



Model-based robot design in Modelica

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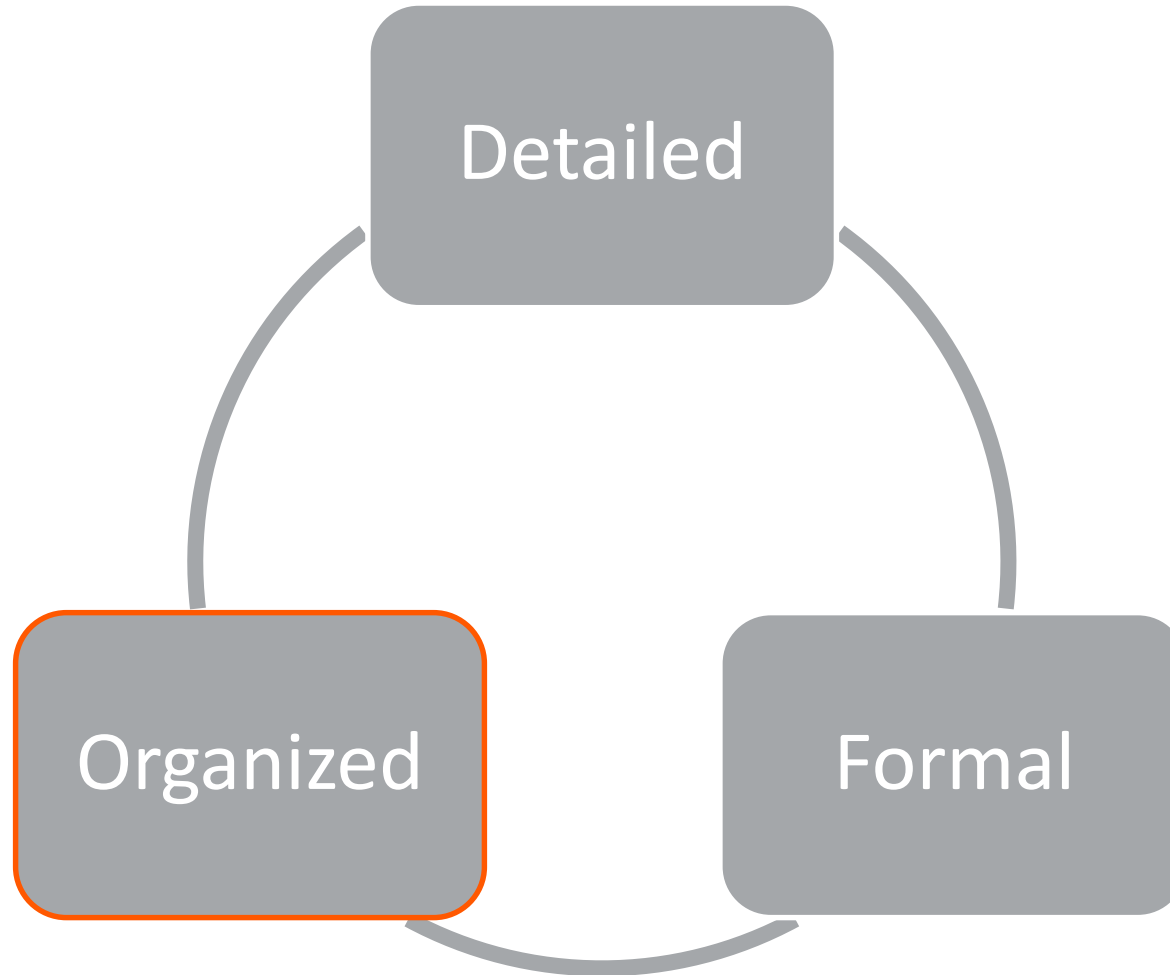
Detailed physical model of robots

- Accurate simulation
- Many robot types
- Integration into development toolchains



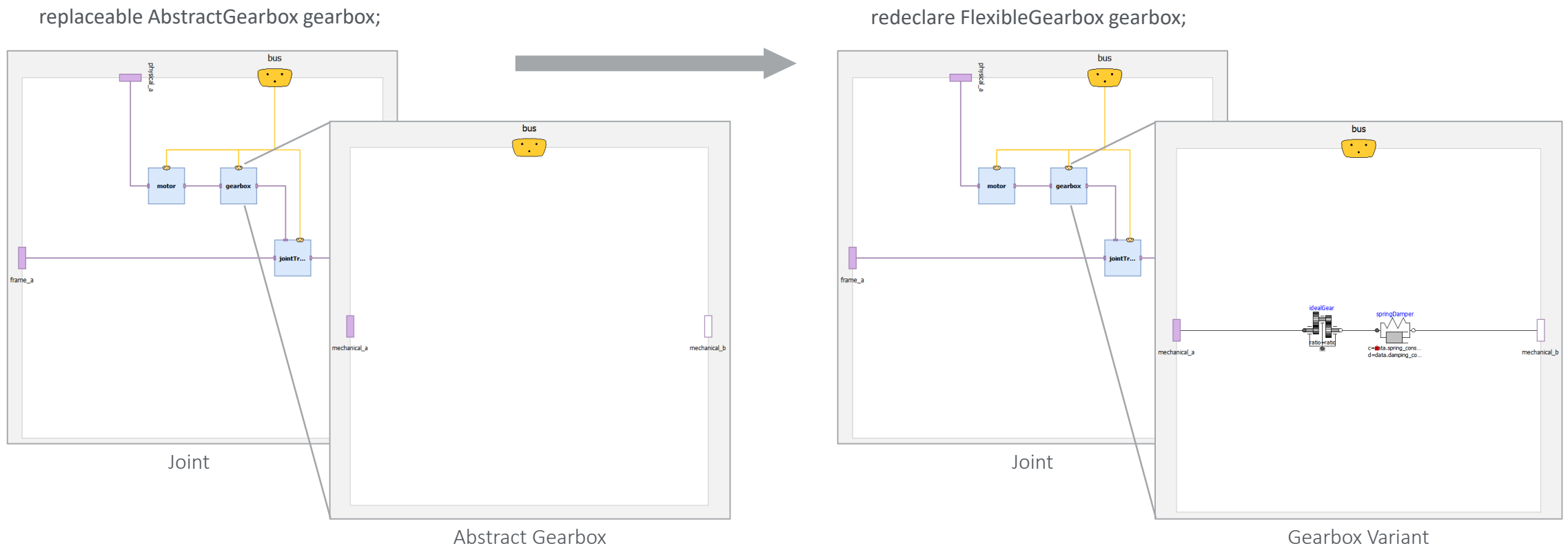


Models that are:

