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SystemVerilog Interface Classes

More Useful Than You Thought

Stan Sokorac
stan.sokorac@arm.com

ARM®

Introduction

- Concept of “interface” popularized in Java
  - Introduced as “protocol” in Objective-C
  - Most modern language implement something like it
  - Different from SystemVerilog interface!
- Introduced into SV fairly late (2012)
  - Not used in UVM
  - Lack of adoption in DV community
- Heavy use in ARM® CPU verification
  - Clean and flexible testbenches

Observer Pattern

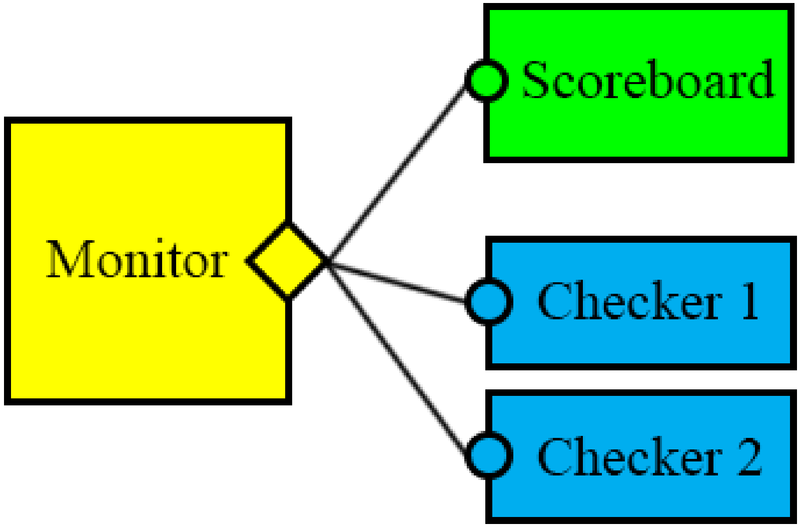
- Observer (also known as Subscriber, or Listener) pattern commonly used in all TBs
- Monitor observes an event
  - Then, it notifies listeners

“Old School” observer pattern

```
function void notify_observers(resolve_txn resolve);
  m_scoreboard.notify(resolve);
  m_checker1.notify(resolve);
  m_checker2.notify(resolve);
endfunction
```

The UVM way

- UVM made it better
- Generic one-to-many connections
- Great for assembling large components
- Limited in smaller testbenches:
  - Static connections
  - Single transaction
  - Macros!



The Interface Class Way

- Removes the limitations, brings peace and happiness ☺
- Dynamic connections
- Rich communication through custom functions calls
- No macros!

- Let’s dig into an example
  - Functionality similar to a UVM analysis port

The Interface Class

- A group of function declarations with no implementations
- A “contract” that describes the interface to the outside world

“pure virtual” because interface classes don’t provide implementation

```
interface class resolve_listener;
  pure virtual function
         void new_resolve(arm_txn_resolve resolve);
endclass
```

The Monitor

A queue of listeners

Register a new listener

Notify listeners

```
class monitor extends uvm_component;
  local resolve_listener
              m_resolve_listeners[$];

  function void add_listener(
           resolve_listener listener);
    m_resolve_listener.push_back(listener);
  endfunction

  virtual task run_phase(uvm_phase phase);
    arm_txn_resolve resolve =
                       get_next_resolve();
    foreach(m_resolve_listeners[i])
       m_resolve_listeners[i].
                    new_resolve(resolve);
  endtask
endclass
```

The Listener

Promise to define functions from the interface class

Base class can be anything (or nothing)

Passes itself as ‘resolve_listener’

Implementation no different from any other virtual function

```
class resolve_checker
     extends uvm_component
     implements resolve_listener;

  virtual function void
        connect_phase(uvm_phase phase);
    super.connect_phase(phase);
    m_config.monitor.add_listener(this);
  endfunction

  virtual function void
      new_resolve(arm_txn_resolve resolve);
    if (resolve.is_abort())
      error(“Aborts are not expected”);
  endfunction
endclass
```

