Rosetta Functional Specification Domains

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What is *Rosetta*?

- **Rosetta is a language for describing systems**
  - Presently the focus is on complex **electronic** systems -> SOC
  - Being explored for complex **mechanical** systems
- **Rosetta defines systems by writing and composing models**
  - Each model is defined with respect to one domain
  - Composition provides definition from multiple perspectives
- **Rosetta consists of a *syntax* *(a set of legal descriptions)* and a *semantics* *(a meaning associated with each description)***

Domains and Interactions

- **A Rosetta *domain* provides a vocabulary for model specificiation**
  - Defines commonly used abstractions
  - Defines state and time
- **A Rosetta *interaction* provides a definition of how specification domains interact**
  - Defines when facts from one domain cause facts to be true in another
  - Causes information to cross domains when models are composed

Understanding Facet Definitions

- **Facets provide mechanisms for defining models and grouping definitions**

Facet Name *Parameter List*

Variables

Domain

Terms

```
facet trigger(x::in real; y::out bit) is
  s::bit;
begin continuous
  t1: s@t+1ns =
       if s=1 then if x>=0.4 then 1 else 0 endif;
                 else if x=<0.7 then 0 else 1 endif;
  t2: y@t+10ns=s;
end trigger;
```

The Logic Domain

- **The logic domain provides a basic set of mathematical expressions, types and operations**
  - Number and character types and operations
  - Boolean and bit types and operations
  - Compound types and operations
    - » bunch, set, sequence, array
  - Aggregate types and operations
    - » record, tuple
  - Function function and operation definition
- **Best thought of as the mathematics facet**
  - No temporal or state concepts

The State-Based Domain

- **The** state-based **domain supports defining behavior by referencing the current and next state**
- **Basic additions in the** state-based **domain include:**
  - S – The state type
  - next::[S->S] – Relates the current state to the next state
  - x@s – Value of x in state s
  - x' – Standard shorthand for x@next(s)

Defining State Based Specifications

- **Define important elements that describe state**
- **Define properties in the current state that specify assumptions for correct operation**
  - Frequently called a precondition
- **Define properties in the next state that specify how the model changes it's environment**
  - Frequently called a postcondition
- **Define properties that must hold for every state**
  - Frequently called invariants

The Pulse Processor Specification

```
facet pp-function(inPulse:: in PulseType;
                  inPulseTime:: in time;
                  o:: out command) is
  use timeTypes; use pulseTypes;
  pulseTime :: time;
  pulse :: PulseType;
begin state-based
  L1: pulseTime >= 0;
  L2: pulse=A1 and inPulse=A2 => pulse'=none;
  L3:pulse=A1 and inPulse=A1 => pulse'=none and
      o'=interpret(pulseTime,inPulseTime);
end pp-function;
```

When to use the State-Based Domain

- **Use state-based specification when:**
  - When a generic input/output relation is known without details
  - When specifying software components
- **Do not use state-based specification when:**
  - Timing constraints and relationships are important
  - Composing specifications is anticipated

The Finite State domain

- **The** finite-state **domain supports defining systems whose state space is known to be finite**
- **The** finite-state **domain is a simple extension of the** state-based **domain where:**
  - S is defined to be or is provably finite

Trigger Example

- **There are two states representing the current output value**
  - S::type = 0++1;
- **The next state is determined by the input and the current state**
  - L1: next(0) = if i>=0.7 then 1 else 0 endif;
  - L2: next(1) = if i=<0.3 then 0 else 1 endif;
- **The output is the state**
  - L3: o’=s;

The Trigger Specification

```
facet trigger(i:: in real; o:: out bit) is
  S::type = 0++1;
begin state-based
   L1: next(0) = if i>=0.7 then 1 else 0 endif;
   L2: next(1) = if i=<0.3 then 0 else 1 endif;
   L3: o'=s;
end trigger;
```

When to use the Finite State Domain

- **Use the** finite-state **domain when:**
  - Specifying simple sequential machines
  - When it is helpful to enumerate the state space
- **Do not use the** finite-state **domain when**
  - The state space cannot be proved finite
  - Usage over specifies the properties of states and the next state function