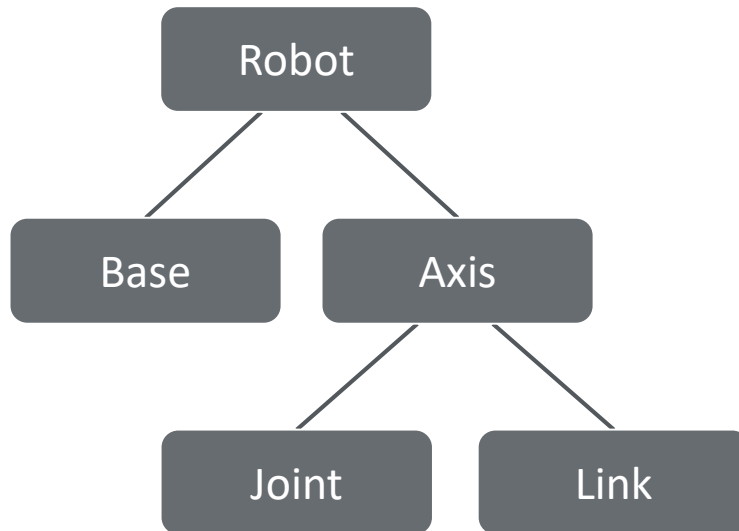


Modelica benefits

- Visual, acausal, multi-domain, hybrid...
- Model inheritance + redeclaration mechanism -> architecture-driven design

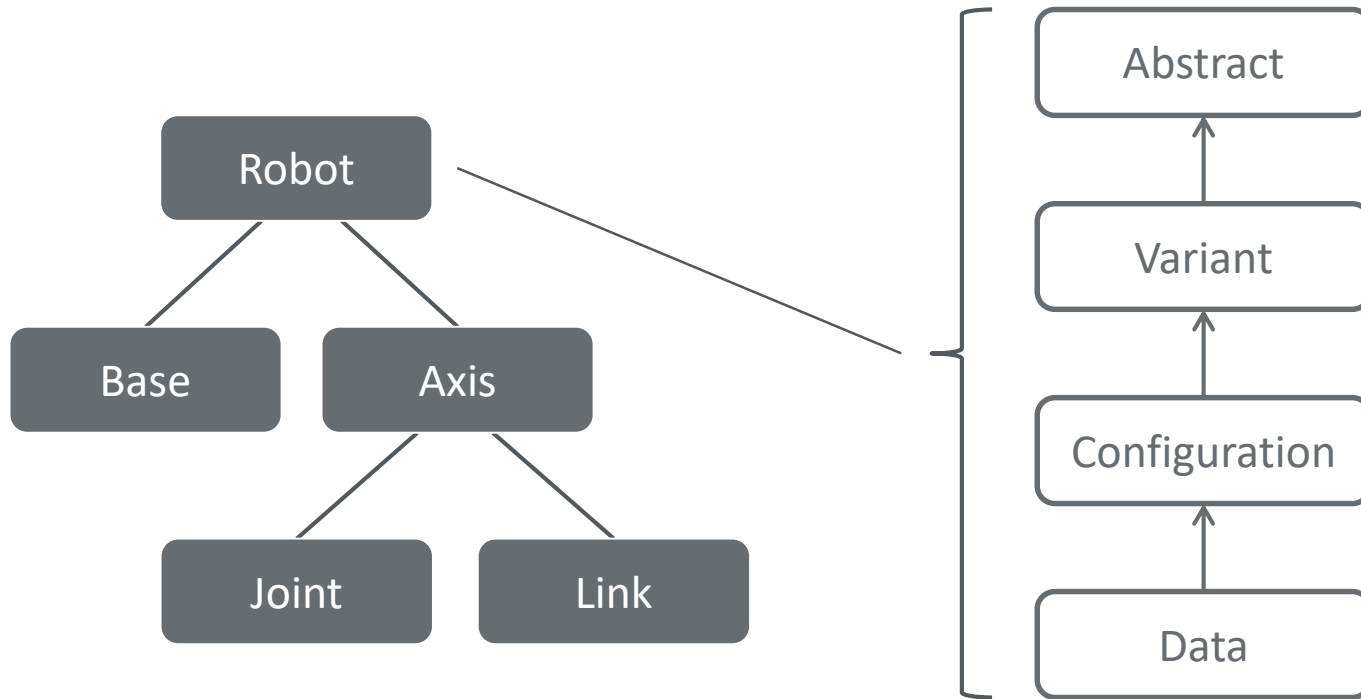


Hierarchical model ...