Building up the functionality

- Dynamic connections
- No components necessary
  – Analysis ports for sequences
  – Reactive stimulus bonanza

Dynamic connect and disconnect calls

```
task run_sequence();
  m_config.monitor.add_listener(this);
  wait(…);
  m_config.monitor.remove_listener(this);
endtask

virtual function void new_resolve(arm_txn resolve);
  if (resolve.is_abort())
     send_flush();
endfunction
```

Passing multiple objects

- Custom function call
  - Pass whatever you like

Multiple objects passed for “analysis”

```
pure virtual function void new_resolve
                  (arm_txn_uop uop, arm_txn_resolve resolve);
```

Complex checking of relationships, simplified

```
virtual function void new_resolve
                  (arm_txn_uop uop, arm_txn_resolve resolve);
    if (uop.is_load() && resolve.is_clean())
      check_load_data(uop);
  endfunction
```

Multiple events

- Not limited to one function
- Rich interface for communicating many events
- Encapsulate complexity of tracking and matching transactions in one place

```
interface class uop_listener;
  pure virtual function void new_resolve
               (arm_txn_uop uop, arm_txn_resolve resolve);
  pure virtual function void new_commit
               (arm_txn_uop uop, arm_txn_commit commit);
  pure virtual function void new_issue(arm_txn_uop uop);
  pure virtual function void uop_flush
               (arm_txn_uop uop, flush_cause_e cause);
endclass
```

Multiple interfaces

- Implementation of multiple interfaces supported directly by the language

No macros! :)

```
class ordering_checker extends arm_checker
          implements uop_listener, ace_listener;

  virtual function void new_commit(arm_txn uop);
    if (uop.is_ordered()) m_order_q.push_back(uop);
  endfunction

  virtual function void new_ace_request(ace_txn req);
    if (!m_order_q[0].matches(req))
      error(“ACE request doesn’t match oldest micro-op”);
  endfunction
endclass
```

The Interface Class Way

- Peace and happiness through:
  - **Dynamic connections**, giving us more flexibility when writing stimulus
  - **Rich communication interfaces**, which push the tracking and matching of transactions into common classes…
  - …which, in turn, **makes our checkers simpler**
  - **Subscription to multiple producers** are supported natively, making debug and maintenance easier

Conclusion

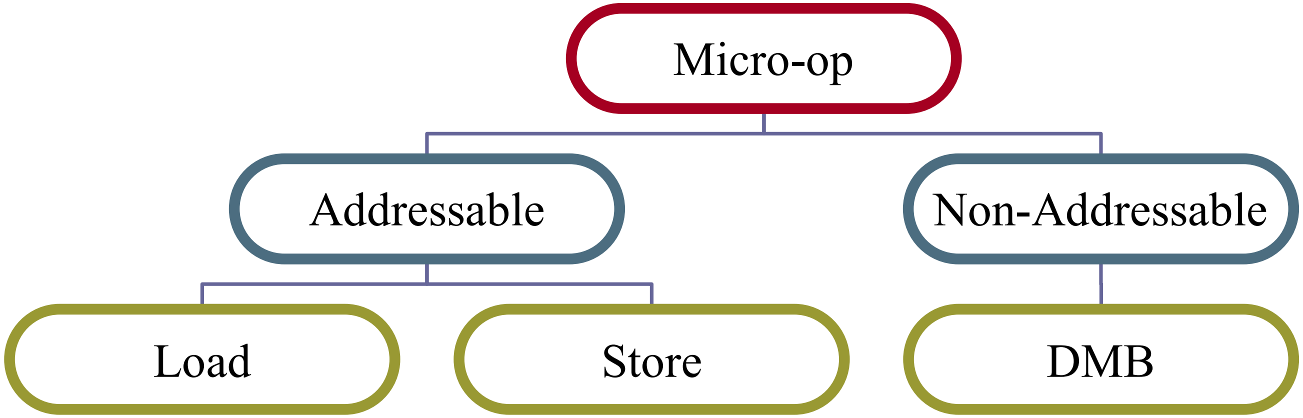
- Interface classes heavily used in CPU verification at ARM®
- Other examples showing off interface class flexibility in the paper:
  - Pseudo-multiple inheritance
  - Data serialization
  - Object clocking
- Will you try interface classes on your next project?

