";
end package body complex_numbers;
ADTs and Signals

```vhdl
use complex_numbers.all;
variable c1, c2 : complex;
signal s1, s2 : complex;

...  
c1 := c1 + c2;
s1 <= s2 + c1;
```

Encapsulation

- ADTs require strong encapsulation
- VHDL packages provide encapsulation
  - weak: concrete type is visible
  - strengthen by adding private types (à la Ada)
- Classes provide encapsulation
  - but replicate aspects of packages
  - complicate the language
Summary

• Both approaches can be made to work
• Prefer programming by extension
  – integrates with existing language better
    • existing features
    • existing style
  – avoids duplication of features
  – integrates with generics to provide mixin inheritance

• SUAVE
  – http://www.ececs.uc.edu/~petera/suave.html