The Infinite State Domain

- **The** infinite-state **domain supports defining systems whose state spaces are infinite**
- **The** infinite-state **domain is an extension to the** state-based **domain and adds the following axiom:**
  - next(s) > s
- **The** infinite-state **domain asserts a total ordering on the state space**
  - A state can never be revisited

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The Pulse Processor Revisited

- **The initial pulse arrival time must be greater than zero**
  - L1: pulseTime >= 0;
- **Adding the infinite state restriction assures that time advances**
- **If the initial pulse is of type A1 and the arriving pulse is of type A2, reset and wait for another pulse**
  - L2: pulse=A1 and inPulse=A2 implies pulse’=none
- **If the initial pulse is of type A1 and the arriving pulse if of type A1, then output command**
  - L3: pulse=A1 and inPulse=A1 implies pulse’=none and o’=interpret(pulseTime,inPulseTime);

The Discrete Time Domain

- **The** discrete-time **domain supports defining systems in discrete time**
- **The** discrete-time **domain is a special case of the** infinite-state **domain with the following definition**
  - next(t)=t+delta;
- **The constant** delta>=0 **defines a single time step**
- **The state type** T **is the set of all multiples of** delta
- **All other definitions remain the same**
  - next(t) satisfies next(t)>t

Discrete Time Pulse Processor

```
facet pp-function(inPulse::in PulseType;
                             o::out command) is
  use pulseTypes;
  pulseTime :: T;
  pulse :: PulseType;
begin discrete-time
  L2: pulse=A1 and inPulse=A2 => pulse@t+delta=none;
  L3:pulse=A1 and inPulse=A1 => pulse@t+delta=none and
        o@t+2*delta=interpret(pulseTime,t);
end pp-function;
```

Discrete Time Pulse Processor

- **State is the last pulse received and its arrival time or none**
- **The initial pulse arrival time must be greater than zero**
  - Guaranteed by definition of time
- **If the initial pulse is of type A1 and the arriving pulse is of type A2, reset and wait for another pulse**
  - L2: pulse=A1 and inPulse=A2 implies pulse@t+delta=none
- **If the initial pulse is of type A1 and the arriving pulse if of type A1, then output command in under 2 time quanta**
  - L3: pulse=A1 and inPulse=A1 implies pulse@t+delta=none and o@t+2*delta=interpret(pulseTime,t);
- **No state should ever have a negative time value**
  - Guaranteed by the definition of time

When to use the Discrete Time Domain

- **Use the** discrete-time **domain when:**
  - Specifying discrete time digital systems
  - Specifying concrete instances of systems level specifications
- **Do not use the** discrete-time **domain when:**
  - Timing is not an issue
  - More general state-based specifications work equally well

The Continuous Time Domain

- **The** continuous-time **domain supports defining systems in continuous time**
- **The** continuous-time **domain has no notion of next state**
  - The time value is continuous – no next function
  - The “@” operation is still defined
    - » Alternatively define functions over t in the canonical fashion
- **Derivative, indefinite and definite integrals are available**

Continuous Time Pulse Processor

- **Not particular interesting or different from the discrete time version**
  - Can reference arbitrary time values
  - Cannot use the next function
  - No reference to discrete time – must know what delta is

Continuous Time Pulse Processor

```
facet pp-function(inPulse::in PulseType;
                            o::out command) is
  use pulseTypes;
  pulseTime :: T;
  pulse :: PulseType;
begin discrete-time
  L2: pulse=A1 and inPulse=A2 => pulse@t+5ms=none;
  L3:pulse=A1 and inPulse=A1 => pulse@t+5ms=none and
        o@t+10ms=interpret(pulseTime,t);
end pp-function;
```

Understanding the Continuous Time Pulse Processor

- **Discrete time references are replaced by absolute time references with respect to the current time**
  - Using 5ms and 10ms intervals rather than the fixed time quanta