Bonus Slides

Second Example: Pseudo-Multiple-Inheritance

Pseudo-Multiple-Inheritance

- No true multiple inheritance in SV
- Interface classes give us some flexibility there



- A *Load-Release* is both a *Load* and a barrier
  - Where does it go without multiple inheritance?

Pseudo-Multiple-Inheritance

- An interface class can describe “barrier” behaviour

```
interface class barrier;
  pure virtual function bit affects_uop
                  (arm_txn_uop uop, dir_e direction);

  pure virtual function bit is_barrier_older
                  (arm_txn_uop uop);
…
endclass
```

- Both *DMB* and *Load-Release* are now *barriers*

```
class load_release extends load implements barrier;
…
class dbm extends non_addressable implements barrier;
…
```

Pseudo-Multiple-Inheritance

- A checker can work on micro-ops from different parts of the class tree

$cast to barrier interface removes dependence on common base class

```
class barrier_checker;
  function void check_out_of_order_resolve
                 (arm_txn_uop first, arm_txn_uop second);

    barrier bar;
    if ($cast(bar, second) &&
                 bar.affects_uop(first, YOUNGER))
      error(“Uop bypassed a barrier it isn’t allowed to.”)
  endfunction
endclass
```

Third Example: Data Serialization

Data Serialization

- Process of dumping data of different types into a file
  - post-processing, debugging, performance analysis
- For example, dumping all interesting simulation events into a SQL database
  - Use interface class to define common fields

```
interface class arm_event;
  pure virtual function int    event_id();
  pure virtual function time_t event_timestamp();
  pure virtual function cpu_t  event_cpu();
  pure virtual function string event_location();
  pure virtual function string event_type();
  pure virtual function string event_description();
endclass
```

Data Serialization

- Central event manager knows how to write an *arm_event* object to SQL
- For example, dumping all interesting simulation events into a SQL database
  - Use interface class to define common fields

Could be any base type

```
class event_manager;
  function void record_event(arm_event e);
    m_sql.insert(e.event_id(), e.event_timestamp(),
                 e.event_cpu(), e.event_location() … );
  endfunction
endclass
```

Data Serialization

- Let’s be even more flexible!
- True data serialization allows each class to define their own way of being recorded
- A *dumpable* interface class allows any class to define its own SQL table and fields

```
interface class dumpable;
  pure virtual function string sql_create_table();
  pure virtual function string sql_insert();
endclass
```

Data Serialization

Implement *dumpable* interface class

Define SQL table fields

Populate the table with values

```
class physical_address_txn extends txn
                          implements dumpable;

  virtual function string sql_create_table();
    return "CREATE TABLE IF NOT EXISTS
              phys_addr_txn(id PRIMARY KEY,
              pa, cache_attr);"
  endfunction

  virtual function string sql_insert();
    return "INSERT INTO phys_addr_txn
              VALUES(m_id, m_pa.to_int(),
              m_cache_attr.convert2string());"
  endfunction
  ...
endclass
```

Data Serialization

- Data recorder is completely generic
- Any object can be tested for *dumpable* interface, and recorded if it is present

Test $cast for *dumpable*

Generic "execute sql" call to record the object data

```
class data_recorder;
  function void dump_to_db();
    foreach(m_events[i]) begin
      dumpable d;
      if($cast(d, m_events[i]))
         execute_sql(
             {d.sql_create_table(),
              d.sql_insert});
    end
  endfunction
endclass
```