Modeling Structure with Blocks in SysML

Critical Embedded Systems

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System Modeling Process

act [Activity] Simplified System Modeling Process

- Collect Textual Requirements
  - Model System Context
  - Model Functional Requirements with Use Cases
    - Elaborate Functional Requirements with Activities
  - Create Data Model
    - Model Interactions between System and Environment
      - Derive System State Model
      - Derive System Interfaces
  - Model System Structures
Block Definitions

Block Definition Diagrams
What is it about?

Context of the Modeling Aspect
Roots & Relations

- Engineers draws blocks from the beginning
  - By hand or with CAD tools
  - Many formats
    - e.g. Entity-relationship diagram
Modeling Aspect

What are the building blocks?
What are their relations in general?
Objectives

- Define component types
  - Support organization into taxonomy (generalization)
- Define data model
- Define system decomposition
- Define interfaces and ports
Example – System Context
Example - Signals

bdd [Package] Information Model [Information Model of CPAS]

- **signal** Notification
  - **signal** Completion Notification
    - **signal** Mowing Completed
    - **signal** Spraying Completed
    - **signal** Irrigation Completed
  - **signal** Error Notification
    - **signal** Spraying Error
    - **signal** Irrigation Error
    - **signal** Mowing Error

- **signal** Control
  - **signal** Initialize
  - **signal** Shutdown

- **signal** Configuration
  - **signal** Timing Configuration
  - **signal** Rule Configuration

- **signal** Spraying Task
- **signal** Diagnostic Information
- **signal** Spraying Report
Example – Component definition
Example – System Decomposition

[Diagram showing the structure of a Cyber Physical Agricultural System (CPAS) with various subsystems and components.]

- **System**
  - **Luminance Sensor**
  - **Humidity Sensor**
  - **Rain Detector**
  - **Temperature Sensor**
  - **Irrigation System**
  - **CPAS Central Controller System**
  - **Mower**
Example – System Context with Ports

![Diagram of a Cyber Physical Agricultural System](image-url)
Relations to other aspects

- Realizes requirements
- Provides types for parts & ports
- Executes actions
- Defines participants in collaborations
- Provides context for state machines
Realizes requirements

Id = "1.1.1"
Text = "The CPAS uses the following sensors: temperature, humidity, luminance, rain (gauge)."
Provides types for parts & ports
Executes actions
Defines participants in collaborations
Provides context for state machines
What are the building blocks?

Modeling Elements & Notation
Essential Elements of Block Definition Diagrams

- **Nodes**
  - Block nodes
  - Signals
  - Value Type, Quantity Kind and Unit
  - Enumeration nodes
  - Actor nodes

- **Paths**

- **Ports and Flows**

- **Constraint blocks**
Block nodes

- Basic structural elements, that describe the structure of the system
- Compartments
  - Property types (e.g. parts, properties, references, values)
  - Behavioral (e.g. operations)
  - Constraints
- Describe
  - (Sub)Systems – Hardware / Software / Data
  - Person
Signal

- A signal is a *specification of send request instances* communicated between objects.
- The receiving object handles the received request instances as specified by its *receptions*.
- The data carried by a send request (which was passed to it by the send invocation occurrence that caused that request) are represented as *attributes of the signal*.
- A signal is defined independently of the classifiers handling the signal occurrence.
Value Type, Quantity Kind and Unit

- Uniform definition of a quantity
- Value Type
  - Data type, that can have Unit and QuantityKind nodes
  - Type for value properties in blocks
- Quantity Kind
  - Identifies a physical quantity
- Unit
  - Describes the structure of a physical unit – the unit of measure
  - Must be related to a Quantity Kind
Enumeration and Actor nodes

- **Enumeration**
  - Defines a type, the value range of which is a limited set of named values, called literals.