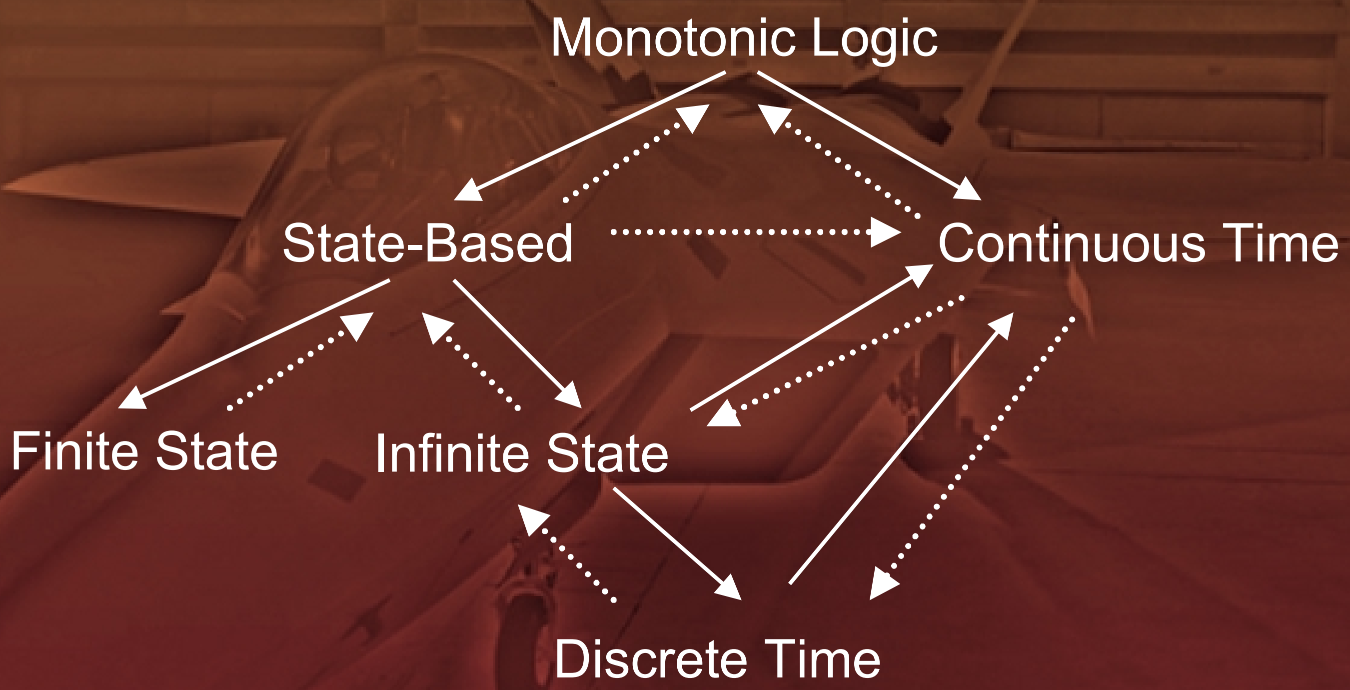
Using the Continuous Time Domain

- **Use the** continuous-time **domain when**
  - Arbitrary time values must be specified
  - Describing analog, continuous time subsystems
- **Do not use the** continuous-time **domain when:**
  - Describing discrete time systems
  - State based specifications would be more appropriate

Specialized Domain Extensions

- **The domain** mechanical **is a special extension of the logic and continuous time domains for specifying mechanical systems**
- **The domain** constraints **is a special extension of the logic domain for specifying performance constraints**
- **Other extensions of domains are anticipated to represent:**
  - New specification styles
  - New specification domains such as optical and MEMS subsystems

Domains and Interactions



- ***Example Requirements definition domains and standard interactions***
  - *Solid lines represent homomorphsisms*
  - *Dashed lines represent incomplete interactions*

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More Information?

- **The new Rosetta web page is available at:**

  http://www.ittc.ukans.edu/Projects/SLDG/rosetta

- **Email the authors at:**

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- **Come to the tutorial yesterday!**
  - Slides will be available via the web page