System Behavior Specification
Using IEEE Std 1175.4

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Prologue

- System behavior is what delivers value into an application domain, but frequently it is not well understood even after the system has been realized.

- The concepts and language for describing system behavior are not adequately addressed in many system development methodologies.

- IEEE Std 1175.4™-2008 provides a conceptual model for describing the behavior of many kinds of engineered systems.
Questions to be Addressed

About System Behavior Description
  – What is the System?
  – What is System Behavior?
  – What is a System Behavior Description?
  – Where does it fit the Development Life Cycle?

About IEEE Std 1175.4
  – What does 1175.4 standardize?
  – What descriptive concepts does it provide?
  – What can be learned from a Behavior Description?

About Using Behavior Descriptions
  – What use is a Behavior Description?
  – How can you use it?
What is the System?

ISO/IEC 15288, Clause 5.1.2
– The system [is] man-made, created and utilized to provide products and/or services in defined environments for the benefit of users and other stakeholders.

Why
– Purpose is to alter some stakeholders’ environment(s)
– Value is the benefit of change to those stakeholders

How
– Through interactions with the environment
What is System Behavior?

A Scientist's View of the Philosophy of Science

– Behavior is the ongoing interaction of the individual with its environment; It is transient

– The environment with which the individual interacts must be described and understood

– The science of behavior must be descriptive and classificatory

– The key to both the methods and concepts of behavior science is measurement

William S. Verplanck  (http://web.utk.edu/~wverplan/apapaper.html)
What is a System Behavior Description?

A Model

– Represents some aspects of the system, but is simpler
– Enhances understanding and agreement about those aspects
– Does not misrepresent the system

Behavior Description

– Represents the interactions of system with its environment and the rules governing the relationships among them (behavior)
– Does not allow inferences about system design
– When quantified, provides product specifications
What is a System Behavior Description?

Black – Box Description

– Describes the behavior patterns of an individual
– Is expressed in terms perceptible outside the system
– Identifies cause-effect and functional relationships

White – Box Description

– Describes the behavior patterns of a collection, given the behavior patterns of the individuals
– Is expressed in terms perceptible inside the system, but outside the individuals
– Identifies causal chains and functional compositions
Where Does It Fit the Development Life Cycle?

Problem Domain: Need for a Result
– Product Criteria, describes desired effects
– Stakeholder Requirements

Solution Domain: Concept for a Thing
– Product Requirements, describes offered capability
– System Requirements
  behavioral, structural, environmental

Boundary between Domains is the System Boundary

• Requirements and Specifications, Michael Jackson (Addison-Wesley, 1995)
• ISO/IEC 15288:2008 Systems and software engineering — System life cycle processes
Where Does It Fit the Development Life Cycle?

Problem Domain = Things with properties and relationships

Product Criteria = Effects created in the problem domain (new things, properties, and relationships)

Solution Domain = System capability interacts with problem domain to bring about required effects
Where Does It Fit the Development Life Cycle?

Mechanization

Conception | Formulation | Implementation | Evaluation

- Problem Requirements
- Behavior Description
- Software Design
- Software Implementation
- Testware Design
- Testware Implementation
- Trace and Pass / Fail

Demonstration
What Does 1175.4 Standardize?

Descriptive Model of System Behavior
– Not a design model for mechanism construction
– Not a mathematical model for proof construction

Goal is Understanding and Agreement
– Identify observables at the system interface
– Identify repeatable patterns of relationships
– Description of all possible lifelines

To Answer
– How will the system be affected by the problem domain, and how will it affect the problem domain?
What Does 1175.4 Standardize?

Presentation
- Graphical Display
- Tabular Display
- Natural Language
- Dynamic Simulation

Viewpoint
- State Transition
- Entity - Relationship
- Data Flow
- Performance

Concept
IEEE Std 1175.4
- Unit, Port, Interaction
- Interaction, Obligation
- Action, State
- Property, Event, Condition
- Assembly, Couple, Aliases
What Descriptive Concepts Does it Provide?

- Assembly
  - Port Alias
  - Port Couple
- Interaction Alias
- Build Structure
- Boundary Interfaces
- Port
- Interaction
- Action
- State
- Obligation
- Behavior Patterns
- Event
- Condition
- Property
- Base Quantities

has, contains, relates, provides, exhibit, characterize
What Descriptive Concepts Does it Provide?

- **Packaging of Behavior**
  - Units, Ports, Interactions
  - Assembly, Couple, and Aliases

- **Observables of Behavior**
  - Interactions, Coordination Patterns
  - Properties, events, conditions

- **Patterns of Behavior**
  - Functionality, causality
  - History dependence
How is Behavior Packaged?

Units, Ports, Interactions

Interaction transfers energy, material, or information

Boundary

Input – interaction entering unit

Output – interaction leaving unit

Ports

Interactions

P1  P4

P2  P5

Unit
How is Behavior Packaged?