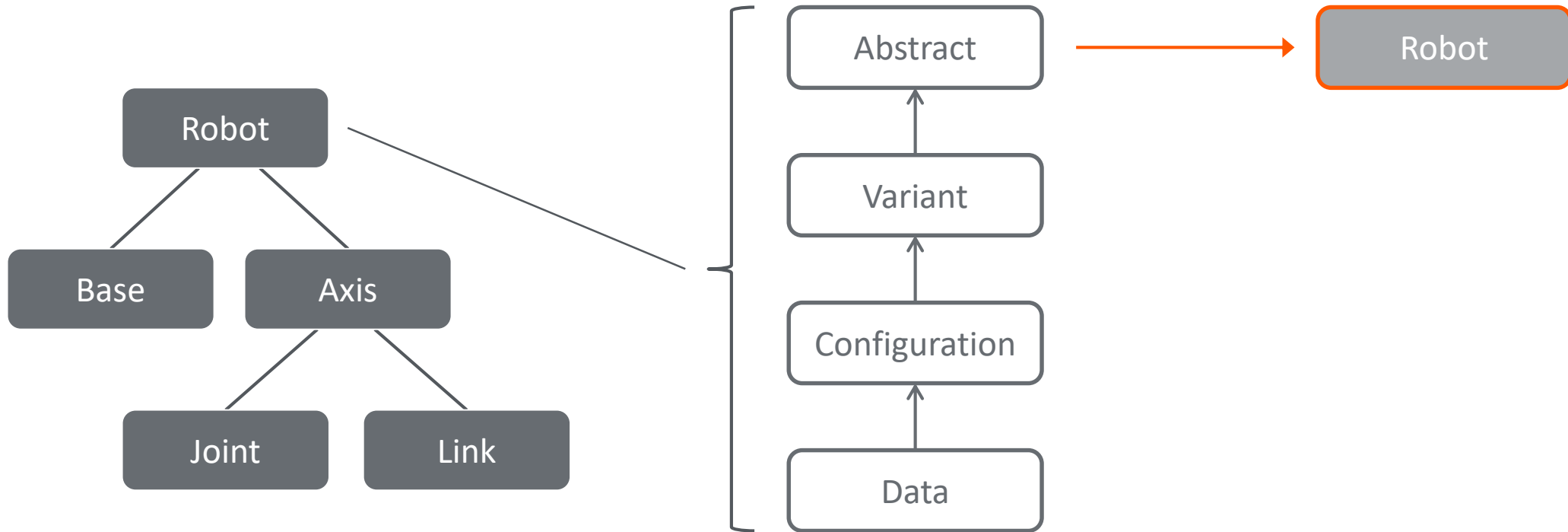


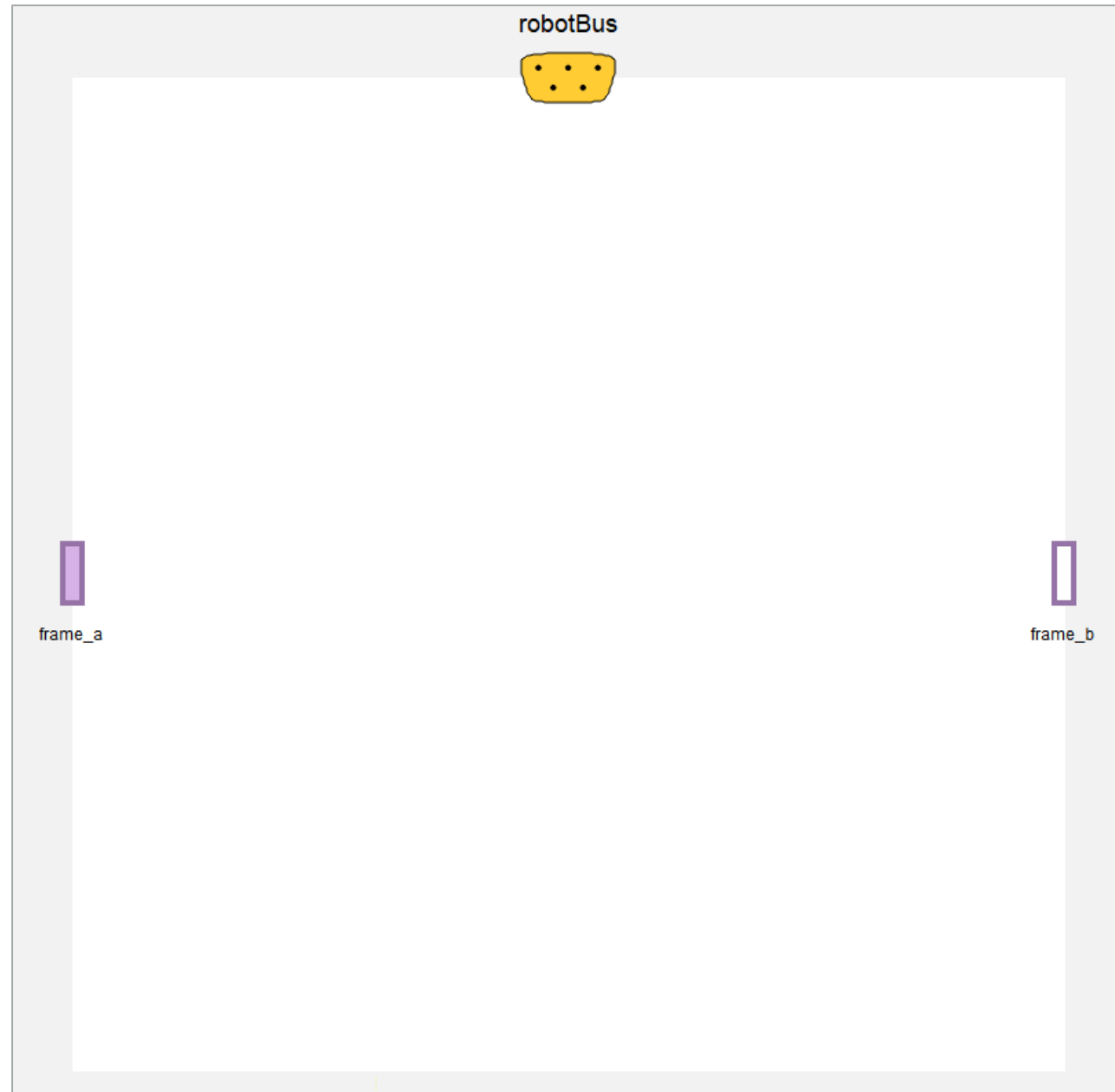
Hierarchical model with abstraction layers