- **Actor**
  - Represents any stakeholder (human, organisation or external system) that participates in the use of the system.
Defining Paths between Blocks

- Paths
  - Part Association
  - Shared Association
  - Reference Association
  - Association Class
  - Generalization
  - Dependency
Part Association

- Specifies a strong whole-part hierarchy
  - From a composite
  - To a composite part
- Denoted with a black diamond on the whole end
- Role name on the part end
- Can be directed or undirected
Shared Association

- Specifies a weaker whole-part hierarchy
  - "Shared" indicates, that the whole part is not the only one, it can be more of it
  - The parts are not owned by the whole part
- Denoted with an empty diamond

![Diagram of Shared Association]
Reference Association

- Represents a relationship between two blocks
  - Undirected: reference in both blocks
  - Directed: reference only in one block

- Can have properties
  - Multiplicity
  - Name
  - Reference on both sides
Association Class

- Describes the structural properties of an association
- Combination of
  - Association
  - Block
Generalization

- Specifies an object oriented relationship between a more general block and a more specific one (ISA relationship)
- Denoted with a closed arrowhead from the specific block to the general one
**Dependency**

- Between two elements
- One element needs the other element for its
  - Specification
  - Implementation
- Almost between any model elements

```plaintext
 «stereotype1»
 dependency1
```

[Diagram of dependency]
Defining Ports and Flows

- Port
- Flow Property
- Interface
Port

- Interaction points at which external entities can be connected
- Limits and differentiates the possible connection types
- Defines the available features (e.g. properties, operations)
- More denotation alternative
Flow Property

- Specifies the possible types of flowing items on a port
  - Part of flow specification
  - *What "can" flow?*
    - Data
    - Material
    - Energy
    - ...

![Cyber Physical Agricultural System Diagram]

```xml
«system»

Cyber Physical Agricultural System

flow properties

«FlowProperty» in temperature : Sensor Data{direction = in}
«FlowProperty» in humidity : Sensor Data{direction = in}
«FlowProperty» in luminance : Sensor Data{direction = in}
«FlowProperty» in rain : Sensor Data{direction = in}
```
Flow Item

- Specifies what flows between the blocks
  - What "does" flow?
Interfaces

Definition

An interface declares a set of public features and obligations that constitute a coherent service offered by a classifier.

- An interface specifies a contract; any instance of a classifier that realizes the interface must fulfill that contract.
Interface

- Specifies the behavioral features of a block
  - Provided interface
    - A service is provided by the block for its environment
    - Denoted with a lollipop / ball symbol
  - Required interface
    - The set of the operations is required by the block for its operation.
    - Denoted with a socket symbol
Defining Constraint Blocks

- **Constraint Block node**
  - Specify a network of constraints to
    - Constrain the physical properties of the system
    - Identify critical performance parameters
  - Constraints represent mathematical expressions
    - \( F = m \times a \)
    - \( a = \frac{dv}{dt} \)
Block Usage

Internal Block Diagrams
What is it about?

Context of the Modeling Aspect
Modeling Aspect

How are components used in a given context or system?
Objectives

- Define how components are interacting with each other within a given system
  - Define relations
  - Define data flow
  - Define interfaces
BDD vs. IBD

- Block Definition vs. Usage
  - Block diagram → Definition of the structure
  - Internal block diagram → Usage of this structure in different contexts
Relations to other aspects

- Interpreted in the context of a block
- Defines usage of blocks
- Item flows can be mapped to object flows in activities
What are the building blocks?

Modeling Elements & Notation
Defining Blocks - 1

- **Nodes**
  - The instances of the nodes from the related block diagram (Part properties)
  - Can have a unique name with type indication
  - Can also be nested into more levels
Defining Blocks - 2

Paths

- The properties can be connected to each other with:
  - Unidirectional Connector
  - Bidirectional Connector
- Connectors are the instances of the associations
- Can have multiplicity on both ends
Defining Ports and Flows

- Ports are to define the interaction points of the part property
- Flows are to specify the items that flow across a connector
- Both are understood in a particular context
Summary

- Block Definition Diagram
  - *What are the elements of the system?*

- Internal Block Diagram
  - *How are elements within a system relates to each other?*