**Unit**
- Recursive architectural element
- System, subsystem, component, module

**Port**
- Means of interconnection
- Serialization of interactions
- Unidirectional or bidirectional

**Interaction**
- Phenomenon shared between unit and environment
- Occurrence events, content properties or structures
- Interaction is point-time or extended-time
How is Behavior Compounded?

Assembly, Alias, Couple

Assembly

Unit A

Unit B

Unit C

Unit D

Unit E

Alias

Couple
How are Behaviors Coordinated?

Inputs

U₁

U₃

Subject Unit

Stimulus

Uncoordinated
Uncontrolled Input

Uncoordinated
Uncontrolled Output

Response

Uncoordinated
Controlled Input

Uncoordinated
Controlled Output

Subordination

Coordinated
Uncontrolled Input

Coordinated
Controlled Output

Outputs

U₂

U₄

Subordinate Unit

U₅

Occurrence Control
How Are Interactions Quantified?

Property

– Measurable (observable) phenomenon of interaction
– Constant or time-varying, simple or compound, discrete or continuous

Event

– Marker for time when an observable change occurs
– Interaction occurrence, time-dependent property changes, or time changes

Condition

– Assertion about properties, events, or other conditions that is observably True/False at a given time
What Is a Behavior Occurrence?

<table>
<thead>
<tr>
<th>Cause</th>
<th>implies</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>This event with these inputs and satisfying these criteria</td>
<td></td>
<td>Those events with those outputs and making these guarantees</td>
</tr>
</tbody>
</table>

A Simplified Table Format

<table>
<thead>
<tr>
<th>A#</th>
<th>X0</th>
<th>C0</th>
<th>E0</th>
<th>X1</th>
<th>C1</th>
</tr>
</thead>
<tbody>
<tr>
<td>An</td>
<td>input</td>
<td>precondition</td>
<td>trigger</td>
<td>output</td>
<td>post condition</td>
</tr>
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</table>
What Is a Behavior Pattern?

• Abstraction of Behavior Occurrences
  – Common set of interactions
  – Common set of conditions
  – Common trigger event
  – Different property values and event times, but within well-defined domain boundaries
  – Same True preconditions

• Action
  – A behavior pattern
  – Describes causal and affective relationships among a set of possible interactions
What Is a Behavior Pattern?

Precondition

State

Required Action

Provided Action

Postcondition

causes

enables

changes

needs

expects

P_1

J_S

P_2

J_R

P_3

J_Q

J_P
How is History Dependence Described?

- Modification of Causal Dependencies
  - Behavior State

- Modification of Functional Dependencies
  - Property State

- Modification of Event Dependencies
  - Temporal State

- Modification of Interaction Dependencies
  - Port State
How is History Dependence Described?

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</thead>
<tbody>
<tr>
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<td>Those events with those outputs advancing unit history and making these guarantees</td>
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<td>final state</td>
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What is a System Behavior Description?

Unit: ⟨Name⟩

- Specification of Ports, Interactions
- Specification of Properties, Events, Conditions, States
- Specification of unique cause-effect and functional relationships with a catalog of Action patterns, e.g.

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<td>post condition</td>
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<td>Sa</td>
<td>Ca</td>
<td>E1</td>
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<td>Cc</td>
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<td>Sb</td>
<td>Ce</td>
<td>E4</td>
<td>U2</td>
<td>Sa</td>
<td>Cf</td>
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What Use Is a Behavior Description?

For Informal Understanding

– Suppose I do \( \langle \text{treatment of unit} \rangle \)

  What should I expect to be the result?

– Suppose I want \( \langle \text{effect in my world} \rangle \)

  How could I get that result?
What Use Is a Behavior Description?

For Formal Checking

– Will Unit deliver expected value into problem domain?

Subject Unit Behavior
\[ \land \text{Environment Assumptions} \land \text{External Unit Behavior} \Rightarrow \text{Desired Result} \]

– Will Unit design provide the Unit behavior?

Component Unit Behaviors
\[ \land \text{Interconnection Structure} \Rightarrow \text{Subject Unit Behavior} \]
How Can You Use It?

Framing Requirements Analysis Work
- Concept instances to be found and identified
- Questions to be asked and answered
- Specifications to be determined

Guiding Test Case Design Work
- Interaction samples for stimuli
- Interaction observations for responses
- Behavior sequences for historical dependencies
How Can You Use It?

Define as a Product Artifact
– Product “Scope and Vision” satisfying product criteria
– Target for product architecture and design
– Target for test architecture and design

Use a Data Metammodel (IEEE P1175.5*)
– Formalized expressions for concepts
– Formalized entity-relation-attribute/object-role-model
– Formalized model consistency verification
– Presentation-level support

* Discuss participation in 1175WG with the presenter after this session
Questions?