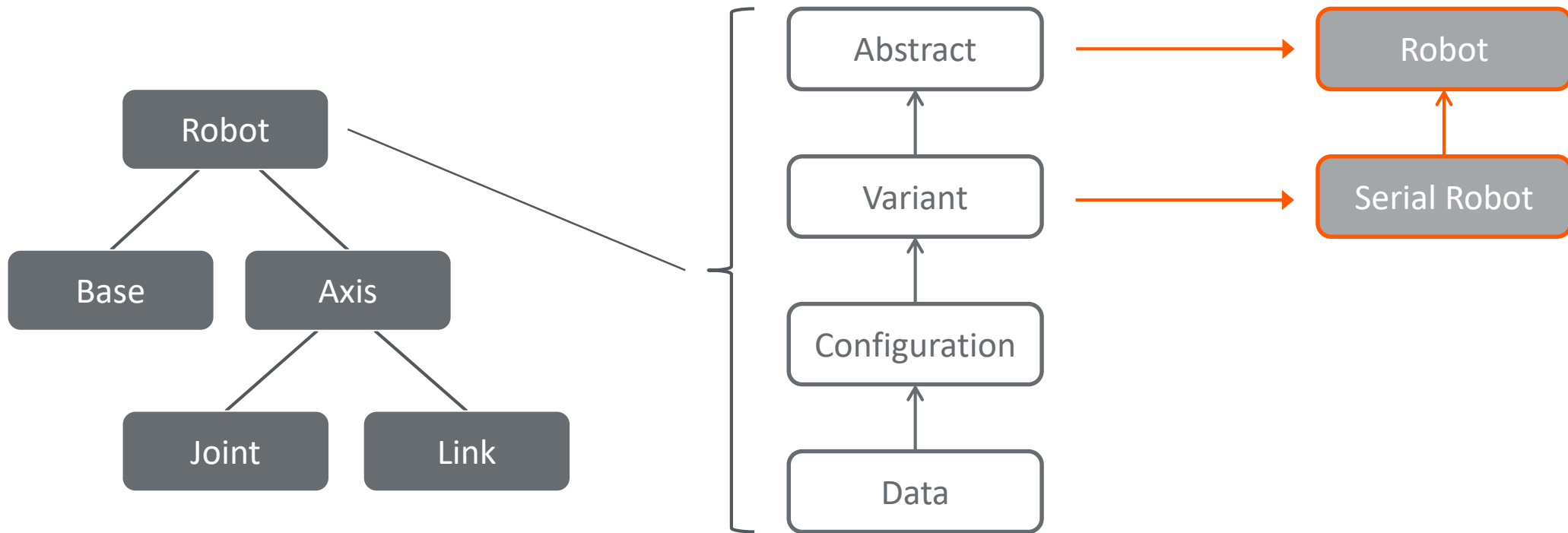
Hierarchical model with abstraction layers: example



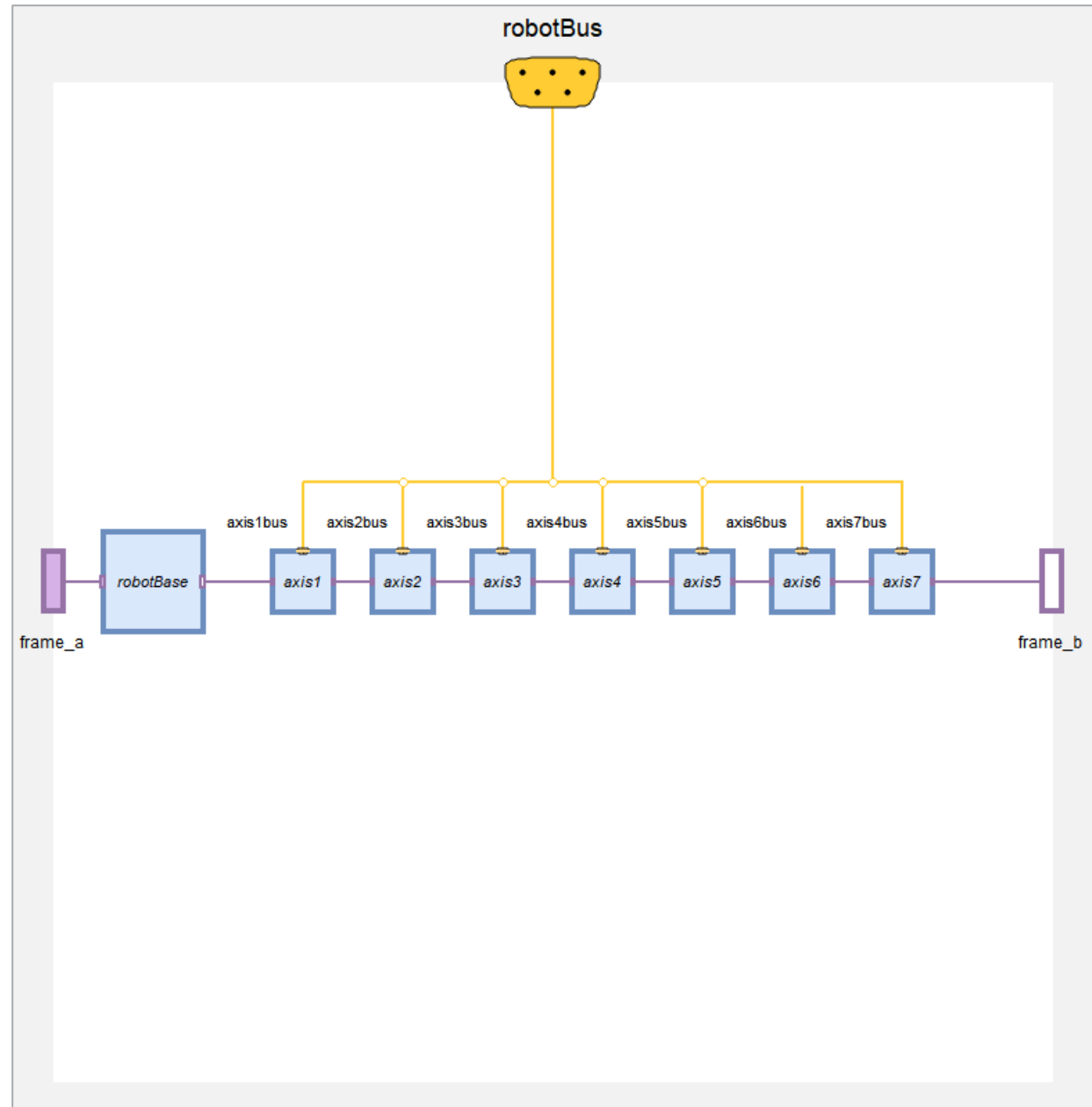




Hierarchical model with abstraction layers: example

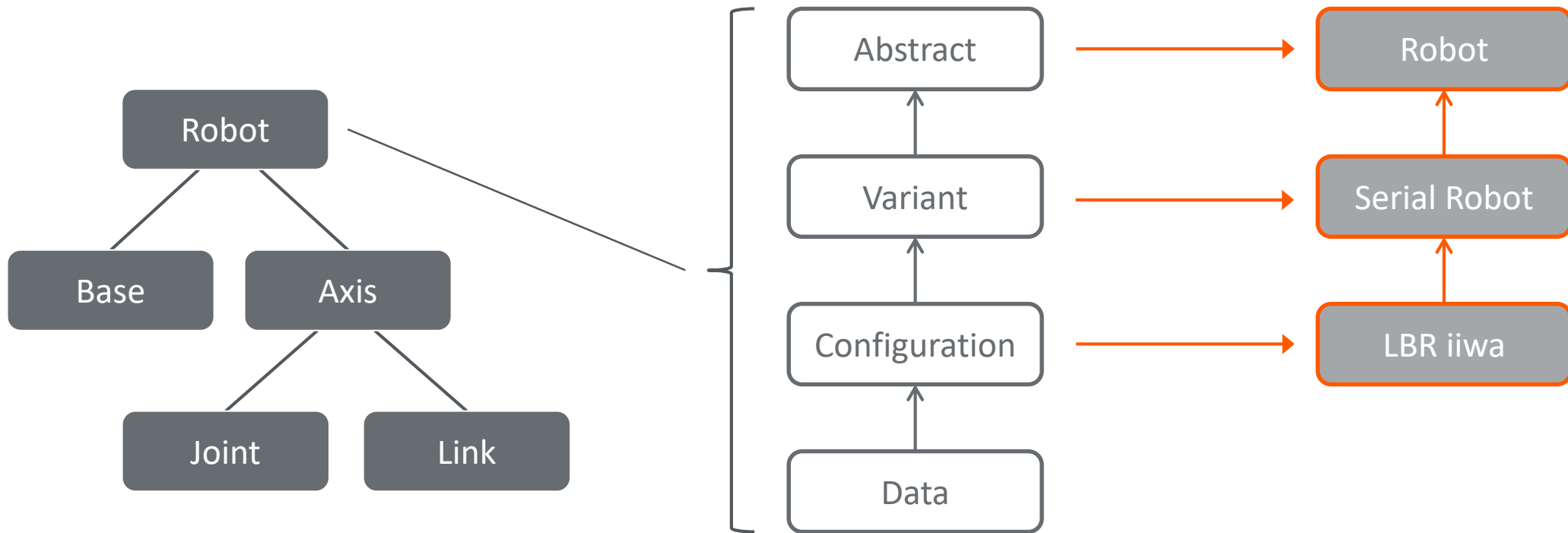


7-axis Serial Robot - Variant





Hierarchical model with abstraction layers: example





LBR iiwa - Configuration

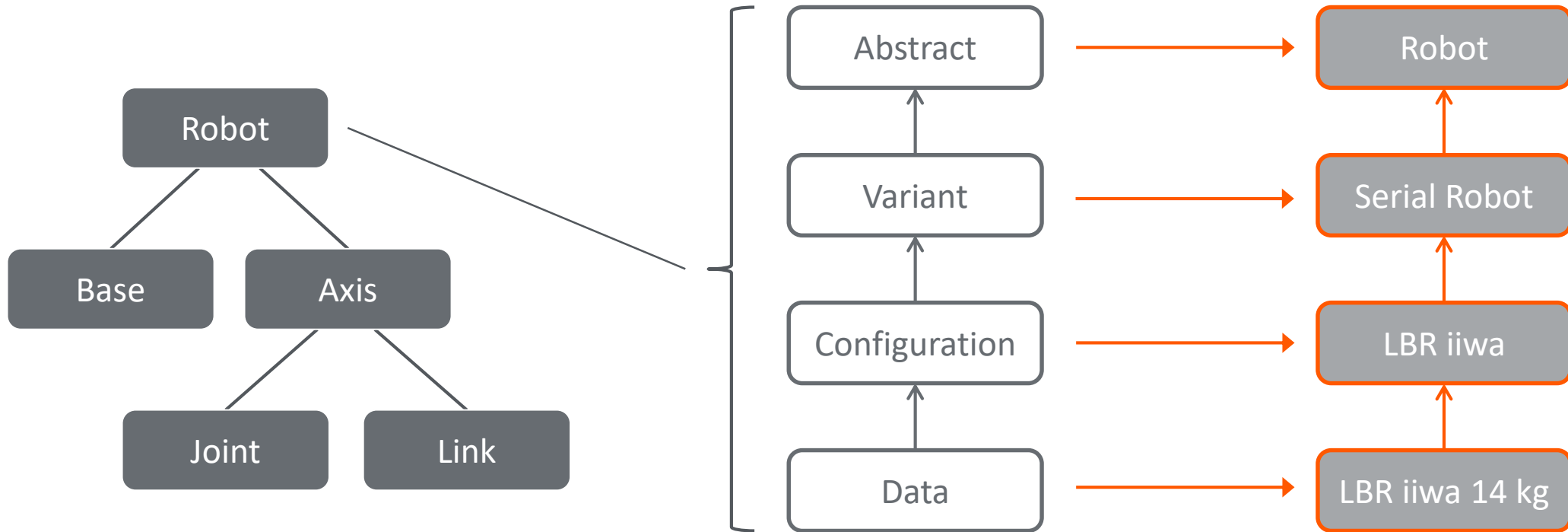
The screenshot displays the 'robotBus' configuration environment. A dialog box titled 'redeclare axis7.joint in LBRiiwa14.LBRiiwa14Model' is open, showing the configuration for a joint component. The dialog has three tabs: 'General', 'Add modifiers', and 'Attributes'. The 'General' tab is active, showing the following fields:

- Component:**
 - Name: redeclare axis7.joint
 - Comment: (empty)
- Model:**
 - Path: MADA.Components.Joint.Variants.BasicJoint.Joint_model
 - Comment: Basic Joint
- Parameters:**
 - data: LBR iiwa Joint 7
 - useEquivalentBody: false
- Custom Parameters:**
 - physical_a: Flange_a
- SubComponents:**
 - motor: DCPM
 - jointTransform: Revolute
 - gearbox: Ideal Gearbox (with a dropdown menu open showing options: Ideal Gearbox, Flexible Gearbox, Linear Gearbox)

At the bottom of the dialog are 'OK', 'Cancel', and 'Info' buttons. In the background, a partial block diagram is visible, showing a block labeled 'axis7bus' connected to a block labeled 'axis7', which is in turn connected to a block labeled 'frame_b'. A yellow line connects the 'robotBus' icon at the top to the 'axis7bus' block.



Hierarchical model with abstraction layers: example





LBR iiwa 14 kg - Data

- ▼ FlexibleGearbox
- Gearbox_model
- LBRiiwa14Gearbox_data

Parameters:

| | | | |
|-------------------|--------------------------------------------------|--------------------|----------------------------------------------------------------------------------------|
| body_data | Body_data(...) | | |
| T_origin | [1, 0, 0, 0; 0, 1, 0, 0; 0, 0, 1, 0; 0, 0, 0, 1] | | Fixed transformation from frame_reference to frame_origin |
| ratio | 40 | 1 | |
| motorShaft_axis | {0,0,1} | 1 | |
| gearboxShaft_axis | {0,0,1} | 1 | |
| spring_constant | 10e2 | N · m/rad | |
| damping_constant | 0.7 | N · m · s/rad | |
| velocityLimit | {-pi,pi} | rad/s | m/s, rad/s; [min,max] linear/angular velocity along joint axis |
| jerkLimit | {-1,1} | rad/s ³ | m/s ³ , rad/s ³ ; [min,max] linear/angular jerk along joint axis |
| effortLimit | {-5,5} | N · m | N, Nm; [min,max] force/torque along joint axis |

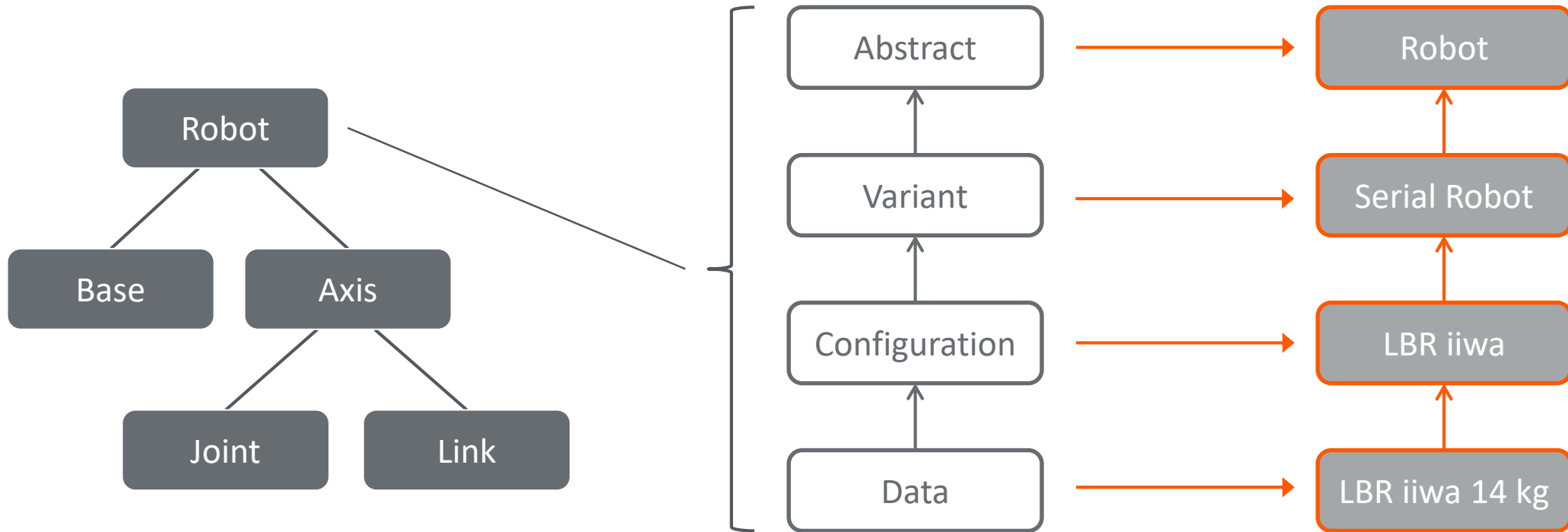


Parameters:

- data: redeclare replaceable parameter Gearbox_data data constrain
- useEquivalentBody: Flexible Gearbox data, LBR iiwa 14 Gearbox



Hierarchical model with abstraction layers: example



Interfaces – default options

Specific – fully defined

 Rotational 1D

 Translational 1D

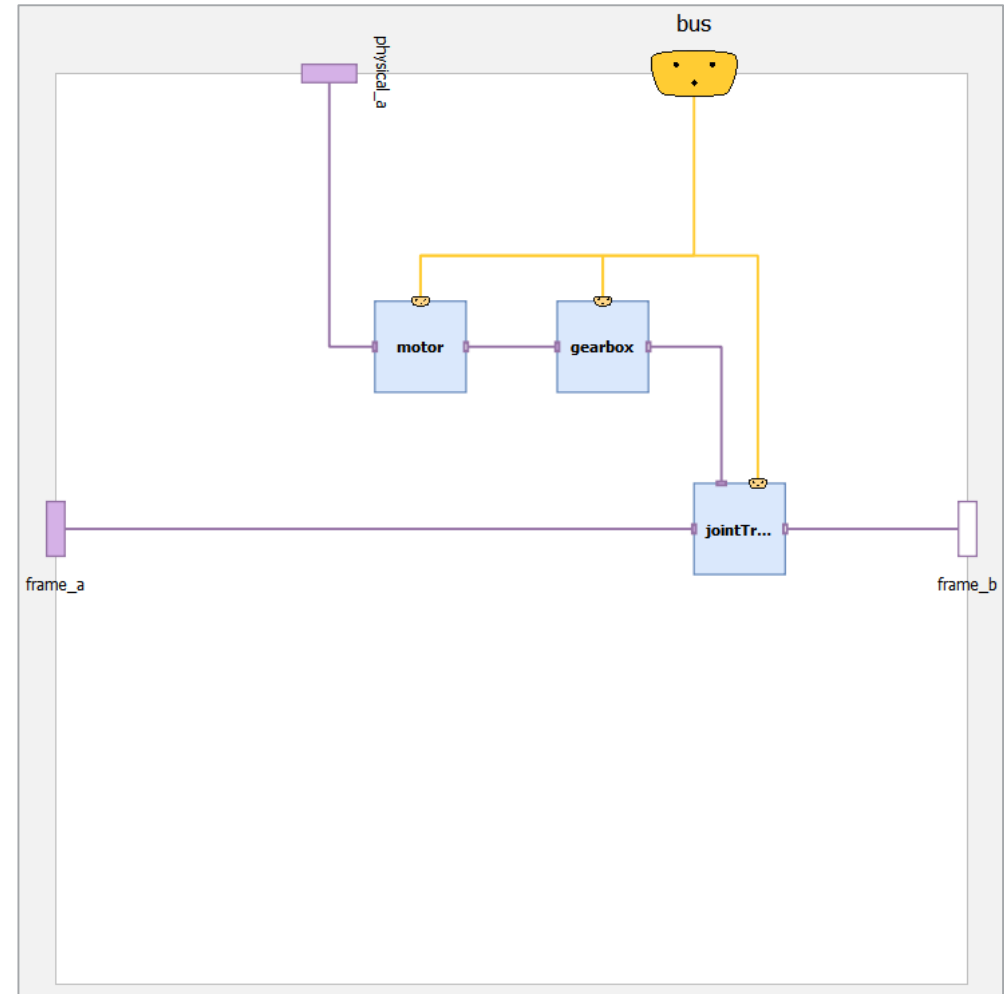
Generic – no constraints

 Expandable bus

Interfaces – more flexibility required

Joint Model:

- Rotational *OR* Translational flange



Simple Joint Model



Interfaces – partially defined option

Specific – fully defined

 Rotational 1D

 Translational 1D

Partially defined/constrained



Mechanical 1D:

 Rotational 1D *or*

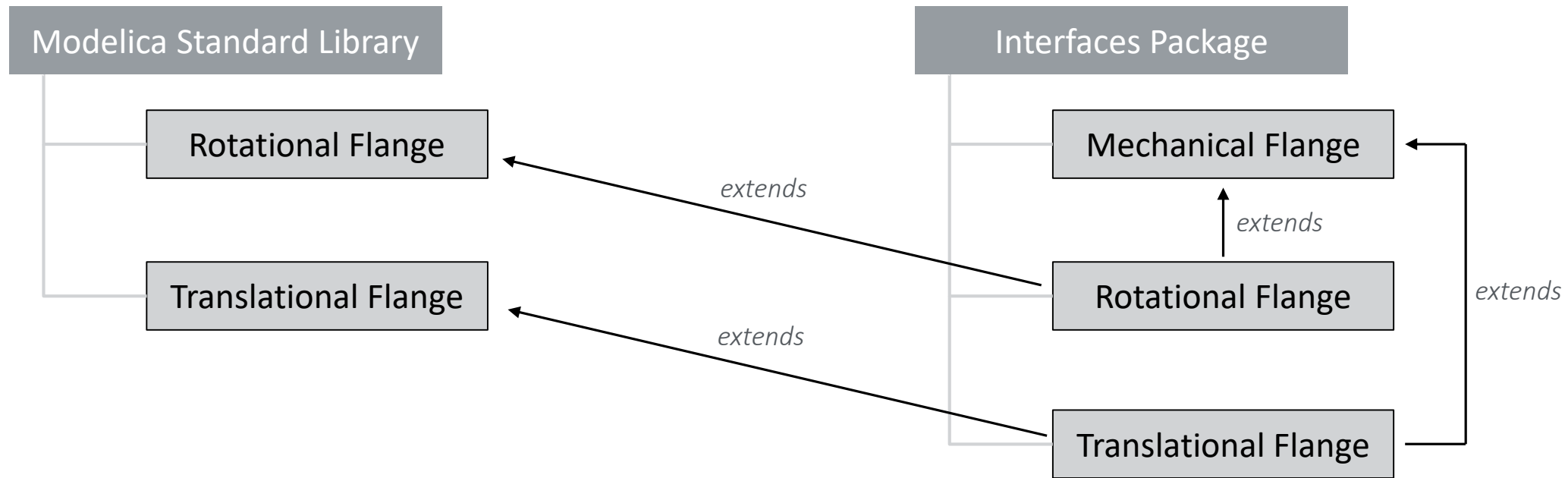
 Translational 1D

Generic – no constraints

 Expandable bus



Interfaces – hierarchy of connectors



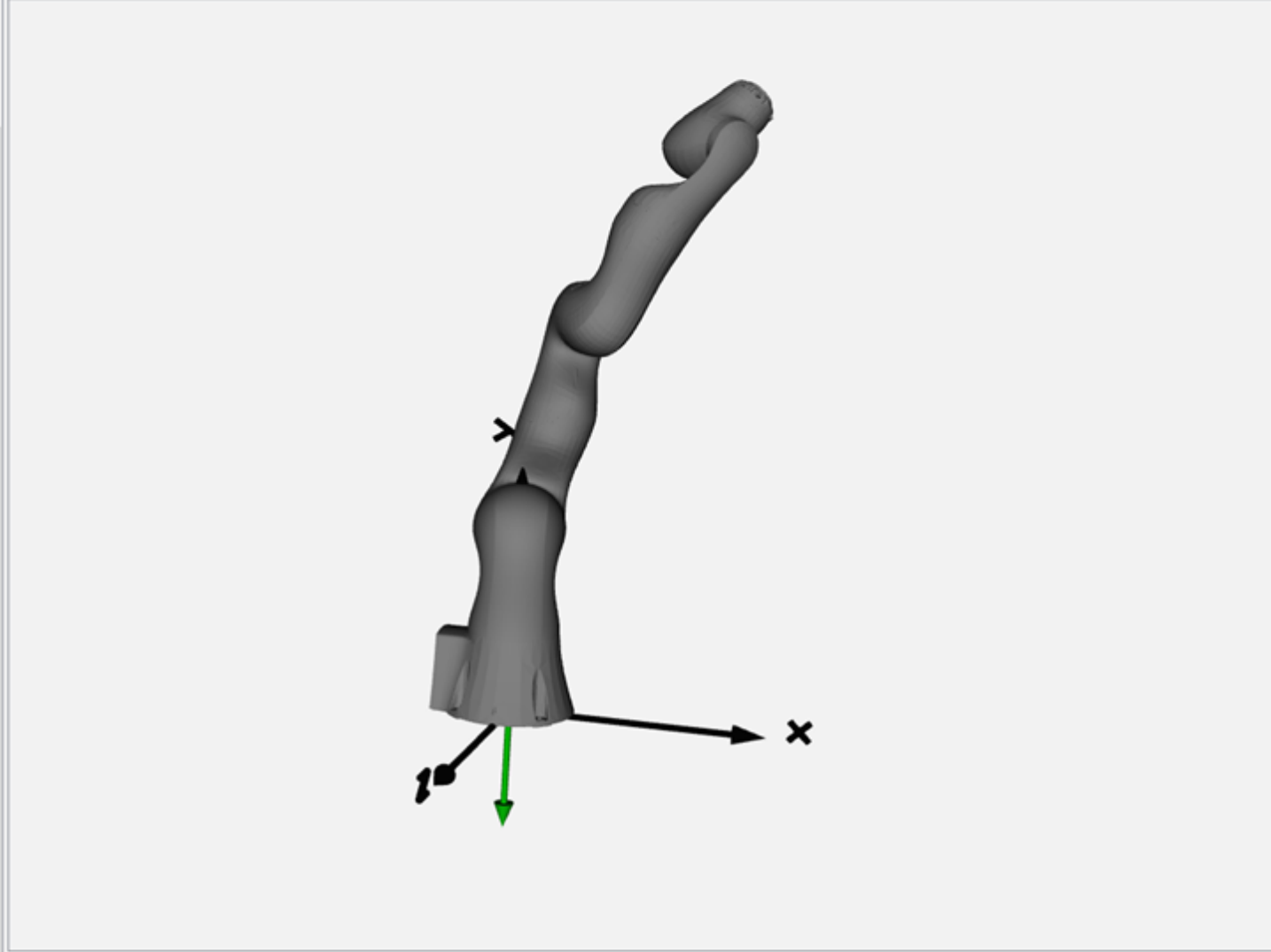
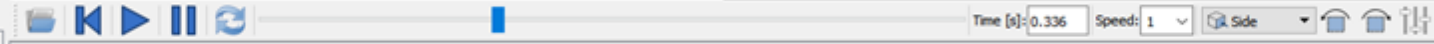


Libraries Browser

Filter Classes

- Libraries
 - MADA
 - Icons
 - PhysicalQuantities
 - Constants
 - Interfaces
 - ComponentTypes
 - Templates
 - Components
 - Robot
 - Axis
 - Joint
 - Link
 - RobotController
 - RobotBase
 - Tool
 - JointController
 - Motor
 - Abstract
 - Variants
 - StandardDCPM
 - StandardDCPM_TorqueSensor
 - DirectTransmission
 - Gearbox
 - Abstract
 - Variants
 - IdealGearbox
 - FlexibleGearbox
 - Linear
 - JointTransform
 - Sensor
 - ControllerBlock
 - Configurations
 - LBRIiwa14
 - LBRIiwa14Model
 - Data
 - Test
 - LBRIiwa14Test
 - LBRIiwa14Test_OM**
 - Data

LBRIiwa14.Test.LBRIiwa14Test_OM_res.mat



Documentation Browser

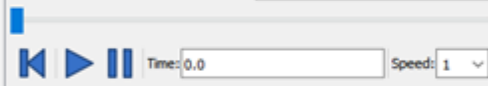


LBRIiwa14.Test.LBRIiwa14Test_OM

Variables Browser

Filter Variables

Simulation Time Unit: s



| Variables | Value | Display Unit | Description |
|-----------------------|-------|--------------|-------------|
| (Active...Test_OM) | | | |
| fixed | | | |
| fixedRotation | | | |
| LBRIiwa14Model | | | |
| robotCont...ler_model | | | |
| tool_model | | | |
| world | | | |

Messages Browser

| All | Notifications | Warnings | Errors |
|-----|---------------|----------|--------|
| | | | |



Current state of the framework

- ✓ Independent components
- ✓ Easy integration of models into the framework
- ✓ Minimal constraints on modelling
- ✓ Easy configuration
- ✓ Transparent data



Future work

- Integration of multiple robots and more detailed models
- Automated data export/import
- Import model configuration
- FMU generation
- OMOptim

Thank you for your attention!